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RESEARCH PAPER

Weed Species, Control Methods and Their Effects on Yield and Quality in Parsley Fields of İzmir Province of Türkiye

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Abstract

Parsley (*Petroselinum crispum* (Mill.) Nyman ex A.W. Hill) is an important vegetable due to its rich vitamin and mineral content, making it both a valuable health resource and a staple in culinary dishes. Weeds are a major challenge that limits the profitability of parsley cultivation. Twenty-four parsley field were surveyed in winter and summer during 2014 growing season. Additionally, the effects of physical (solarization) and mechanical (manual weeding) weed control on weed density, dry biomass, and yield and quality of parsley were determined with a two-year (2015-2016) field trial. As a result of survey studies, 45 different weed species belonging to 24 plant families were identified. *Urtica urens* had the highest plant density (12.6 plants m^{-2}) and *Stellaria media* was the most prevalent (68.3%) among dicotyledon weed species in winter. Among monocotyledon species, *Bromus tectorum* had the highest density (2.5 plants m^{-2}), while *Alopecurus myosuroides* was the most common (25.3%). In summer, *Portulaca oleracea* had both the highest density (14.1 plants m^{-2}) and prevalence (59.5%) among dicotyledons, while *Cyperus rotundus* exhibited similar dominance among monocotyledons (8.7 plants m^{-2}, 46.5%). As a result of field trial solarization (91.27%) and manual weeding (70.63%) were effective methods for weed control. Solarization proved to be promising for managing weeds in small, vacant areas, particularly in July. Effective weed control was shown to be important for improving the yield and quality of parsley.

1. Introduction

Parsley (*Petroselinum crispum* (Mill.) Nyman ex A.W. Hill), along with other raw vegetables, is an essential component of the human diet. It contributes not only to the visual and sensory qualities of meals with its vibrant color and distinct flavor but also provides substantial nutritional benefits (Dobričević et al., 2019). The antioxidants, vitamins, and minerals contained in parsley and other raw vegetables provide a range of health benefits, including the regulation of the digestive system, the neutralization of harmful substances, and the detoxification of the body (Eşiyok, 2012). The world's total minor vegetable production is approximately 298 million tons. China ranks first with around 170 million tons, followed by India in second place with 41 million tons, and Vietnam in third with 16 million tons. Türkiye ranks 30th in minor vegetable production, with approximately 647 thousand tons (FAOSTAT, 2022). Parsley production, which has an important place among minor vegetables in Türkiye, is approximately 127 thousand tons, and the Aegean region ranks 4th in production after the Mediterranean, Marmara and Black Sea Regions. Izmir is the province where the most parsley is grown in the region with a production of approximately 2000 metric tons (TÜİK, 2023).

Parsley, a typical Mediterranean plant, thrives in temperate and humid areas. In the mild climate of the Mediterranean and Aegean regions, parsley can be grown year-round (Eşiyok, 2012). Additionally, the ecological conditions in İzmir province support parsley production throughout the year, allowing for continuous agricultural activity in winter without leaving fields fallow. One of the most significant challenges in parsley cultivation is the weeds (Karkanis et al., 2012). Weeds, as with other cultivated plants, are a major factor negatively affecting yield and quality (Üstüner, 2022). When weeds are not adequately controlled, they cause substantial losses in both yield and quality. In parsley production, weed control is primarily conducted mechanically through hand weeding. However, this method is highly labour-intensive and costly, thereby increasing production costs (Simerjeet Kaur et al., 2017). In recent years, problems related to weed control in parsley production have been reported to the Plant Protection Research Institute in Bornova by producers, as well as by the Provincial and District Directorates of the Ministry of Agriculture and Forestry. Additionally, field studies have revealed similar issues. The lack of research on weeds in parsley production has contributed to the persistence of these problems. This study aims to identify the weed species, their density, and the control methods in parsley production areas in Izmir, as well as to assess the impact of weeds on yield and quality. The data obtained from this study are expected to provide solutions to the weed problem in parsley production areas and to guide future research in this field.

