

Bitki Koruma Bülteni / Plant Protection Bulletin

<http://dergipark.gov.tr/bitkorb>

Original araştırma (Original article)

The relationships of weeds and their distributions with ecological factors in hazelnut orchards in Ordu

Ordu ili fındık bahçelerinde sorun olan yabancı otlar ve dağılımlarının ekolojik faktörlerle ilişkilendirmesi

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ARTICLE INFO

Article history:

DOI: [10.16955/bitkorb.1646813](https://doi.org/10.16955/bitkorb.1646813)

Received : 26-03-2025

Accepted : 31-07-2025

Keywords:

hazelnut production, climate, indicator species, Ordu, weed

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ABSTRACT

Ordu Province ranks first in the world and in Türkiye in terms of hazelnut production. In this study, the prevalence and density of problematic weed species in hazelnut orchards in the province of Ordu and the influence of ecological factors on the distribution of weed populations was investigated. In this direction, the study was carried out in 2021-2022 in two different survey periods in a total of 75 different hazelnut orchards, divided into three agro-ecological regions according to the geographical location of the orchards (height and distance to the coast) to represent the research zone. The weed species identified during the surveys were associated with climate and soil characteristics and the data obtained were analyzed by using the CANOCO (Program for Analysis and Visualization of Multiple Ecological Data) and SPSS (Statistical Package for the Social Sciences) package programs together with multivariate analyses and related distribution characteristics. To reveal the effects of soil and climate characteristics on weeds, the data obtained were evaluated by the Canonical Correspondence Analysis (CCA) method. A total of 194 weed species belonging to 49 families were detected as a result of the two-year surveys. The weed species with the highest frequency (%) and density (plants/m²) in the first period (April-May) was *Bellis perennis* L. and in the second period (August-September) was *Urtica dioica* L. *Rumex crispus* L. and *U. dioica*, which were considered by producers to be the most problematic, especially due to their high frequency and density, were positively correlated with organic matter, while *Pteridium aquilinum* (L.) Kuhn and *Dryopteris filix-mas* (L.) Schott were identified as indicator species because they were negatively correlated with lime, Ca, EC and pH.

INTRODUCTION

Türkiye is home to many endemic and cosmopolitan plants due to its different ecological structures. Given its strategic geographical location, it is inevitable that the plant and fruit species grown in Türkiye should be cultivated for

commercial purposes and provide significant benefits to the national economy. Hazelnut is a hard-shelled fruit species with high nutritional value and contributes significantly to the national economy. Hazelnut fruit, is an important

nutrient for human nutrition due to its protein, fat, vitamin, carbohydrate and mineral content (Şimşek and Aslantaş 1999). Hazelnut, which is an important agricultural export product of Türkiye, was exported with a total of 318,322.68 thousand tonnes worldwide in 2021. Türkiye, which is one of the few countries in the world with suitable climatic conditions for hazelnut production, accounts for an average of 65% of the world hazelnut production, although this varies from year to year. According to FAOSTAT 2021 data, Türkiye is the leading hazelnut producer in the world with 738,920 ha (71.11%) and 684,000 tonnes (63.50%) of production. However, Türkiye does not rank first in terms of yield per hectare and lags behind developed countries. For example, while the United States of America receives an average of 284.82 kg of shelled hazelnuts per decare, Türkiye receives 92.57 kg, or about a third less per decare (Anonymous 2021a).

Almost all of Türkiye's hazelnut cultivation and production takes place in the Black Sea region. Ordu Province, which is located in the Black Sea region, ranks first in terms of hazelnut production in Türkiye and in the world. In fact, when Ordu Province is compared with other hazelnut-growing countries, it ranks first with respect to its production capacity (Anonymous 2021b, 2022). For this reason, Ordu Province is the world's hazelnut production center. However, although it ranks first in terms of area and total production, it lags behind in yield per decare. As a result of the research on hazelnut yield in Ordu, an average of 56 kg of shelled hazelnuts per decare was calculated, which is quite low compared to other countries and provinces in periods of yield (Özkutlu et al. 2016). One of the main reasons for this is weeds that cause problems in hazelnut orchards. Weeds are defined as plants that grow where and when human beings do not want them to, that cause more harm than good, and that cause direct and/or indirect damage to crops (Özer et al. 2001, Üremiş and Uygur 2002). Moreover, weeds are among the most important factors that reduce yield in hazelnut orchards, increase host diseases and pests, increase input costs, increase harvesting difficulties, and negatively affect the quality and quantity of the product (Mennan et al. 1999, Yonat and Kolören 2023).

Since weed populations are more resistant to ecological factors due to their characteristics, they respond to changes in nature by adapting very well compared to cultivated plants (Önen and Özer 2001). Therefore, weeds are highly competitive with cultivated plants and cause damage, especially to the whole agroecosystem. The soil structure, land use, crop type and climate of the region significantly affect weed population dynamics (Önen et al. 2018). Therefore, it is possible to observe weed species and densities specific to the region and crop (Önen et al.

2018, Özcan 2016, Sırrı 2022). In addition, climate change caused by global warming, which has been the subject of many recent studies, has made some weed species dominant in agricultural ecosystems, while others have become less important over time (Ziska and George 2004). However, invasive weed species currently pose a threat in agricultural areas, and it is important to investigate their relationships with ecological factors in order to monitor and control their spread (Shabani et al. 2020).

Various studies have been conducted worldwide and in Türkiye to identify weed species, determine the relationship between weeds and ecological factors. Perennial weed species are generally better indicators than annual weed species (Hill and Ramsay 1977). In a study conducted to determine indicator weed species according to water, light, pH, nitrogen and salinity requirements of plant species, *Xanthium stumarium* L. and *Amaranthus* sp. were found as light indicators, while *Stellaria media* (L.) Vill., *Echinochloa crus-galli* (L.) P.B. and *A. retroflexus* were found as nitrogen indicators (Ellenberg 1979). They also reported that soil nitrogen was positively associated with *Digitaria sanguinalis* (L.) Scop. and *Tribulus terrestris* L. weeds (Elahi et al. 2010). Soil pH was found to be the main factor influencing the composition of weed species in cereal fields in Western Hungary. The most responsive weed species to soil pH were *Papaver rhoeas* L. and *Camelina microcarpa* Andr. ex DC, which were identified as indicators of alkaline soils (Pinke et al. 2010). It was determined that pH, EC, organic matter and lime content in pasture soils have a significant effect on plant distribution (Doğan 2011). *Cyperus rotundus* L., the most dominant weed species in sugar beet production areas, showed a positive correlation with P, K and clay content (Lousada et al. 2013). In a study on weed density and diversity in young olive orchards, organic and inorganic fertilisers were found to affect weed density and diversity (Platis et al. 2023).

Similarly, in a study on the changes in weed species according to ecological parameters in the Yüksekova basin, weed species distributed according to clay and sand content were determined (Sırrı 2022). According to studies on the response of weed species prevalence and density to ecological factors, climate, soil physical and chemical properties have significant effects on weed species diversity and population dynamics. In Türkiye, several studies have been carried out on problematic weeds and their control in hazelnut orchards (Kaya-Altın et al. 2016, Kolören 2020, Mennan et al. 2006, Yonat and Kolören 2023). However, there are no studies on the associations of weeds with ecological factors. Therefore, this research is the first in the world and in Türkiye on the topic of weeds in hazelnut orchards and their relationships with ecological factors.

Table 1. General information to the hazelnut orchards surveyed

Region	Numbers	Sampling points	Orchard (decare)	Coordinates and location	Altitude (m)	Relief*
Coastal zone	1	Gülyalı Ayrılık	30	40.573154 37.044771	113	F
	2	Gülyalı Turnasuyu	2	40.572776 38.002309	80	FN
	3	Altınordu Cumhuriyet	20	40.583062 37.571766	7	FN
	4	Altınordu Yukarıtepe	5	40.937156 37.960401	249	M
	5	Altınordu Eyüplü	10	40.553920 37.563222	21	FN
	6	Altınordu Bayadı	2	40.900213 37.884549	250	M
	7	Altınordu Dedeli	25	40.893514 37.831590	195	M
	8	Altınordu Yemişli	10	40.928142 37.853676	115	FN
	9	Altınordu Boztepe	16	40.582072 37.514118	100	M
	10	Altınordu Kurtuluş	2.5	40.984343 37.784066	60	M
	11	Perşembe Efirli	8	41.016421 37.795854	120	M
	12	Perşembe Çınar	4	41.097225 37.766161	90	ST
	13	Perşembe Çaytepe	5	41.121053 37.687964	60	M
	14	Fatsa Yalıköy	1	41.047257 37.606698	10	ST
	15	Fatsa Konakbaşı	8	41.017895 37.537377	11	M
	16	Fatsa Bağlarca	10	40.990733 37.552573	190	M
	17	Fatsa Sefaköy	8	40.978651 37.496713	60	FN
	18	Fatsa Ayazlı	15	41.017983 37.473381	25	FN
	19	Fatsa Eskiordu	12	40.974098 37.425899	100	ST
	20	Ünye Yüceller	10	41.103291 37.385291	23	FN
	21	Ünye Cevizdere	10	41.111042 37.339491	10	FN
	22	Ünye Gürecülü	2	41.118378 37.290756	14	ST
	23	Ünye Nadırlı	4	41.091446 37.219184	185	FN
	24	Ünye Gölevi	10	41.140753 37.223134	9	FN
	25	Ünye Aydın-tepe	13	41.098223 37.156530	180	ST
Middle zone	1	Kabadüz Esenyurt	5	40.883280 37.904541	252	M
	2	Kabadüz Karakiraz	8	40.864288 37.887878	480	M
	3	Kabadüz Başköy	8	40.848734 37.875590	460	ST
	4	Ulubey Akpınar	5	40.901900 37.795486	260	ST
	5	Ulubey Kumrulu	3	40.880455 37.780283	420	M
	6	Ulubey Merkez	11	40.879465 37.755094	500	ST
	7	Ulubey Gündüzlü	5	40.866175 37.780843	395	ST
	8	Ulubey Çukur	8	40.859464 37.782105	330	M
	9	Ulubey Yolbaşı	4	40.841096 37.759797	400	M
	10	Çamaş Hisarbey	4	40.929637 37.502342	280	M
	11	Çamaş Danışman	6	40.935506 37.532776	251	M
	12	Çamaş Merkez	4	40.902771 37.526223	490	ST
	13	Çatalpınar Göller	2	40.920812 37.454452	440	ST
	14	Çatalpınar Kıran	5	40.890901 37.443867	270	M
	15	Çatalpınar Karşıyaka	8	40.857237 37.443711	270	ST
	16	Çatalpınar Madenköy	8	40.859830 37.413534	450	M
	17	Fatsa Bacanak	5	40.919974 37.409523	400	M
	18	Kumru Karaağaç	1.5	40.900788 37.318176	330	SL
	19	Kumru Merkez	2	40.871502 37.263957	500	SL
	20	Ünye İnkur	8	41.037977 37.215823	380	ST
	21	Ünye Dizdar	3	40.983683 37.163547	490	M
	22	Çaybaşı Hanyanı	3	41.054272 37.130011	450	M
	23	Çaybaşı Çayır	4	41.052906 37.125724	490	SL
	24	İkizce Kocaman	2	41.043328 37.061588	251	FN
	25	İkizce Ağcaalan	20	41.071470 37.087249	252	FN