2. Material and Methods

2.1. Survey studies

Surveys were conducted in 2014 in the Kemalpaşa, Menemen, and Torbalı districts, where parsley cultivation is most concentrated within İzmir Province. Using a random sampling method, areas representing 2% of the total cultivation area were selected (Bora and Karaca, 1970). Care was taken to ensure that the samples accurately represented the region. Given that parsley production occurs year-round, both winter and summer weed species were identified separately. The identification of winter weed species was carried out in February-March, while summer weed species were detected during two periods, from July to September (Table 1).

During the surveys, weed density was determined based on field size. In fields with an area of 0.5 ha four sample points were established; in areas of 0.5-1.0 ha, six points; in areas of 1.0-2.0 ha, eight points; and in areas over 2.0 ha, twelve sample points were selected (Bora and Karaca, 1970). At each sample point, 1 m² frames were used to count the weed species. Field selection was made to ensure representative sampling across different field sizes.

In the weed counts, broad-leaved weeds were evaluated as whole plants, while the stems of narrow-leaved weeds were counted individually. Weed density and frequency were calculated based on the collected data. The prevalence of weed species was calculated using the formula by (Odum and Barrett, 1971).

$$PWS\ (R.S) = \frac{NM}{TNM} \times 100$$

where; PWS: The prevalence of weed species, NM: Number of measurements, TNM: Total number of measurements

The identification of weed species was conducted using the *Flora of Turkey* by (Davis, 1965), and the nomenclature was based on (Uluğ et al., 1993).

2.2. Weed control trials

Weed control trials were conducted in 2015 and 2016 in the Torbalı District of İzmir Province, where parsley production is concentrated. The weed species present in the trial fields were recorded and identified according to (Davis, 1965) and (Uluğ et al., 1993). The experiment was designed using a Randomized Block Design with four replications, and the plot size was 4.5 m² (Width: 3.0 m, Length: 1.5 m).

The weed control methods tested included mechanical (manual weeding) and physical (solarization) control. Prior to solarization, the soil was tilled and watered, and once the soil reached the appropriate moisture level, it was covered with a transparent plastic sheet of 50 µm thickness. The edges of the plastic cover were buried in furrows to secure it. The cover was removed after six weeks.

Table 1. The numbers and the areas of surveyed fields of parsley in the İzmir province in 2014.

District	Number of fields		Field area (da)	
	Winter* production	Summer** production	Winter production	Summer production
Menemen	4	11	0.7	4.8
Torbalı	1	3	0.4	17.5
Kemalpaşa	2	3	1.0	0.3
Total	24		24.7	

* in February-March, ** in July-September

Table 2. Practices, doses, application dates and forms in weed control experiments conducted in 2015 and 2016 in İzmir (Torbalı), parsley areas.

Applications	Dose	Application date		Methods of application
		2015	2016	
Solarization	-	28.08.2015 02.10.2015	20.07.2016 29.08.2016	The soil was treated, watered, covered with plastic after 5 weeks the cover was removed
Control	-	-	-	No application has been done
Manual weeding	2 times	01.09.2015 10.09.2015	29.09.2016 05.10.2016	Weeds taken by hand

Details of the applications and dosages used for weed control is provided in Table 2.

To determine the effectiveness of the treatments, weed species and their numbers were recorded by placing a 1 m² frame in each plot five times. Counts and observations were conducted 20 days after the treatments. The effectiveness of the applications was calculated using Abbott's formula:

$$\%\,Effect = \frac{NWCA - NWAA}{NWCA} \times 100$$

where; NWCA: Number of weeds in the control area, NWAA: Number of weeds in the application area.

For dry weight data collection, a 0.25 m² frame was placed in each plot four times. Parsley plants and weeds within each frame were cut, placed on paper bags, and labelled. The wet weights of these samples were measured in the laboratory, and they were then dried in an oven at 72°C for 48 hours. After drying, the samples were weighed to determine their dry weight.