	1	Ulubey Şeyhler	7	40.849078	37.724422	530	ST
	2	Ulubey Akoluk	27	40.833287	37.692080	600	M
	3	Gürgentepe Eskiköy	5	40.889730	37.625102	630	ST
	4	Gürgentepe Şirinköy	9	40.830614	37.627971	1030	ST
	5	Gürgentepe Merkez	5	40.793024	37.594496	1230	M
	6	Gürgentepe Okçabel	3	40.800861	37.547853	1200	M
	7	Gürgentepe Işıktepe	3	40.819487	37.526449	1140	ST
	8	Çamaş Uzunali	6	40.874811	37.537117	900	ST
	9	Gölköy Emirler	2	40.743304	37.621618	1070	M
	10	Gölköy Kuşluvan	6	40.702511	37.621685	980	M
	11	Gölköy Güzelyurt	8	40.698408	37.507468	950	ST
	12	Kabataş Şifasuyu	10	40.735611	37.561372	505	ST
High zone	13	Kabataş Eceli	3	40.732598	37.437491	540	M
	14	Aybastı Çukur	5	40.714164	37.420457	560	ST
	15	Aybastı Merkez	5	40.688918	37.399264	770	M
	16	Aybastı Sağlık	6	40.677930	37.382385	900	M
	17	Aybastı Hacı Seyfakümevleri	3	40.678318	37.353219	1230	FN
	18	Aybastı Düzağıl	3	40.664786	37.334535	1300	FN
	19	Korgan Merkez	15	40.836843	37.350036	770	ST
	20	Korgan Yenipınar	6	40.806437	37.348181	724	M
	21	Korgan Aşağıyaylacık	1	40.826964	37.315658	700	M
	22	Akkuş Esentepe	3	40.894138	37.072138	950	ST
	23	Akkuş Muratlı	4	40.892860	37.037808	1100	M
	24	Mesudiye Darıcabaşı	1	40.707556	37.843533	510	ST
	25	Mesudiye Pınarlı	5	40.660759	37.774874	1050	ST

*Flat slope: F, Flat-near slope: FN, Middle slope: M, Slight slope: SL, Steep slope: ST

Therefore, in this study, we aimed to determine the population dynamics of weed species in hazelnut orchards in Ordu and their relationships with ecological factors in order to provide direction for weed control in hazelnut, which is a very important cultural plant in Türkiye and the region. In addition, by looking at the weed distribution in their orchards, growers will be able to make predictions without the need for detailed analysis of soil characteristics and without loss of time.

MATERIALS AND METHODS

The main material of the surveillance study consisted of weed species, soil characteristics and ecological data obtained from the hazelnut orchards in Ordu. Moreover, tools and equipment such as 1/4 m² frames were used for weed counting, GPS was used to determine the height and coordinates, cameras were used to observe the weed species *in situ*, and herbarium bags, knives, shovels, plastic bags, acetate pens, and labels were used to collect weed samples. Weed samples collected from hazelnut orchards were taken to the herbarium of Ordu University, Faculty of Agriculture, Department of Plant Protection Phytopathology Laboratory, and the books entitled "Flora of Turkey and The East Aegean Islands", "Turkey's Weeds and Some Characteristics" and "Some Important Weeds of Turkey" were used for weed

identification (Davis 1965-1989, Özer et al. 1999, Uluğ et al. 1993). Bayer codes and abbreviations were also used for weeds (Anonymous 2016). The soil samples were analysed at the Giresun Fiskobirlik Soil Analysis Laboratory. Ordu has a typical Black Sea climate with cool winters and mild summers. However, with the increase in altitude in the districts located in the interior of the province, cold weather is effective (Tali 2020). Hazelnut production in Türkiye is carried out between 40-42° latitude and 31-42° longitude, and it is cultivated economically up to 60 km inland from the coast and in places where the altitude does not exceed 1000 meters. The study was conducted within these borders and covered all districts of the province (Özkutlu et al. 2016).

Determination of population dynamics of weed species in hazelnut orchards

Considering the climatic factors that have a significant impact on the distribution of weeds, the province of Ordu has been divided into three agro-ecological zones based on altitude and distance above sea level. The area between 0-250 m above sea level and 10 km inland is called the coastal zone; the zone between 251-500 m and 11-20 km inland is called the middle zone; and the zone above 500 m and more than 20 km inland is called the highland zone (Özçağırın et al. 2014). The survey was conducted in two different

periods, the first period (April–May) and the second period (August–September) from 2021 to 2022. When conducting the survey in hazelnut orchards, care was taken to ensure that the weeds were in the appropriate phenological period, taking into account that there are summer and winter species. General information on the hazelnut orchards surveyed is given in Table 1.

Each sampling zone included hazelnut orchards of a certain size (at least 1 deca) and location to represent the land in a particular settlement. With an average distance of 10 km between the sampled hazelnut orchards, the hazelnut orchards were selected to be as representative as possible for each region and sampling was carried out in a zigzag pattern in an east-west direction. In order not to be influenced by the edge of the orchard entered, 1/4 m² frames were placed from a distance of 10 m, 4 times for 1-5 da, 6 times for 6-10 da, 8 times for 11-15 da, 10 times for 16-20 da and 12 times for orchards larger than 20 da, and counts were made in the direction of the diagonals (Önen 1995). Counts were made using 1/4 m² frames and weeds entering the frames were counted and identified by species. Stem counts were made for monocotyledonous weeds, and plant root counts were made for dicotyledons and seedless plants. After determining the weed species, their density and coverage in each orchard, the frequency (%), species coverage (%), density (plants/m²), similarity indices and dominance of each species used to evaluate the population were calculated. The necessary formulas are given below (Odum 1971, Uygur 1991).

$$\text{Frequency (F \%)} = 100 \times n/m$$

in the form and here it is

n : in how many of the samplings were encountered with that species

m : the total number of samples.

The species coverage (SC %) is the average value at which any weed species covers the soil surface. It is divided into a general coverage area (GCA) and a specific coverage area (SCA).

$$\text{GCA (\%)} = SC/m$$

in the form and here it is

SC : The sum of the area occupied by each species,

m : the total number of samples.

$$\text{SC (\%)} = SC/n$$

in the form and here it is

SC : The sum of the area occupied by each species,

n : in how many of the samplings were encountered with

that species.

Density (plants/m²): Weed density was determined using the arithmetic mean. For this purpose, weed density (plants/m²) was determined by dividing the value obtained as a result of the counts made for each weed species in an orchard by the total area counted in that orchard.

Similarity index (%): The similarity index was used to compare the similarity of weed species in hazelnut orchards according to period, year and region (coastal zone, middle zone and highland zone). The similarity index was calculated using with the following formula (Odum 1971):

The similarity index is multiplied by 100 to express the percentage of similarity.

$$S.I. = 3D/(A+B+C) \times 100$$

in the form and here it is

S.I. : Similarity index

A : Number of weeds detected in the coastal zone

B : Number of weeds detected in the middle zone

C : Number of weeds detected in the highland zone

D : Refers to the number of weeds common to all 3 zones

Dominance of weeds: Dominance, which provides information about species structure, expresses the importance of one species over all other species (Uygur 1991). The dominance (D) was calculated using the formula below:

$$D = SC/TSGCA$$

in the form and here it is

SC (%) : The sum of the area occupied by each species

TSGCA (%) : Refers to the total area covered by all species

Determination of ecological factors, measurement techniques and their relationship to weeds

Soil texture, relief, soil lime content, soil pH, soil salinity, soil organic matter, available phosphorus and exchangeable cations were determined separately during the investigation and determination of the ecological factors. Prior to sample collection, site heterogeneity (e.g., slope, soil type and color, altitude, and groundwater status) was assessed. For this purpose, soil samples were taken from 0-30 cm depth with the help of a shovel or auger from 5-10 different points depending on the size of the orchard, by making drawing random zigzags in the hazelnut orchards or within a plan (Kacar 1995). These soil samples were thoroughly mixed. A 2 kg of soil sample was then taken from the mixture and brought to the laboratory for analysis. The soil samples

brought to the laboratory were dried at room temperature, sieved through a 2 mm sieve and prepared for analysis.

- *Soil reaction (pH)*: The pH values of the soils were measured in saturated sludge using a pH meter. The amount of hydrogen ions formed in the medium prepared by mixing the soil with pure water in certain proportions was measured potentiometrically with a pH meter (Richards 1954).

- *Lime (%)*: A 0.5 g soil sample was weighed, and the % lime content was calculated using 10% hydrochloric acid with a Scheibler calcimeter based on the CO₂ output volume, temperature and atmospheric pressure of the environment analysed (Kacar 1995).

- *Electrical conductivity (EC)*: Saturation sludge was analyzed using a conductivity device (Richards 1954).

- *Organic matter (OM)*: Organic matter was determined according to the "Modified Walker-Black" method (Nelson and Sommers 1982, Smith and Weldon 1941).

- *Useful phosphorus (ppm)*: The amount of phosphorus available to the plant was determined by considering the acidic nature of the soil (Olsen 1954).

- *Exchangeable calcium, potassium and sodium*: Calcium (Ca), potassium (K) and sodium (Na) ions that can be extracted from the soil, i.e., taken up by the plant, were determined using the 1 N ammonium acetate method (Helmke and Sparks 1996).

To determine the relationship between the distribution and density of weed species and climatic characteristics, climate data (1970-2020) for the surveyed hazelnut orchards were obtained from the WorldClim web database, which contains the current climate data for the whole world. The ESRI format and 19 bioclimatic variables with a 1 km grid were used to download the data. The coordinates obtained from the surveys and the climate data were transferred to the ArcGIS package (Hijmans et al. 2005). After transferring the climate data, the extraction function was used to obtain the location data.

Multivariate analyses were performed using SPSS (IBM 2017) and CANOCO 5 (Ter Braak and Smilauer 2012) packages to evaluate the data obtained from the survey studies. In this framework, ecological factors were associated with weeds, and it was revealed which ecological factors were most effective in determining the distribution of weed species. The data obtained from the soil analysis and weed surveys were subjected to Canonical Correspondence Analysis (CCA) to determine the effects of ecological factors on weed growth. The results of the analysis were used to determine which ecological factors (soil and climatic characteristics) were most effective in influencing weed growth.

RESULTS

Prevalence and density of weed species

As a result of the survey conducted in the hazelnut orchards of Ordu Province in the first period (April-May) of 2021-2022, it was determined that the most problematic weeds belonged to the Asteraceae, Lamiaceae, Fabaceae and Poaceae families. In the second period (August-September), it was determined that the most problematic weeds belonged to the Asteraceae, Poaceae, Lamiaceae and Apiaceae families. As a result of the survey conducted over two years, a total of 194 weed species belonging to 49 families were identified. Of the weed species, 6 were seedless, 27 were monocotyledons and 161 were dicotyledons (Table 2).

The 2 weed species with the highest square metre density (plants/m²) according to the survey conducted in the first period (April-May) were *Bellis perennis* L. (15.97) and *Urtica dioica* L. (15.29). The 2 weed species with the highest frequencies (%) identified in the survey conducted in the first period of 2021-2022 were *B. perennis* (76.00%) and *U. dioica* (62.00%). The 2 weed species with the highest square meter density (plants/m²) according to the survey conducted in the second period (August-September) based on the averages of 2021-2022 were *U. urtica* (10.71) and *Convolvulus arvensis* L. (3.98). The 2 weed species with a high frequency (%) according to the survey conducted in the second period, averaged over the periods of 2021-2022, were *U. dioica* (79.34%) and *C. arvensis* (74.00%) (Table 3). According to the survey conducted in the first period, which averaged from on a period basis, the 2 weed species with the highest coverage (%) were *B. perennis* (18.55%) and *U. dioica* (17.46%). The two weed species with the highest specific coverage (%) in the first period of were *B. tectorum* (23.94%) and *A. myosuroides* (18.96%), respectively. The 2 weed species with the highest coverage (%) in the second period of 2021-2022 were *U. dioica* (11.69%) and *C. arvensis* (4.81%), respectively. According to the survey conducted in the second period of 2021-2022 (August-September), the 2 weed species with the highest specific coverage (%) were *Carex leporina* L. (28.97%) and *Brachypodium sylvaticum* (Huds.) P. B. (20.77%) (Table 3).

The 10 weed species with the greatest dominance according to the survey of the first and second period were given in Table 4. *B. perennis* (0.098) and *U. dioica* (0.091) were in the first two ranks. Similarity indices were calculated for weed species detected as a result of surveys conducted in hazelnut orchards of Ordu in different years, periods and three different regions (Table 4). When evaluated on a regional basis as a result of the survey conducted in the first period of 2021, the similarity rate between the coastal region and the

Table 2. Number of species and percentage of weeds detected in hazelnut orchards in the first (April-May) and second (August-September) periods of 2021-2022 according to the families to which they belong

Weed family	First Year (2021)		Second Year (2022)	
	First period (April-May)	Second period (August-September)	First period (April-May)	Second period (August-September)
Amaranthaceae	-	3	6	3
Amaryllidaceae	1	-	-	-
Apiaceae	7	6	-	5
Apocynaceae	1	1	1	1
Araceae	1	1	1	1
Araliaceae	1	2	1	2
Asparagaceae	1	-	1	-
Aspleniaceae	1	1	1	1
Asteraceae	17	22	19	24
Boraginaceae	2	2	2	2
Brassicaceae	4	4	6	5
Campanulaceae	-	5	-	5
Caprifoliaceae	1	1	1	1
Caryophyllaceae	5	2	3	2
Cistaceae	1	1	-	-
Commelinaceae	1	1	-	1
Convolvulaceae	1	1	1	1
Cyperaceae	1	3	1	3
Dennstaedtiaceae	1	1	1	1
Dryopteridaceae	1	1	1	1
Equisetaceae	-	1	2	1
Euphorbiaceae	3	4	3	4
Fabaceae	10	5	10	4
Gentianaceae	-	1	-	1
Geraniaceae	4	5	4	4
Hypericaceae	-	1	-	1
Iridaceae	1	-	1	-
Juncaceae	2	1	1	2
Lamiaceae	11	14	12	13
Liliaceae	1	1	1	1
Lythraceae	-	1	-	1
Malvaceae	2	1	2	1
Orchidaceae	2	-	3	1
Oxalidaceae	1	1	1	1
Papaveraceae	1	1	1	1
Phytolaccaceae	1	1	1	1
Plantaginaceae	2	3	1	3
Poaceae	8	15	12	19
Polygonaceae	2	2	4	2
Polypodiaceae	1	-	-	1
Primulaceae	4	1	2	1
Ranunculaceae	3	1	3	1
Rosaceae	5	6	6	6
Rubiaceae	1	1	1	1
Scrophulariaceae	4	3	4	2
Smilacaceae	1	1	1	1
Solanaceae	-	3	1	2
Urticaceae	1	1	1	1
Violaceae	1	-	1	-
Total	120	133	125	136

Table 3. The 10 weed species with the highest density (adet/m²), frequency (%), coverage (%) and special coverage (%) of in first and second year hazelnut orchards in 2021-2022

Weed species	First period (April-May)				Second period (August-September)			
	Density (adet/m ²)	Frequency (%)	Coverage (%)	Special coverage (%)	Density (adet/m ²)	Frequency (%)	Coverage (%)	Special coverage (%)
<i>Bellis perennis</i> L.	15.97	76.00	18.55	12.17	-	-	-	-
<i>Urtica dioica</i> L.	15.29	62.00	17.46	14.45	10.71	79.34	11.69	14.82
<i>Geranium palustre</i> L.	9.26	48.00	9.95	10.12	0.17	2.67	0.17	6.72
<i>Bromus tectorum</i> L.	8.61	20.67	9.35	23.94	-	-	-	-
<i>Alopecurus myosuroides</i> Huds.	5.99	17.34	6.95	18.96	0.33	2.00	0.25	11.23
<i>Convolvulus arvensis</i> L.	5.20	57.34	6.89	5.98	3.98	74.00	4.81	6.22
<i>Artemisia vulgaris</i> L.	4.87	21.80	4.96	11.31	3.19	25.34	3.53	13.88
<i>Medicago arabica</i> (L.) Huds.	4.75	24.00	4.58	9.39	-	-	-	-
<i>Galium aparine</i> L.	4.10	38.67	4.46	5.79	0.22	6.00	0.21	3.38
<i>Trifolium repens</i> L.	4.01	27.34	4.74	8.69	0.58	8.67	0.60	6.55
<i>Euphorbia helioscopia</i> L.	3.23	40.00	4.20	5.26	0.40	13.34	0.42	2.88
<i>Rumex crispus</i> L.	2.28	37.33	2.60	3.45	0.96	32.67	1.01	3.11
<i>Ranunculus acris</i> L.	3.55	32.67	4.21	6.41	-	-	-	-
<i>Lapsana communis</i> L.	3.88	30.00	4.82	8.32	2.16	40.67	2.53	5.95
<i>Lamium purpureum</i> L.	3.61	29.34	4.13	6.79	0.10	1.34	0.07	2.50
<i>Pteridium aquilinum</i> (L.) Kuhn	3.96	27.58	4.97	8.97	3.54	40.00	3.57	8.62
<i>Oplismenus undulatifolius</i> (A.) P. B.	0.08	1.34	0.07	1.40	3.12	26.67	3.37	12.59
<i>Setaria viridis</i> (L.) P. B.	0.25	1.34	0.31	5.87	3.09	24.00	2.86	15.24
<i>Lolium perenne</i> L.	0.96	3.33	1.14	15.43	2.46	16.67	2.64	15.74
<i>Dryopteris filix-mas</i> (L.) Schott	1.26	12.67	4.97	8.97	1.99	32.00	2.09	6.55
<i>Salvia pratensis</i> L.	0.63	9.34	0.94	4.89	1.84	32.00	1.93	6.05
<i>Coryza canadensis</i> (L.) Cronquist	0.80	11.33	0.96	3.96	1.82	43.33	1.86	4.32
<i>Geum urbanum</i> L.	0.36	4.67	0.38	3.86	1.82	38.67	1.55	3.95
<i>Rubus canescens</i> DC.	1.28	24.67	1.79	3.68	1.03	34.00	1.15	3.33
<i>Carex sylvatica</i> Hudson	1.85	8.67	1.57	13.81	1.01	5.33	0.92	17.24
<i>Sorghum halepense</i> (L.) Pers.	3.43	14.67	3.72	12.88	0.89	6.67	0.87	14.26
<i>Geranium pratense</i> L.	2.24	12.67	2.30	12.74	0.59	10.67	0.56	5.21
<i>Hordeum murinum</i> L.	1.69	8.67	2.06	11.91	1.63	13.34	1.76	12.54
<i>Oplismenus undulatifolius</i> (A.) P. B.	1.69	1.34	0.07	1.40	3.12	26.67	2.02	12.59
<i>Carex leporina</i> L.	-	-	-	-	0.37	1.33	0.32	28.97
<i>Brachypodium sylvaticum</i> (Huds.) P. B.	-	-	-	-	0.58	3.34	0.73	20.77
<i>Juncus effusus</i> L.	0.03	0.67	0.03	1.00	0.43	2.00	0.47	19.95
<i>Hydrocotyle verticillata</i> Thunb.	-	-	-	-	0.56	2.67	0.49	18.05
<i>Agrostis capillaris</i> L.	-	-	-	-	0.23	1.33	0.24	17.50
<i>Avena fatua</i> L.	0.19	1.33	0.14	5.08	0.23	1.33	0.26	15.07

Table 4. The 10 weed species with the greatest dominance in hazelnut orchards in the first, second periods of 2021-2022 and similarity indices of weed species according to region, period and year