2.3. Effect of weeds on yield and quality of parsley

During harvest, a 0.25 m² frame was placed in each plot four times. The parsley plants and weeds within each frame were cut, placed into separate bags, and labelled. The fresh weights of these samples were measured in the laboratory, and yield values per decare were subsequently calculated. During the harvest, approximately 700 g of parsley from each plot were sampled, placed in separate bags, and labelled for quality assessment. These samples were then evaluated in the laboratory for their physical properties, including decay status, colour, freshness, and other allure characteristics. The presence of weeds in the harvested crop was also assessed by counting and weighing any weeds present in the samples.

2.4. Statistical analysis

The data obtained were analysed using the SPSS statistical package. Variance analysis was performed, and the means were compared using Duncan's test at a 5% significance level. Additionally, interactions between the years were analysed, as the results provided include the average values for both years.

3. Results and Discussion

3.1. Survey studies

As a result of survey studies, 45 different weed species belonging to 24 families were identified, including one parasitic species, *Phelipanche ramosa* (L.) Pomel. Among the identified weeds, 8 species were monocotyledon, while the remaining were dicotyledons broad-leaved (Table 3). During the weed species counts in parsley fields, the following observations were made: The most prevalent winter dicotyledon weed was *Stellaria media*, followed by *Urtica urens*, *Capsella bursa-pastoris*, *Chenopodium album, Euphorbia microsphaera, Datura strumarium, Daucus carota, Hibiscus trionum*, and *Lactuca serriola*. The most prevalent winter monocotyledon weed was *Alopecurus myosuroides* followed by *Bromus tectorum*. The most prevalent summer dicotyledon weed was *Portulaca oleracea*, followed by *Lactuca serriola* L., Convolvulus arvensis, *Chenopodium album*, *Amaranthus albus*, and *Hibiscus trionum* L. The most prevalent summer monocotyledon weed was *Cyperus rotundus*. It was determined that *Stelleria media* (68.3%) was the most frequently encountered species, followed by *Urtica urens* (67,9%) and *Portulaca olearace* (59.5%) in winter and summer growing season (Table 3). Relevant literature indicates similarities and differences in weed species across different regions. For instance, (Karkanis et al., 2012) conducted a study in Greece and identified *Amaranthus retroflexus*, *Datura stramonium* L., and *Solanum nigrum* L. as problematic weed species. In a survey by (Telli & Üremiş, 2010) in parsley cultivation in Samandağ (Hatay), the most significant weed species were found to be *Orobanche aegyptiaca* Pers., *Orobanche ramosa* L., *Calendula arvensis* L., and *Cyperus rotundus*, respectively. Similarly, in Sweden, Norway, Finland, Germany, and France, frequent weed species included *Sinapis arvensis* L., *Polygonum persicaria* L., *Galium aparine* L., *Polygonum lapathifolium* L., *Myosotis arvensis* L., *Senecio vulgaris*, *Chenopodium album* L., and *Capsella bursa-pastoris*. Prevalence of *Papaver rhoeas* L., *Thlaspi arvense* L., *Silene noctiflora* L., *Poa annua*, *Chenopodium album*, and *Poa aviculare* reported in Israel (Brendstrup and Kloster, 1998; Rubin & Benjamin, 1983). Additionally, they reported *Melilotus sulcatus* L., *Malva nicaeensis* L., *Astragalus boeticus* L., and *Cyperus rotundus* among annual weeds. Most of the weed species

Table 3. The frequency (%) and the density (plant m^{-2}) of the weed species winter and summer season in İzmir, 2014.