Weed species	Dominance		Regions and periods	Similarity Index	
	First period (April-May)	Second period (August-September)		First period (April-May)	Second period (August-September)
<i>Bellis perennis</i> L.	0.098	-	Coastal zone-Middle zone	73.10	68.11
<i>Urtica dioica</i> L.	0.091	0.132	Coastal zone-High zone	70.96	66.67
<i>Geranium palustre</i> L.	0.052	0.009	Middle zone-High zone	72.91	73.68
<i>Bromus tectorum</i> L.	0.049	-	Coastal-Middle-Highland zone	60.20	55.00
<i>Alopecurus myosuroides</i>	0.036	0.003	First period-Second period		66.67
<i>Convolvulus arvensis</i> L.	0.036	0.052	2021 year-2022 year		98.52
<i>Pteridium aquilinum</i> (L.)	0.026	0.041			
<i>Artemisia vulgaris</i> L.	0.026	0.040			
<i>Lapsana communis</i> L.	0.025	0.028			
<i>Trifolium repens</i> L.	0.025	0.007			
<i>Oplismenus undulatifolius</i>	0.004	0.038			
<i>Setaria viridis</i> (L.) P. B.	0.002	0.036			
<i>Lolium perenne</i> L.	0.006	0.029			
<i>Dryopteris filix-mas</i> (L.)	0.025	0.024			
<i>Glechoma hederecea</i> L.	0.018	0.022			

Table 5. Information of the location of hazelnut orchards and some physical and chemical characteristics of the soil

Region	Sample number	Sampling points	pH	Lime (%)	Organic matter (%)	EC (dS/m)	Phosphor P ₂ O ₅ (kg/da)	Potassium K ₂ O (kg/da)	Ca (mg/kg)	Na (me/100 g)	Texture classrom
Coastal zone	1	Gülyalı Ayrılık	4.2	0.56	2.39	0.22	0.17	53	10	0.02	Clay
	2	Gülyalı Turnasuyu	6.4	2.02	2.22	0.52	1.20	29	498	0.02	Clay-Loamy
	3	Altınordu Cumhuriyet	5.2	0.48	2.97	0.33	1.20	21	287	0.03	Clay-Loamy
	4	Altınordu Yukarıtepe	4.2	0.65	3.52	0.10	1.83	45	75	0.03	Clay-Loamy
	5	Altınordu Eyüplü	5.4	0.73	3.20	0.38	3.72	36	324	0.03	Clay-Loamy
	6	Altınordu Bayadı	5.3	0.33	2.02	0.70	1.95	52	789	0.07	Clay
	7	Altınordu Dedeli	5.6	0.49	1.54	1.19	3.21	66	1013	0.04	Clay
	8	Altınordu Yemişli	5.6	0.49	1.46	0.64	1.09	55	465	0.03	Clay
	9	Altınordu Boztepe	6.1	0.65	2.30	0.26	6.07	56	790	0.05	Clay
	10	Altınordu Kurtuluş	5.8	0.57	5.55	0.12	20.55	216	490	0.03	Clay
	11	Perşembe Efirli	5.7	0.49	2.32	0.69	4.35	87	966	0.04	Clay
	12	Perşembe Çınar	5.8	0.49	3.47	0.53	10.08	36	736	0.03	Clay-Loamy
	13	Perşembe Çaytepe	4.4	0.41	1.69	0.62	1.89	117	672	0.04	Clay
	14	Fatsa Yalıköy	6.1	0.58	1.99	0.75	2.52	62	774	0.04	Clay
	15	Fatsa Konakbaşı	5.6	0.42	3.33	0.67	1.32	21	464	0.04	Clay
	16	Fatsa Bağlarca	5.5	0.42	3.10	0.43	2.63	66	424	0.02	Clay
	17	Fatsa Sefaköy	5.4	0.40	2.7	0.81	1.72	15	604	0.06	Clay
	18	Fatsa Ayazlı	5.3	0.42	3.28	0.62	2.35	49	454	0.02	Clay
	19	Fatsa Eskiordu	6.9	1.25	2.74	0.60	0.86	245	450	0.02	Clay
	20	Ünye Yüceller	5.2	0.33	2.57	0.23	0.57	12	84	0.05	Clay-Loamy
	21	Ünye Cevizdere	6.0	0.33	3.76	0.40	3.32	10	185	0.03	Clay-Loamy
	22	Ünye Gürecülü	4.4	0.42	2.99	0.46	0.86	21	320	0.02	Clay-Loamy
	23	Ünye Nadırlı	4.3	0.42	1.65	0.62	0.92	37	442	0.02	Clay
	24	Ünye Gölevi	6.0	0.33	3.97	0.45	1.49	14	389	0.03	Clay
	25	Ünye Aydın-tepe	5.2	0.33	2.57	0.23	0.69	12	95	0.03	Clay-Loamy

Middle zone	1	Kabadüz Esenyurt	6.6	0.57	2.86	0.99	3.09	73	795	0.02	Clay
	2	Kabadüz Karakiraz	6.8	0.49	2.09	0.79	2.18	28	758	0.02	Clay-Loamy
	3	Kabadüz Başköy	5.7	0.41	3.42	0.34	1.2	20	248	0.01	Clay
	4	Ulubey Akpınar	7.4	15.40	0.99	0.14	0.86	72	703	0.02	Clay
	5	Ulubey Kumrulu	7.7	23.72	0.49	0.95	0.4	42	1143	0.03	Clay
	6	Ulubey Merkez	7.1	5.83	1.94	1.12	0.69	64	911	0.02	Clay
	7	Ulubey Gündüzlü	7.1	27.05	2.01	0.95	0.46	42	643	0.02	Clay-Loamy
	8	Ulubey Çukur	7.2	10.40	1.69	1.07	0.29	66	905	0.01	Clay
	9	Ulubey Yolbaşı	7.4	22.89	1.09	0.83	0.23	47	846	0.01	Clay
	10	Çamaş Hisarbey	5.4	0.50	1.1	0.54	0.29	26	378	0.02	Clay
	11	Çamaş Danışman	6.6	0.83	0.58	0.89	0.23	44	799	0.03	Clay
	12	Çamaş Merkez	4.9	0.42	1.77	0.31	0.34	131	358	0.06	Clay
	13	Çatalpınar Göller	7.1	15.10	1.53	0.80	2.12	56	1089	0.03	Clay
	14	Çatalpınar Kıran	4.9	0.33	2.78	0.40	2.29	104	541	0.10	Clay
	15	Çatalpınar Karşiyaka	5.5	0.41	4.49	0.20	1.89	23	336	0.02	Clay-Loamy
	16	Çatalpınar Madenköy	4.1	0.49	3.42	0.07	1.03	19	17	0.01	Clay
	17	Fatsa Bacanak	5.2	0.42	4.01	0.32	0.92	459	273	0.07	Clay
	18	Kumru Karaağaç	5.9	0.40	2.73	0.59	11.51	245	409	0.02	Clay-Loamy
	19	Kumru Merkez	7.2	28.35	1.01	0.77	0.86	29	764	0.05	Clay
	20	Ünye İnkur	7.3	7.49	2.37	0.71	0.74	46	587	0.02	Clay
	21	Ünye Dizdar	5.7	0.50	2.41	0.30	0.92	19	273	0.02	Clay-Loamy
	22	Çaybaşı Hanyanı	5.6	0.42	3.02	0.49	1.77	32	279	0.06	Clay-Loamy
	23	Çaybaşı Çayır	5.4	0.42	2.08	0.44	0.11	22	555	0.09	Clay
	24	İkizce Kocaman	5.3	0.42	3.21	0.21	7.27	18	167	0.02	Clay-Loamy
	25	İkizce Ağcaalan	6.8	0.67	2.50	0.55	2.52	35	196	0.01	Clay-Loamy
High zone	1	Ulubey Şeyhler	7.4	6.66	0.59	0.86	1.66	47	1097	0.02	Clay-Loamy
	2	Ulubey Akoluk	6.6	0.67	0.85	0.93	2.86	61	758	0.02	Clay
	3	Gürgentepe Eskiköy	5.9	0.42	2.13	0.48	6.30	134	568	0.02	Clay-Loamy
	4	Gürgentepe Şirinköy	4.6	0.41	4.31	0.01	1.66	66	104	0.02	Clay
	5	Gürgentepe Merkez	4.8	0.49	5.38	0.02	2.4	67	200	0.02	Clay
	6	Gürgentepe Okçabel	4.3	0.41	5.81	0.01	4.18	52	46	0.01	Clay
	7	Gürgentepe Işıktepe	4.5	0.41	3.68	0.06	1.72	29	73	0.02	Clay
	8	Çamaş Uzunali	5.3	0.41	5.81	0.20	1.49	73	241	0.02	Clay
	9	Gölköy Emirler	4.3	0.41	4.08	0.20	6.81	213	203	0.01	Clay-Loamy
	10	Gölköy Kuşlvan	5.2	0.33	1.60	0.30	1.09	42	363	0.01	Clay-Loamy
	11	Gölköy Güzelyurt	6.6	0.33	2.49	0.50	1.43	33	742	0.04	Clay
	12	Kabataş Şifasuyu	5.2	0.41	1.17	0.20	1.20	24	206	0.01	Clay-Loamy
	13	Kabataş Eceli	7.4	12.90	1.34	0.79	0.46	36	903	0.02	Clay-Loamy
	14	Aybastı Çukur	6.4	0.67	2.21	0.62	0.29	44	466	0.02	Clay-Loamy
	15	Aybastı Merkez	5.9	0.50	2.79	0.44	1.09	33	332	0.03	Clay-Loamy
	16	Aybastı Sağlık	5.5	0.42	1.56	0.48	3.89	30	480	0.03	Clay-Loamy
	17	Aybastı Hacı Seyfakümevleri	4.8	0.50	3.94	0.19	2.52	40	216	0.02	Clay
	18	Aybastı Düzağıl	4.9	0.42	4.21	0.33	2.35	48	296	0.01	Clay
	19	Korgan Merkez	7.3	2.91	1.01	0.68	0.46	39	477	0.01	Clay-Loamy
	20	Korgan Yenipınar	7.1	10.53	2.44	0.83	1.09	29	501	0.01	Clay
	21	Korgan Aşağıyaylacık	5.0	0.40	2.68	0.39	4.87	33	415	0.02	Clay-Loamy
	22	Akkuş Esentepe	5.3	0.41	2.50	0.37	1.95	99	381	0.02	Clay
	23	Akkuş Muratlı	4.5	0.40	3.74	0.21	1.43	64	260	0.02	Clay
	24	Mesudiye Darıcabaşı	5.9	0.42	2.51	0.23	2.18	44	206	0.02	Clay-Loamy
	25	Mesudiye Pınarlı	5.2	0.40	3.38	0.17	1.66	30	148	0.02	Clay

central region (76.66) was the highest and the lowest among the three regions (60.00) (Table 4).

Relating weed populations to ecological factors

A total of 75 hazelnut orchards were sampled in three regions, 25 in each region, to best represent the province to reveal the changes in weed species and densities that are problematic in hazelnut orchards in Ordu according to the physical and chemical properties of the soil. For 75 hazelnut orchards, the physical and chemical properties of the soil together with the location information are given in Table 5. The descriptive statistical parameters of some of the physical and chemical properties of the soil samples are also given in Table 6.

The coefficient of variation (CV), which is one of the measures of dispersion in the data, was also calculated to better understand the variability of soil properties in hazelnut orchards. It is stated that the variability is low when the CV is between 0-15%, moderate when the CV is between 15-30% and high at values higher than these rates (Wilding et al. 1983).

The average pH of the surveyed hazelnut orchard soils varied between 5.40 and 6.20. The lowest average pH value was detected in the coastal region. The lime content of the soils in the study zone varied between 0.60 and 6.60 on average. Again, the lowest lime content was found in the coastal region. The average organic matter content was higher in the upland zone than in the other zones. One of the reasons for this is the grazing of animals (cows, sheep,

chickens, etc.) in the hazelnut orchards in higher zones. The average EC values of the soils varied between 0.40 and 0.60. The average potassium values of the soils varied between 56.90 and 70.90. The average phosphorus values of the soils varied between 1.80 and 3.10 and were found to be the lowest in the middle zone. When the average Ca amounts were analyzed, they varied between 387 and 558. The lowest average was detected in the highland zone. The soils of the hazelnut orchards consisted of clay and clay-loam soils. The variation between the zones in periods of texture class is very low. According to the results for the soils in the study zones, the greatest variability in the coefficient of variation (%) occurred for Na. The lowest CV ratio of sodium was found in the highland zone (Table 6).

The analysis results and distribution of 75 soil samples taken from hazelnut orchards in Ordu Province are given in Table 7. The texture classes of the soils were clayey and clayey-loamy and proportionally 61.33% clayey and 38.67% clayey-loamy. Total salt contents of the soils were analysed in saturation extract and all of them were found to be salt-free. The pH of the soils determined as 13.33% extreme acid, 9.33% very strong acid, 25.33% strong acid, 20% moderate acid, 4% mild acid, 21.33% neutral and 6.67% slightly alkaline. The lime levels of the soils were determined as 80% very low in lime, 4% were low in lime, 8% were medium in lime, 5.33% were high in lime and the remaining 2.67% very high in lime. When the organic matter levels of the soils of the region were evaluated proportionally, it was determined that 6.67% of the soils were classified as very low, 22.67% as low, 37.33% as medium and 33.33% as high.

Table 6. Complementary statistical parameters of physical and chemical properties of hazelnut orchard soils

Soil properties	Minimum			Maximum			Mean			Standard deviation			Coefficient of Variation		
	Coastal zone	Middle zone	Highland zone	Coastal zone	Middle zone	Highland zone	Coastal zone	Middle zone	Highland zone	Coastal zone	Middle zone	Highland zone	Coastal zone	Middle zone	Highland zone
pH	4.20	4.10	4.30	6.90	7.70	7.40	5.40	6.20	5.60	0.70	1.00	1.00	12.90	16.00	17.90
Lime (%)	0.30	0.30	0.30	2.00	28.40	13.00	0.60	6.60	1.70	0.40	9.60	3.30	64.30	146.00	197.00
Organic matter (%)	1.50	0.50	0.60	5.60	4.50	5.80	2.80	2.20	2.90	0.90	1.10	1.50	32.90	47.30	52.10
EC (dS/m)	0.10	0.10	0.10	1.20	1.10	0.90	0.50	0.60	0.40	0.30	0.30	0.30	50.00	52.50	73.70
Phosphor P ₂ O ₅ (kg/da)	0.20	0.10	0.30	20.60	11.50	6.80	3.10	1.80	2.30	4.20	2.50	1.70	137.00	141.00	74.00
Potassium K ₂ O (kg/da)	10.20	18.90	24.90	245.00	459.00	213.00	57.70	70.90	56.90	58.20	94.20	40.80	100.00	132.00	71.70
Ca (mg/kg)	10.00	17.00	46.00	1013.00	1143.00	1097.00	472.00	558.00	387.00	273.00	305.00	263.00	57.00	54.00	68.00
Na (me/100 g)	0.10	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.30	0.00	400	800	50.00
Texture classrom	1.00	1.00	1.00	2.00	2.00	2.00	1.40	1.30	1.50	0.50	0.50	0.50	36.00	36.40	34.50

When the available phosphorus contents of the local soils were analysed proportionally, it was determined that 80% of the soils contained very little phosphorus, 10.67% contained little phosphorus, 5.33% contained sufficient phosphorus, 2.67% contained excess phosphorus and 1.33% contained very high phosphorus. When the available potassium contents were evaluated proportionally with the same method, it was determined that 72% of the soils contained sufficient potassium, 17.33% contained little potassium, and 10.67% contained very little potassium. Ca and Na were found to be deficient in hazelnut orchards.

In the first period (April-May), the data obtained from the soil analyses and the weed species that were problematic in the hazelnut orchards were evaluated via Canonical Correspondence Analysis (CCA), and the spatial changes in the population dynamics of the weeds were revealed. CCA explained 8.18% of the change in species distribution on the four axes. Overall, 2.80% of the variance was explained by the 1st axis, 4.88% by the 2nd axis, and 6.61% by the 3rd axis. The first four axes contributed 59.50% of the variability between weed species and soil properties (Table 8). In the second period (August-September), the data obtained from the soil analyses and the weed species that were problematic in the hazelnut orchards were evaluated via Canonical Correspondence Analysis (CCA), and the spatial changes in the population dynamics of the weeds were revealed. CCA explained 7.69% of the change in species distribution on the four axes. Overall, 2.73% of the variance was explained by the first axis, 4.60% by the second axis, and 4.20% by the third axis. The first four axes contributed 59.75% to the variability between weed species and soil properties (Table 8).

The correlations between weed species and soil properties, which were found to be statistically significant at the $P < 0.01$ and $P < 0.05$ levels in the first period of hazelnut orchards, are shown in Table 9. In particular, the following weed species had a high frequency (%) and density (plants/m²): *B. berennis*, *G. pratense*, *P. vulgaris*, *S. officinale* and *T. pratense* had a positive correlation with lime, while *P. aquilinum* and *D. filix-mas* had a negative correlation; *U. dioica*, *R. crispus*, *S. exalsa*, *B. rapa* and *V. sativa* had a positive relationship with organic matter; *A. maculatum*, *G. palustre* and *T. pratense* had a negative relationship; *E. helioscopia*, *G. urbanum*, *R. crispus*, *U. dioica* had a negative relationship with EC; *A. maculatum*, *G. palustre*, *S. officinale*, *T. pratense* and *V. persica* had a positive relationship; *A. vulgaris*, *C. bursa-pastoris*, *C. sylvatica*, *L. purpureum*, *M. officinalis*, *M. annua*, *R. crispus*, *S. pratensis*, *U. dioica* and *V. major* had a positive relationship with phosphorus negative relationship with *H. ptytaenium* and *S. officinale*; *A. lappa*, *A. vulgaris*, *C. bursa-pastoris*, *C. sylvatica*, *D. filix-mas*, *F. vesca*, *L. purpureum*, *M. arabica*, *S. exalsa* and *S. holostea* positively related to potassium; *G. aparine*, *G. urbanum* and *T. officinale* negatively related to Ca, *G. palustre*, *T. pratense*, positively related; *M. annua* positively correlated with Na and negatively correlated with *A. millefolium* (Table 9).

Figure 1 shows that some of the weed species identified in the correlation between soil properties and weeds as a result of the survey conducted in the first period were selective for soil properties, while others were not. The distribution of weed species that were found to be significant as a result of correlation was determined by CCA. In soils with high organic matter (Nelson and Sommers), *U. dioica*, *R. crispus*, *R. rapa*, *G. urbanum*, *R. raphanistrum*, *S. exalsa* and *V.*

Table 8. Canonical Correspondence Analysis (CCA) results for the changes in weed communities in the first and second period of the survey depending on the physical and chemical structure of the soil

Statistic	First period (April-May)				Second period (August-September)			
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.1667	0.1240	0.1026	0.0933	0.2047	0.1408	0.1199	0.1125
Weed species and environmental correlations	0.8355	0.8713	0.8592	0.8210	0.9052	0.8612	0.8269	0.8187
Cumulative percentage change in weed species data	2.80	4.88	6.61	8.18	2.73	4.60	4.20	7.69
Cumulative percentage change in the relationship between weed species and environment	20.39	35.55	48.09	59.50	21.16	35.71	48.11	59.75

Table 7. Properties of the soil samples, evaluation, limit values and distribution according to region