Weed species	Winter season		Summer season	
	Frequency (%)	Density (plant m^{-2})	Frequency (%)	Density (plant m^{-2})
Alopecurus myosuroides	25.3	1.0	35.3	8.7
Amaranthus albus			27.3	2.0
Bromus tectorum	25.0	2.5		
Capsella burs-pastoris	45.2	6.5		
Chenopodium album	45.0	9.5	32.5	2.1
Convolvulus arvensis			36.8	2.4
Conyza canadensis	1.6	0.2		
Cyperus rotundus			46.5	8.7
Datura stramonium	26.7	2.7		
Daucus carota	25.0	3.0		
Echinochloa colonum			7.5	4.0
Echinochloa crus-galli			42.9	2.9
Elymus repens			34.8	8.2
Euphorbia microsphaera	40.0	3.2		
Heliotropium europaeum	10.7	2.7		
Hibiscus trionum	25.0	1.0	23.3	4.3
Lactuca serriola	25.0	2.0	36.9	2.0
Lolium perenne	6.8	1.9		
Malva neglecta	8.3	1.4		
Matricaria chamomilla	22.8	4.4		
Onopordum bracteatum	13.7	1.0		
Phelipanche ramose (L.)			0.0	0.0
Poa annua	2.3	0.3		
Portulaca oleracea			59.5	14.1
Raphanus raphanistrum	12.4	1.0		
Senecio vulgaris	25.0	1.3		
Sinapis arvensis	1.5	0.4		
Sisymbrium officinale	3.0	1.2		
Solanum nigrum			18.0	1.0
Sorghum halepense			5.3	1.5
Stellaria media	68.3	9.8		
Urtica urens	67.9	12.6		

Tablo 4. Weed species in the İzmir (Torbalı), in 2015 and 2016.

Years	Aplications	Species name
2015	Control	*Amaranthus retroflexus L., Hibiscus trionum* L., *Portulaca oleracea* L., *Cyperus rotundus* L., *Echinochloa crus-galli* L., *Sonchus oleraceus* L., *Solanum nigrum* L., *Matricaria chamomilla* L., *Lactuca serriola* L., *Silybum marianum* L., *Sorghum halepense* L.
	Manual weeding	*A. retroflexus, H. trionum , P. oleracea, C. rotundus*, *Echinochloa crus-galli* L., *S. oleraceus, S. nigrum*, *M. chamomilla*, *L. serriola, S. marianum, Alopecurus myosuroides* L., *Capsella bursa-pastoris* L., *Malva sylvestris* L., *Euphorbia helioscopia* L., *Eruca vesicaria*
	Solarization	*C. rotundus*, *Sorghum halepense* L.
2016	Control	*A. retroflexus, A.albus, C. album*, *C. canadensis*, *Convolvulus arvensis., H. trionum, P. oleracea* , *Poa anua*, *C. rotundus, E. crus-galli, Silybum marianum* L., *Sonchus oleraceus* L., *Solanum nigrum* L., *Matricaria chamomilla* L., *Lactuca serriola* L., *Silybum marianum* L., *Sorghum halepense* L., *Tribulus terrestris* L., *Erodium cicutarium* L., *Raphanus raphanistrum* L., *Conyza canadensis* L.
	Manual weeding	*A. retroflexus, A. Albus* L., *H. trionum, P. oleracea, C. rotundus*, *E. crus-galli*, *C. arvensis.*, *Raphanus raphanistrum* L., *Medicago* spp.
	Solarization	*C. rotundus*, *S. halepense*, *C. arvensis, P. oleracea*

detected in our parsley fields align with those identified in these studies, highlighting the commonality of certain problematic weeds across different regions.

3.2. Weed control trials

Different weed species that was found in the trial area are presented in the Table in 4 both years. The total weed density and the efficiency (%) of the applications are presented in Table 5. Table 5 reveals that in both 2015 and 2016, the number of weeds and the prevalence of common weed species were significantly reduced in areas treated with solarization compared to the control and manual weeding treatments. Solarization demonstrated the highest efficiency and was observed to be the most effective treatment. Solarization allows the soil temperature to be maintained above 40°C, effectively killing weed

Table 5. Effectiveness of the applications and total weed density in Izmir (Torbalı), Parsley, 2015 and 2016.