Soil properties	Limit values	Evaluation	Number of samples	Total distribution (%)	Coastal zone		Middle zone		Reference		
					Number	%	Number	%	Number	%	
Available P ₂ O ₅ (kg/da)	<3	Very little	60	80.00	18	30.00	22	36.67	20	33.33	Ülgen and Yurtsever 1995
	3-6	Little	8	10.67	4	50.00	1	12.50	3	37.50	
	6-9	Sufficient	4	5.33	1	25.00	1	25.00	2	50.00	
	9-12	More	2	2.67	1	50.00	1	50.00	0	0	
	>12	Too much	1	1.33	1	100	-	-	-	-	
Available K ₂ O (kg/da)	<20	Very little	8	10.67	5	62.50	3	37.50	0	0	Sillanpää 1990
	20-30	Little	13	17.33	4	30.77	6	46.15	3	23.08	
	>30	Sufficient	54	70.00	15	27.78	16	29.63	23	42.59	
Ca (mg/kg)	<238	Very little	17	22.67	5	29.41	3	17.65	9	52.94	Maas 1986
	238-1150	Little	58	77.33	20	34.48	22	37.93	16	27.59	
	1150-3500	Sufficient	0	0	-	-	-	-	-	-	
	3500-10000	More	0	0	-	-	-	-	-	-	
EC dS/m (1:2.5 soil:water)	<4	Unsalted	75	100	25	33.33	25	33.33	25	33.33	Sönmez 2008
	4-8	Lightly salted	0	0	-	-	-	-	-	-	
	8-15	Medium salty	0	0	-	-	-	-	-	-	
	>15	Too salty	0	0	-	-	-	-	-	-	
CaCO ₃ (%)	<1	Very little limy	60	80.00	23	38.33	16	26.67	21	35.00	Ülgen and Yurtsever 1995
	1-5	Little limy	3	4	2	66.67	0	0	1	33.33	
	5-15	Medium limy	6	8	0	0	3	50.00	3	50.00	
	15-25	Too limy	4	5.33	0	0	4	100	0	0	
	>25	Too much limy	2	2,67	0	0	2	100	0	0	
Na (me/100 g)	2-10	Very sensitive	75	100	25	33.33	25	33.33	25	33.33	Smith and Weldon 1941
	10-20	Sensitive	0	0	-	-	-	-	-	-	
	20-40	Medium durable	0	0	-	-	-	-	-	-	
	40-60	Durable	0	0	-	-	-	-	-	-	
Organic matter (%)	>60	Very durable	0	0	-	-	-	-	-	-	Kellegg 1952
	0-1	Very little	5	6.67	0	0	3	60.00	2	40.00	
	1-2	Little	17	22.67	5	29.41	7	41.18	5	29.41	
	2-3	Middle	28	37.33	11	39.29	9	32.14	8	28.57	
	3-6	More	25	33.33	9	36.00	6	24.00	10	40.00	
pH (In saturation mud)	6 <	Too much	0	0	-	-	-	-	-	-	Özcan 2012
	≤ 4.5	Extreme acid	10	13.33	5	50.00	1	10.00	4	40.00	
	4.5-5.0	Very strong acid	7	9.33	0	0	2	28.57	5	71.43	
	5.1-5.5	Strong acid	19	25.33	8	42.11	5	26.32	6	31.58	
	5.6-6.0	Moderate acidity	15	20.00	8	53.33	4	26.67	3	20.00	
	6.1-6.5	Slightly acid	3	4.00	3	100	0		0	0	
	6.6-7.3	Neutral	16	21.33	1	6.25	10	62.50	5	31.25	
	7.4-7.8	Slightly alkaline	5	6.67	0	0	3	60.00	2	40.00	
	7.9-8.4	Alkaline	0	0	-	-	-	-	-	-	
8.5-9.0	Strongly alkaline	0	0	-	-	-	-	-	-		
Relief	>9.1	Very strong alkali	0	0	-	-	-	-	-	-	Ülgen and Yurtsever 1995
	%0-2	Flat-near slope	14	18.67	10	71.43	2	14.29	2	14.29	
	%2-6	Slight slope	3	4.00	0	0	3	100	0	0	
	%6-12	Middle slope	33	44.00	10	30.30	12	36.36	11	33.33	
Texture (%)	%12-18	Steep slope	25	33.33	5	20.00	8	32.00	12	48.00	Ülgen and Yurtsever 1995
	0-30	Sandy	0	-	-	-	-	-	-	-	
	30-50	Loamy	0	-	-	-	-	-	-	-	
	50-70	Clay-Loamy	29	38.67	9	31.03	8	27.59	12	41.38	
	70-110	Clay	46	61.33	16	34.78	17	36.96	13	28.26	
>110	Heavy clayey	0	-	-	-	-	-	-	-		

Table 9. Correlation analysis between weed species and soil properties in hazelnut orchards in the first period (April-May)

Weed species	pH	Lime (%)	Organic Matter (%)	EC (dS/m)	P ₂ O ₅ (kg/da)	K ₂ O (kg/da)	Ca (mg/kg)	Na (me/100 g)
<i>Achillea millefolium</i> L.	-0.88	-0.43	0.78	-0.43	0.98	-0.98	-0.73	-.990*
<i>Arctium lappa</i> L.	0.05	-0.08	0.18	0.26	0.01	.760**	0.05	0.05
<i>Artemisia vulgaris</i> L.	0.29	0.04	0.20	0.02	.590**	.500*	0.23	0.10
<i>Arum maculatum</i> L.	0.53	0.55	-.780**	.640*	-0.44	0.27	0.50	-0.40
<i>Bellis perennis</i> L.	0.18	.280*	-0.22	0.19	-0.22	-0.20	0.17	-0.08
<i>Brassica rapa</i> L.	-0.50	-0.41	.820*	-0.70	-0.12	0.13	-0.64	-0.55
<i>Capsella bursa-pastoris</i> (L.) M.	-0.33	-0.52	0.17	-0.13	.990**	.890*	-0.33	0.17
<i>Carex sylvatica</i> Hudson	0.37	0.32	-0.07	0.41	.590*	.600*	0.46	-0.09
<i>Dryopteris. filix-mas</i> (L.) Schott	-.560*	-.400*	-0.06	-0.14	-0.06	.680*	-0.10	0.14
<i>Euphobia helioscopia</i> L.	-0.20	-0.11	0.20	-.330*	0.27	0.00	-0.31	-0.03
<i>Euphorbia stricta</i> L.	0.12	0.43	-0.25	0.42	0.39	-.730*	0.09	0.19
<i>Fragaria vesca</i> L.	-0.19	-0.36	0.04	-0.11	0.37	.390*	-0.12	0.16
<i>Galium aparine</i> L.	-0.14	-0.06	0.17	-0.25	0.10	-0.04	-.330*	-0.12
<i>Geranium palustre</i> L.	.280*	0.15	-.330*	.480**	-0.24	-0.07	.440**	0.22
<i>Geranium pratense</i> L.	0.31	.530*	-0.06	0.28	-0.09	-0.03	0.12	-0.01
<i>Geum urbanum</i> L.	-0.76	-0.69	0.71	-.880*	-0.25	-0.01	-.870*	-0.60
<i>Heracleum ptytaenium</i> Boiss.	0.86	0.41	0.15	0.01	-.980*	0.30	0.05	0.17
<i>Lamium purpureum</i> L.	0.19	0.23	0.04	0.06	.400*	.550**	0.24	-0.10
<i>Medicago arabica</i> L.	-0.06	-0.07	-0.02	-0.03	0.37	.540**	-0.11	-0.11
<i>Melissa officinalis</i> L.	0.31	0.12	0.33	0.02	.640*	-0.36	-0.07	-0.18
<i>Mercurialis annua</i> L.	-0.01	0.05	0.05	-0.49	.640**	0.05	0.09	.510*
<i>Prunella vulgaris</i> L.	0.17	.470*	-0.22	0.10	0.13	-0.14	0.14	-0.16
<i>Pteridium aquilinum</i> (L.) K.	-0.22	-.330*	0.12	-0.04	0.18	0.03	0.15	0.31
<i>Raphanus raphanistrum</i> L.	-0.55	-0.56	0.84	-0.78	.910*	-0.40	-0.75	-0.58
<i>Rumex crispus</i> L.	-0.29	-0.12	.280*	-.400*	.360*	0.17	-0.28	-0.20
<i>Salvia pratensis</i> L.	-0.05	-0.36	0.01	0.17	.740*	-0.13	0.33	0.34
<i>Scrophularia scopolii</i> H.P.	-0.52	-.890*	0.17	-0.14	-0.33	0.30	-0.13	-0.23
<i>Senecia vulgaris</i> L.	-.690*	-0.37	0.60	-0.60	.680*	-0.21	-0.48	-0.35
<i>Sisymbrium officinale</i> L.	0.86	.970**	-0.71	.880*	-.890*	0.76	0.75	-0.23
<i>Smilax exalsa</i> L.	-0.33	-0.52	.900*	-0.28	.880*	.890*	-0.03	0.50
<i>Stellaria holostea</i> L.	0.49	0.93	-0.07	0.83	0.93	1.00**	0.68	0.54
<i>Taraxacum officinale</i> L.	-0.24	-0.20	0.08	-0.28	-0.31	-0.14	-.430*	-0.09
<i>Trifolium pratense</i> L.	.740*	.750*	-.670*	.640*	-0.57	-0.26	.650*	0.14
<i>Urtica dioica</i> L.	-0.21	-0.17	.570**	-.260*	.490**	0.10	-0.24	-0.24
<i>Verbascum thapsus</i> L.	-0.87	0.31	1.00*	-0.64	-0.22	-0.64	-0.58	-0.69
<i>Veronica persica</i> Poirlet	0.35	-0.34	-0.75	.870*	-0.46	-0.17	0.55	0.09
<i>Vicia sativa</i> L.	-0.41	-0.04	.530*	-0.37	0.28	0.36	-0.26	-0.38
<i>Vinca major</i> L.	-0.89	-0.63	0.67	0.17	.960*	0.64	0.08	0.87

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

thapsus; in soils with low lime, EC, Ca, Na and pH, *D. filix-mas*, *P. aquilinum*, *S. vulgaris*, *S. scopolii* and *S. pratensis*; *B. perennis*, *P. vulgaris*, *T. pratense*, *T. officinale* and *M. officinalis* in soils with high lime, EC, Ca and pH; and *A. vulgaris*, *L. purpureum*, *S. exalsa* and *G. urbanum* in soils with high phosphorus content. However, the soil properties that limit the distribution of most weed species with precise lines have not been identified (Figure 1).

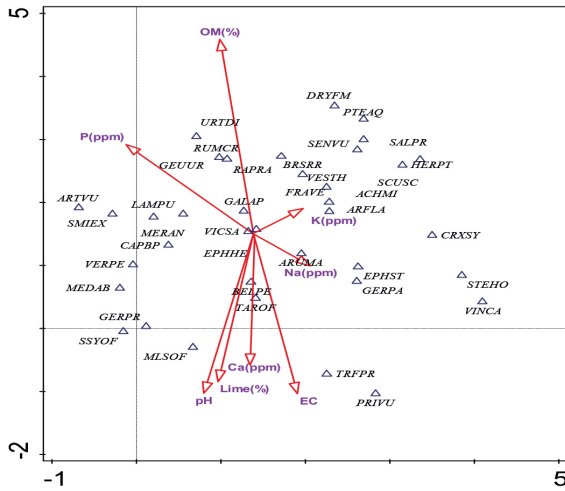


Figure 1. Distribution of weed species that are problematic in hazelnut orchards in the first period (April-May) according to soil properties*

[*ACHMI: *A. millefolium*, ARFLA: *A. lappa*, ARTVU: *A. vulgaris*, ARUMA: *A. maculatum*, BELPE: *B. perennis*, BRSRR: *B. rapa*, CAPBP: *C. bursa-pastoris*, CRXSY: *C. sylvatica*, DRYFM: *D. filix-mas*, EPHHE: *E. helioscopia*, EPHST: *E. stricta*, FRAVE: *F. vesca*, GALAP: *G. aparine*, GERPA: *G. palustre*, GERPR: *G. pratense*, GEUUR: *G. urbanum*, HERPT: *H. platytaenium*, LAMPU: *L. purpureum*, MEDAB: *M. arabica*, MEUOF: *M. officinalis* MERAN: *M. annua*, POLVU: *P. vulgare*, PTEAQ: *P. aquilinum*, RAPRA: *R. raphanistrum*, RUMCR: *R. crispus*, SALPR: *S. pratensis*, SCUSC: *S. scopolii*, SENVU: *S. vulgaris*, SSYOF: *S. officinale*, SMIEX: *S. excelsa*, STEHO: *S. holostea*, TAROF: *T. officinale*, TRFPR: *T. pratense*, URTDI: *U. dioica*, VESTH: *V. thapsus*, VERPE: *V. persica*, VICSA: *V. sativa*, VINMA: *V. major*]

The correlations between weed species and soil properties, which were found to be statistically significant at $P < 0.01$ and $P < 0.05$ in the second period in the hazelnut orchard, are shown in Table 10. The weed species with high frequency (%) and density (plants/m²) were *C. arvensis*, *A. maculatum* and *T. pratense*, which were positively correlated with pH and lime; *P. aquilinum*, which was negatively correlated with lime; *U. dioica*, *R. crispus*, *M. officinalis* and *P. minor*, which were positively correlated with organic matter; *G. parviflora*, *T. pratense* and *O. stricta*, which were negatively correlated; *A. vulgaris*, *A. maculatum*, *C. glomerata*, *T. pratense* and *P. hydropiper*, which were positively correlated with EC and negatively correlated with *C. arvensis*, *G. palustre*, *H. perforatum*, *R. crispus* and *U. dioica*; *A. podagraria*, *L.*

communis, *S. verticillata*, *M. neglectum* and *U. dioica*, which were positively correlated with phosphorus; *C. glomerata* and *S. glauca*, which were negatively; *L. communis* and *S. verticillata* positively correlated with potassium; *A. vulgaris*, *A. maculatum*, *C. arvensis*, *F. vesca*, *P. dilatatum* and *T. pratense* positive relationship with Ca, *U. dioica* negative relationship; *C. dactylon*, *F. vesca*, *T. pratense* showed positive correlation with Na and negative correlation with *C. erythraea*, *P. annua* and *P. major* (Table 10).

In periods of the correlation between soil properties and weeds, some of the weed species were found to be selective in periods of soil properties, while others were not (Figure 2). The distribution of weed species that were found to be significant as a result of correlation was made by CCA. *O. vulgare*, *U. dioica*, *R. crispus*, *P. aquilinum* and *P. minor* in soils with high organic matter (OG) and low EC, lime, Ca, pH and K; *A. maculatum*, *E. helioscopia*, *T. pratense*, *C. dactylon* and *L. amplexicaula*; *F. vesca*, *S. viridis* and *G. parviflora* weed species were indicator plants in soils with high phosphorus and Na contents.

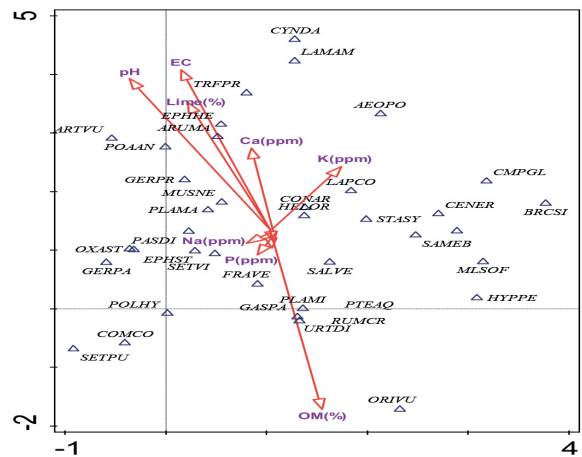


Figure 2. Distribution of weed species that are problematic in hazelnut orchards in the second period (August-September) according to soil properties*

[**A. podagraria*: AEOPO, *A. vulgaris*: ARTVU, *A. maculatum*: ARUMA, *B. sylvaticum*: BRCSI, *C. glomerata*: CMPGL, *C. erythraea*: CENER, *C. communis*: COMCO, *C. arvensis*: CONAR, *C. dactylon*: CYNDA, *E. helioscopia*: EPHHE, *E. stricta*: EPHST, *F. vesca*: FRAVE, *G. parviflora*: GASPA, *G. palustre*: GERPA, *G. pratense*: H. orientalis: HELOR, *H. perforatum*: HYPPE, *L. amplexicaula*: LAMAM, *L. communis*: LAPCO, *M. officinalis*: MLSOFF, *M. neglectum*: MUSNE, *O. vulgare*: ORIVU, *O. stricta*: OXAST, *P. dilatatum*: PASDI, *P. hydropiper*: POLHY, *P. major*: PLAMA, *P. minor*: PLAMI, *P. annua*: POAAN, *P. aquilinum*: PTEAQ, *R. crispus*: RUMCR, *S. verticillata*: SALVE, *S. ebulus*: SAMEB, *S. glauca*: SETPU, *S. viridis*: SETVI, *S. sylvatica*: STASY, *T. pratense*: TRFPR, *U. dioica*: URTDI]

Relationships between weed populations and climatic characteristics

To determine the relationships between the distribution and density of weed species and climatic characteristics,

Table 10. Correlation analysis between weed species and soil properties in hazelnut orchards in the second period (August-September)

Weed species	pH	Lime (%)	Organic Matter (%)	EC (dS/m)	P ₂ O ₅ (kg/da)	K ₂ O (kg/da)	Ca (mg/kg)	Na (me/100 g)
<i>Aegopodium podagraria</i> L.	0.13	0.05	0.06	-0.01	.470*	-0.11	-0.05	-0.23
<i>Artemisia vulgaris</i> L.	0.33	0.23	-0.30	.480*	-0.02	-0.02	.560**	-0.02
<i>Arum maculatum</i> L.	.980**	.890*	-0.22	.900*	-0.18	0.10	.930*	-0.31
<i>Brachypodium sylvaticum</i> P.B.	0.20	-0.21	-0.30	0.74	0.87	0.68	1.00*	0.78
<i>Campanula glomerata</i> L.	0.59	0.02	-0.87	.990*	-.990*	-0.72	0.95	0.91
<i>Centaureum erythraea</i> L.	-0.22	-0.30	-0.90	-0.34	0.03	0.39	0.10	-.980*
<i>Commelina communis</i> L.	-0.28	.940**	0.11	-0.28	-0.02	-0.29	-0.48	-0.41
<i>Convolvulus arvensis</i> L.	.400**	.310*	-0.19	.390**	0.02	-0.04	.430**	0.06
<i>Cynodon dactylon</i> (L.) Pers.	0.81	.950*	-0.84	0.48	-0.29	-0.65	0.64	.990*
<i>Euphorbia helioscopia</i> L.	0.41	.630**	-0.44	0.33	-0.42	0.24	0.31	0.06
<i>Euphorbia stricta</i> L.	0.79	.960*	-0.71	0.72	-0.45	-0.27	0.33	-0.35
<i>Fragaria vesca</i> L.	0.42	0.09	-0.39	0.35	0.25	0.23	.610*	.550*
<i>Galinsoga parviflora</i> Cav.	0.66	0.62	-.980*	0.77	-0.09	0.23	0.93	0.43
<i>Geranium palustre</i> L.	-0.19	-0.14	-0.10	-.990*	0.32	-0.95	-0.94	-0.14
<i>Geranium pratense</i> L.	0.43	.680*	-0.16	0.45	-0.18	-0.06	0.60	-0.18
<i>Helleborus orientalis</i> Lam.	0.01	0.36	0.13	0.21	-.520*	0.04	-0.26	0.02
<i>Hypericum perforatum</i> L.	-0.65	-0.06	0.46	-.970*	-0.50	-0.26	-0.77	-0.63
<i>Lamium amplexicaula</i> L.	0.83	.910*	-0.63	0.81	-0.49	-0.49	0.84	0.47
<i>Lapsana communis</i> L.	0.27	0.11	-0.15	0.29	.330*	.520**	0.30	-0.03
<i>Melissa officinalis</i> L.	-0.32	-0.53	1.00*	-0.95	-0.57	-0.53	-0.89	-0.76
<i>Muscari neglectum</i> Guss.	0.14	-0.01	0.25	0.06	.990**	0.54	0.25	-0.06
<i>Origanum vulgare</i> L.	-0.08	1.00	0.98	-0.71	.990*	1.00*	0.81	1.00**
<i>Oxalis stricta</i> L.	.670**	.870**	-.550*	.750**	-0.38	-0.04	.670**	-0.29
<i>Paspalum dilatatum</i> Poir.	-0.48	-0.34	0.54	-0.65	-0.05	-0.67	-.860**	0.12
<i>Persicaria hydropiper</i> L.	0.69	0.71	-0.82	.940*	-0.31	-0.40	0.54	-0.04
<i>Plantago major</i> L.	0.03	-0.01	-0.14	-0.05	-0.17	-0.13	0.03	-.370*
<i>Plantago minor</i> L.	-0.57	0.83	.890*	-0.24	0.25	0.47	0.05	-0.70
<i>Poa annua</i> L.	0.17	-0.34	-0.14	0.13	0.91	0.98	0.14	-.990*
<i>Pteridium aquilinum</i> (L.) Kuhn	-0.17	-.390*	-0.16	0.04	0.09	-0.10	0.19	-0.06
<i>Rumex crispus</i> L.	-0.32	-0.31	.490**	-.460*	0.11	0.30	-0.29	-0.29
<i>Salvia verticillata</i> L.	-0.66	0.42	0.45	-0.25	.950**	.980**	-0.31	-0.49
<i>Sambucus ebulus</i> L.	-0.11	-0.15	-0.05	-0.13	0.22	.790**	0.04	-0.27
<i>Setaria glauca</i> (L.) P.B.	-0.75	-0.05	-0.53	-0.56	-.930*	0.63	-0.58	-0.70
<i>Setaria viridis</i> (L.) P.B.	0.32	.400*	-0.06	0.13	0.01	-0.02	0.07	0.09
<i>Stachys sylvatica</i> L.	.680*	0.43	-0.55	0.28	-0.28	-0.20	0.55	-0.10
<i>Trifolium pratense</i> L.	.630**	.560*	-.590*	.720**	-0.16	-0.10	.720**	.520*
<i>Urtica dioica</i> L.	-0.16	-0.17	.510**	-.250*	.260*	0.16	-.250*	0.09

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level

data on 19 different bioclimatic variables (1970–2020) of hazelnut orchards were obtained from the WorldClim Web (Anonymous, 2023), where current climate data for the whole world are available. The data were downloaded using the ESRI format and 19 bioclimatic variables with a 1 km grid. The coordinates and bioclimatic data obtained from the surveys were transferred to the ArcGIS package (Hijmans et al. 2005). Correlation analyses were performed between bioclimatic variables and weed species determined as a result of the first and second period surveys in hazelnut orchards. The correlations were found to be statistically significant at the $P < 0.01$ and $P < 0.05$ levels, and the data obtained were evaluated via the CCA method to determine the population distribution of weed species. As a result of the evaluation, no bioclimatic variables limiting the distribution of weed species with clear lines were determined.