Applications	2015		2016		Average of 2015-2016	
	Total weed density (plant m^{-2})	Effectiveness (%)	Total weed density (plant m^{-2})	Effectiveness (%)	Total weed density (plant m^{-2})	Effectiveness (%)
Control	107.75	-	59.50	-	83.62	-
Manual weeding	39.75	63.11 b	13.00	78.15 ab	26.37	70.63 b
Solarization	4.31	96.00 a	8.00	86.55 a	6.15	91.27 a

** Different letters refer to different statistical groups (Duncan, P <0.05)

Table 6. Dry biomass of weeds and effectiveness of the obtained from the practice of combat tests in Izmir Province (Torbalı), Parsley, 2015 and 2016.

Applications	2015		2016		2015-2016	
	Weed dry biomass (g)	Effectiveness (%)	Weed dry biomass (gr)	Effectiveness (%)	Weed dry biomass (gr)	Effectiveness (%)
Control	31.32	-	38.84	-	35,05	-
Manual weeding	21.14	32.5 b	27.31 b	29.68 b	24.22 b	30.89 b
Solarization	11.57	63.0 a	21.04 a	45.82 a	16.30 a	53.49 a

** Different letters refer to different statistical groups (Duncan, P <0.05)

Table 7. Effects of the weed control treatment on yield (g ha^{-1}) of parsley.

Aplications	2015		2016	
	(g ha^{-1})	(bunch pieces^{-1})	(g ha^{-1})	(bunch pieces^{-1})
Control	5682 b	10.026 b	5003 b	10.006 b
Manual weeding	5917 a	10.795 a	5378 a	10.757 a
Solarization	5968 a	10.562 a	5331 a	10.663 a

** Different letters refer to different statistical groups (Duncan, P <0.05)

seeds and seedlings (Chase et al., 1999). In certain species, if the lethal temperature is not achieved, dormancy can be broken, leading to the emergence of a new wave of weed seedlings; this phenomenon can occur within the topsoil layer (Vidotto et al., 2013). When comparing the two-year results of the applications, solarization consistently provided the best efficiency (%), followed by manual weeding. Additionally, it was observed that perennial weeds, such as *Cyperus rotundus* L., *Sorghum halepense* L., and *Convolvulus arvensis*, as well as annual weeds like *Portulaca oleracea* L., were present in the solarization areas, particularly after irrigation. Because weed species have varying sensitivity to solarization: annual weeds are generally sensitive, but *Avena fatua* and *P. oleracea* show slight tolerance, while *Conyza canadensis* (L.) Cronq. is relatively tolerant. Perennial weeds, such as *Convolvulus arvensis* L., *Cyperus* spp., *C. dactylon, S. halepense*, and *Equisetum* spp., can range from relatively sensitive to tolerant (Pannacci et al., 2017).

Many minor crops, such as certain vegetables (e.g., cabbages, artichokes), seed crops, herbs, medicinal plants, and spices, can be managed using hoes for manual weed control. The effectiveness of hoe weeding depends on soil properties (such as moisture and texture), weather conditions after cultivation, and the characteristics of the tool (size, shape, and working depth). Rainy conditions following soil cultivation can reduce weeding effectiveness by 30-40% (Lichtenhahn et al., 2005). Due to their significant impact on the soil, manual weeding can control weeds from early stages (2-4 true leaf stage) to later stages when weeds are well-developed. However, in the case of perennial weeds, the effectiveness of hoeing may be reduced (Pannacci et al., 2017). The dry biomass of weeds is given in Table 6. Dry biomass of weeds was significantly reduced in both solarization, and manual weeding applications compared to the control. Solarization achieved the greatest reduction in dry weight, demonstrating the highest effectiveness, followed by manual weeding. Mechanical weed control methods are effective, fast, and leave no chemical residues on crop plants (Pannacci & Tei, 2014). For these reasons, mechanical methods are the primary means of directly suppressing weeds in organic and low-input cropping systems.