DISCUSSION

Determination and distribution of weed populations

A two-year survey (2021-2022) in Ordu hazelnut orchards revealed that most of the weeds belonged to the Asteraceae family. This is consistent with regional and national floristic studies, as Asteraceae is one of the largest and most widespread plant families in Türkiye (Düzenli et al. 1993, Mennan et al. 1999, Özbucak et al. 2016, Mutlu and Avcı 2023, Şenkul and Kaya 2017). These families are common in agricultural ecosystems, from horticulture to field crops, and include many problematic weed species (Özcan 2012, Türe and Köse 2000). During the 2021-2022 survey periods, 194 weed species were identified and analysed by region. Most showed a broad ecological tolerance, occurring in two or three zones, while others showed shade and elevation preferences. For example, *Campanula* spp. were mostly found in middle and high zones and *Verbascum* spp. in high zones. Weed density was generally higher in upland areas and lower in coastal areas. This pattern is consistent with previous studies showing that elevation influences weed distribution (Fried et al. 2008, Özcan 2016, Pinke et al. 2010, Ramôa et al. 2015). Although weeds have specific ecological ranges, they are spread by animals, humans, wind, water, soil movement and agricultural tools. Species such as *A. barbatiflora*, *Campanula* sp., *H. orientalis*, *P. elatior* and *Salvia* sp., which are common in the highlands, were occasionally observed in the lowlands, showing their adaptability to new environments. In the first study period, *B. perennis* and *U. dioica* had the highest density (plants/m²) and frequency (%), while in the second period *U. dioica* and *C. arvensis* dominated. These results are consistent with previous studies on hazelnut and kiwifruit weeds in Ordu (Sezer and Kolören 2019, Yonat and Kolören 2017, 2023). Perennial and tall weeds such as *U. dioica*, *P. aquilinum*, *R.*

crispus and *C. arvensis* pose a significant challenge to local agriculture. The dominance of *U. dioica* in both periods is linked to the widespread use of unburned animal dung (Platis et al. 2023), which facilitates its spread. Farmers report difficulties in controlling this species (Yonat and Kolören 2023). Dominance, as described by Uygur (1991), reflects the ecological importance of a species within a plant community.

Relating weed populations to ecological factors

The coefficient of variation (CV) was calculated to assess the variability of the soils in the hazelnut orchards. According to Wilding et al. (1983), CV values between 0-15% indicate low variability, 15-30% moderate variability and values above 30% high variability. In this study, pH, a key factor in weed distribution, showed low to moderate variability, while Na, lime, organic matter, EC, phosphorus, potassium, Ca, Na and texture class showed high variability. However, the variability of soil texture was low across regions, as most orchards had clay or clay-loamy soils (61.33% clay, 38.67% clay-loamy), reflecting local soil characteristics (Özkutlu et al. 2016, Tarakcıoğlu et al. 2003). Soil salinity was negligible (Maas 1986), while the pH distribution was mostly acidic, with 13.33% of the soils being extremely acidic. As hazelnuts thrive on mildly acidic soils (5.6-7.0), many orchards fall outside this range (Turan and İslam 2020). Lime levels were generally low, with 80% of soils being very low in lime (Ülgen and Yurtsever 1995). Organic matter levels were mostly adequate, with 37.33% being medium and 33.33% high (Smith and Weldon 1941). Phosphorus levels were mostly very low (80%), while potassium levels were adequate in 72% of the soils (Olsen 1954). Calcium and sodium were deficient throughout the region. Overall, soil properties were consistent across the region and in line with previous studies of hazelnut soils in Ordu (Horuz et al. 2017, Özkutlu et al. 2016, 2019).

Correlation analyses between weed species and soil properties showed statistically significant results at both $P < 0.01$ and $P < 0.05$ levels. The distributions of significant weed species were further analysed using Canonical Correspondence Analysis (CCA). The results showed that *U. dioica* and *R. crispus*, which are problematic for producers, were indicators of soils rich in organic matter, while *P. aquilinum* and *D. filix-mas* indicated soils low in lime, EC, Ca, pH and K. These results are consistent with previous studies on the soil preferences of *U. dioica* (Çalışkan and Ayan 2011, Şansal 2017), *R. crispus* (Zaller 2004), *P. aquilinum* (Marrs and Watt 2006, Wherry 1921), and *D. filix-mas* (Falkengren-Grerup et al. 2006, Owen et al. 1999), confirming consistency with previous research on the relationship between weeds and ecological factors.

In order to analyse the population distribution of the weed species found to be statistically significant, the data were analysed using the CCA method. No specific bioclimatic variables limiting the distribution of weed species were identified. Most of the weed species detected are cosmopolitan, able to thrive in different regions, suggesting that similar ecological conditions contribute to their spread. These findings are consistent with previous studies in Türkiye on the relationship between ecological factors and weeds in various crops (Altıncı and Cangi 2018, Eşitmez 2014, Gündüz 2005, Önen et al. 2018, Özcan 2016, Özdemir 2014, Yılmaz et al. 2019).

Analysis of soil samples showed that despite the large area and ecological diversity of the Ordu, pH, a key factor influencing weed distribution, showed low to moderate variability in the CV ratio. Sodium showed the highest CV variability. Most hazelnut orchards had sloping terrain, clay soil structure, low lime and pH, very low salt content, sufficient organic matter, very low phosphorus, sufficient potassium and low Ca and Na. The relationship between weed species and ecological factors showed that some species are selective for soil characteristics, while others are not. *U. dioica* and *R. crispus*, which are problematic for hazelnut growers due to their high densities, were found to be indicators of soils rich in organic matter. In contrast, *P. aquilinum* and *D. filix-mas* were associated with soils low in EC, Ca, K, pH and lime. Although some weeds are harmful, they can also provide information on soil properties. This study suggests that the distribution of certain weed species can help to estimate soil properties (e.g. organic matter, pH, EC, lime, Ca, K) without the need for detailed analyses, thus saving time. In addition, by studying weed species on land, we can obtain information about the weed structure of areas where crops will be grown. However, most weed species are cosmopolitan and can thrive in a variety of conditions, so the precise soil characteristics that limit their distribution have not been identified.

Data from both survey periods were analysed using CCA to investigate the relationship between weed species and bioclimatic variables. Some weed species clustered around specific bioclimatic variables, but no precise bioclimatic limits were found for most species. The majority of weeds detected were cosmopolitan, able to grow in different regions and problematic in areas with similar ecological conditions. Regional distribution analysis showed that most weeds had a wide tolerance and were found in all three zones, although some, such as *Campanula* sp., *Salvia* sp. and *Verbascum* sp., were more common in the middle and highland zones. Although weeds have natural habitat boundaries, their seeds are spread across regions by animals, humans and other factors. This allows weeds to adapt and thrive in new areas.

Weed population structures varied even between orchards in the same region due to ecological differences, including soil properties, fertilisation, soil texture, tillage, relief and altitude. While ecological factors had a limited effect on most weed species, some problematic species were identified as indicators. For sustainable agriculture and effective weed management, detailed information on these weed species and their characteristics will help to develop region-specific solutions tailored to local ecological factors.

In conclusion, this study aimed to guide weed management in hazelnut orchards, an important crop in the region, by investigating the relationships and population structures of problematic weed species in Ordu. The study also identified key ecological factors influencing weed distribution and highlighted several important weed species as indicator plants, providing valuable insights for producers to better understand and manage agroecosystems.

Author's Contributions

Authors declare that each author's contribution is equal.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

ÖZET

Ordu ili, fındık üretimi konusunda dünyada ve Türkiye'de ilk sırada yer almaktadır. Bu çalışmada, Ordu ili fındık bahçelerinde sorun olan yabancı ot türlerinin yaygınlık ve yoğunluklarının belirlenmesi ile ekolojik faktörlerin yabancı ot popülasyonlarının dağılımı üzerine etkisi araştırılmıştır. Bu doğrultuda, araştırma alanını temsil edecek şekilde bahçelerin coğrafi konumuna (yükseklik ve sahile olan uzaklık) göre üç agroekolojik bölgeye ayrılarak, toplamda 75 farklı fındık bahçesinde 2021-2022 yıllarında ve iki farklı survey döneminde çalışma yürütülmüştür. Survey çalışmalarında tespit edilen yabancı ot türleri, iklim ve toprak özellikleriyle ilişkilendirilerek elde edilen veriler çok değişkenli analizler ve ilgili dağılım özellikleriyle birlikte CANOCO (Çoklu Ekolojik Verilerin Analizi ve Görselleştirme Programı) ve SPSS (Sosyal Bilimler İçin İstatistik Programı) paket programları kullanılarak incelenmiştir. Toprak ve iklim özelliklerinin yabancı otlar üzerindeki etkisini ortaya koymak için elde edilen veriler Kanonik Uyum Analiz (CCA) yöntemi ile değerlendirilmiştir. İki yıl boyunca yapılan survey sonucunda toplam 49 familyaya ait 194 yabancı ot türü tespit edilmiştir. Birinci dönem (nisan-mayıs) rastlanma sıklığı (%) ve yoğunluğu (adet/m²) en yüksek olan yabancı ot türü *Bellis perennis* L.; ikinci dönem (ağustos-eylül) ise *Urtica dioica* L. olarak saptanmıştır. Özellikle rastlanma sıklığı ve yoğunluklar yönüyle üreticilerin en fazla sorun

olarak gördüğü *Rumex crispus* L. ve *U. dioica* organik madde ile pozitif ilişkili; *Pteridium aquilinum* (L.) Kuhn ve *Dryopteris filix-mas* (L.) Schott yabancı ot türleri ise Ca, EC, pH ve kireç ile negatif ilişkili oldukları için indikatör türler olarak saptanmıştır.

Anahtar kelimeler: fındık üretimi, iklim, indikatör türler, Ordu, yabancı ot

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Cite this article: Yonat, H., & Kolören, O.(2025). The relationships of weeds and their distributions with ecological factors in hazelnut orchards in Ordu. Plant Protection Bulletin, 65-4. DOI: 10.16955/bitkorb.1646813

Atıf için: Yonat, H., & Kolören, O.(2025). Ordu ili fındık bahçelerinde sorun olan yabancı otlar ve dağılımlarının ekolojik faktörlerle ilişkilendirmesi. Bitki Koruma Bülteni, 65-4. DOI: 10.16955/bitkorb.1646813