3.3. Effects of weeds on yield and quality of parsley

Table 7 presents the yield values per decare, calculated from data obtained from each plot during harvest. The results indicate that the efficiency of the applications was higher compared to the control, with all applications falling into the same statistical group (a) according to variance analysis. Additionally, during the surveys, parasitic weeds (*Phelipanche ramosa*) found in the parsley production areas of Menemen-Görece were associated with symptoms such as yellowing of parsley plants, growth retardation, and the formation of bare patches. Similarly, in a study conducted by (Üstüner, 2022), it was found that the presence of parasitic weed, dodder (*Cuscuta campestris* Yunck.) significantly reduced both the yield and quality of parsley. Field dodder had a 100% impact on the height development of parsley plants. It caused a 38.0% reduction in parsley yield and decreased the parsley's protein content by 8.31%, crude oil by 30.20%, calcium by 12.43%,

Table 8. Effects of the weed control treatment on quality of parsley in 2015 and 2016.

Aplications	2015			2016		
	Weed			Weed		
	Count (piece)	Weight (g)	Species	Count (piece)	Weight (g)	Species
Control	8.25	35.98	*C. arvensis* *P. olereceae* *E. crus-galli* *C. album* *C. rotundus* *M. oficinalis*	7.25	34.62	*C. arvensis* *P. olereceae* *E. crus-galli* *C. rotundus* *H. trionum* *S. nigrum*
Hand weedling	2.75	32.65	*C. album* *P. olereceae* *C. arvensis* *E. crus-galli*	1.75	23.41	*C. arvensis* *C. rotundus* *P. olereceae*
Solarization	2.00	21.23	*E. crus-galli* *C. arvensis*	1.52	21.56	*C. arvensis* *C. rotundus*

iron by 64.65%, and phosphorus by 14.22%, and sodium by 51.26%. Additionally, beyond the direct damage to parsley growth, dodder branches visually diminished the quality of parsley bundles by entangling the branches and leaves from the outside.

Table 8 presents the data on the mixture of weeds and parsley in terms of both numbers and weights, as well as information on common weed species. It was found that weeds contaminated to the 0.25% to 1.65% of the parsley samples. Among the eight different weed species identified, *Portulaca oleracea*, *Convolvulus arvensis*, *Echinochloa crus-galli*, and *Cyperus rotundus* were the most prevalent. The physical properties of the samples were consistent across the different weed species. In Italy, both mechanical and cultural methods are employed alone or in combination to manage weeds in parsley cultivation (Campagna et al., 2012). In Greece, mechanical control during the early growth stages is deemed necessary to prevent yield loss (Karkanis et al., 2012). Additionally, (Shaddad et al., 2009) reported similar results where solarization of corn, parsley, and arugula plants for 6 weeks (August-September) led to a reduction in weed numbers and an increase in yield and quality 21 days after planting. However, more detailed information on the trial results should be provided.

4. Conclusion

This study investigated weed control methods in parsley cultivation in İzmir, focusing on the effectiveness of mechanical and physical approaches, specifically solarization and manual weeding. The results demonstrated that solarization was the most effective method, significantly reducing weed density and dry weight compared to the control and manual weeding treatments. The presence of parasitic weeds, particularly *Phelipanche ramosa*, was noted to adversely affect parsley growth, leading to yellowing, growth retardation, and the formation of bare patches. The consistency of results across different studies highlights the reliability of these methods. However, further detailed exploration of trial results and a more extensive comparison with previous research are necessary to fully understand the implications and optimize weed control strategies in parsley cultivation. Mechanical and physical weed control methods, when used within an Integrated Weed Management Strategy (IWMS), can also help reduce reliance on herbicides, prevent the selection of herbicide-resistant species, and maintain sustainable weed management for minor crops.

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