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## SOIL & CROP SCIENCES | RESEARCH ARTICLE

# Dominant weed species exert significant impacts on hazelnut orchards and rural livelihoods

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**Abstract:** Turkey contributes ~76% towards global hazelnut production; thus, it has significant socioeconomic impacts in the country. However, product losses due to weeds and challenges faced during harvesting impair hazelnut production. Therefore, weed management in hazelnut orchards is one of the major challenges faced by hazelnut producers in Turkey. Multiple complaints are received regarding weed spreading in hazelnut orchards of Turkey to different institutes. This study aimed at determining the dominant weed taxa faced by hazelnut producers and providing basic data for the precautionary measures and management strategies that could be opted to manage weed spreading. For this purpose, face-to-face interviews were conducted with the hazelnut producers between 2018 and 2020. Weed species causing significant problems in hazelnut orchards were identified according to their life forms, morphological and biological characteristics and defined as “dominant/robust” species. Considering this definition, the hazelnut producers complained of 32 taxa belonging to 19 families in hazelnut orchards. The identified taxa were compared with the earlier reported taxa from hazelnut orchards in the Black Sea region (the primary growing region of hazelnut production in Turkey) and this comparison revealed 14.81–38.89% similarities. In addition, it has been determined that the most problematic weeds in hazelnut orchards are *Calystegia sepium*, *Coronilla varia*, *Dioscorea communis*, *Hedera* spp., *Rubus* spp. The results showed that significant changes occurred in hazelnut fields over time and the main reason for this change was the dominant weeds. For this reason, it is recommended to consider the management strategies according to the dominant weed species in the hazelnut production areas. The results also provide empirical data for the development of effective management strategies in the region.

**Subjects:** Agriculture & Environmental Sciences; Agricultural Development; Agricultural Engineering; Agriculture and Food

**Keywords:** agriculture; hazelnut; impact; management; sustainability; weed

### 1. Introduction

Hazelnut (*Corylus avellana* L.) is one of the most important fruits that contribute to human health with high nutritional and mineral properties. It serves as a raw material for many products. For instance, 80% is used as sliced, chopped, and ground in the chocolate sector, while 20% is used in the cake-biscuit-bakery products, snack-ice cream sector, and oil industry (Kılıç Topuz et al., 2019). Furthermore, the by-products such as nutshell have many potential utilities of industries (Demirbaş et al., 2008). Growing hazelnut in the areas with heavy rainfall, steep slopes, and where other crops cannot be grown both provides income and prevents soil erosion (Demirbaş et al., 2008; İslam, 2018).

Hazelnut is grown in many countries, especially Turkey, Italy, the USA, Azerbaijan, Spain, and Georgia. Turkey is the leading hazelnut producer contributing ~76% towards global hazelnut production and 82% towards exports, followed by Italy with 20% production and 15% export (İslam, 2018). Therefore, it has a significant contribution to Turkey's economy through national income, employment, and exports (İslam, 2018; Kılıç Topuz et al., 2019; Mennan et al., 2020a). Hazelnut is produced in Turkey across 16 provinces and 123 districts connected by regulation number 2014/7253 (ZMO, 2018). Hazelnut orchards are abundant in the North Anatolian mountains and northern transition regions of Turkey. The Black Sea coast has the ideal growing conditions for hazelnut, and plenty of orchards are seen along the coast up to 1300 meters above sea level (Doğanay, 2012). Approximately 60% of hazelnut produced in Turkey comes from the Eastern Black Sea region, while the central and western regions account for 15% and 25% of the production (İslam, 2018). However, the yield per hectare increases from west to east with as much as 55.1% sub-regional variation on average (Erdogan, 2018).

European Union is the main market for Turkish hazelnuts, and the money made from exporting these nuts is crucial to the country's economy. Indeed, hazelnut production is the primary income source for rural households in the Black Sea region, which provides employment to approximately five million people (Kılıç et al., 2009; Zaman, 2004). For this reason, issues with hazelnut production are needed to be addressed so that hazelnut output and quality can meet and compete with international standards. Rigorous programs for disease, insect, and weed management as well as enhancing soil fertility and plant growth are crucial for sustainable hazelnut production. Despite ranking first in the world in terms of production and cultivation areas, Turkey trails behind the USA, China, Georgia, Azerbaijan, Italy, and Spain in terms of yield per unit area (İslam, 2018).

In Turkey, multi-stemmed bush (locally called an "Ocak") and hedge production systems are used for establishing hazelnut orchards. The multi-stemmed bush system, which is most preferred and practiced in established hazelnut orchards in Turkey (İslam, 2018), compared to hedgerow systems, requires intensive fertilization and effective management measures against pests, diseases, weeds, and sucker, which means sooths protruding from the three/bush base (Mennan et al., 2020a,b). In addition, the common multi-stemmed bush system in hazelnut orchards in Turkey supports the establishment of several weed species (Mennan et al., 2020a, 2006). Weeds negatively affect hazelnut production/yield by competing for water and nutrients, hosting diseases and pests, and interfering with harvest operations (Başaran & Adıgüzel, 2001; Demir & Işık, 2020; Işık et al., 2014; Mennan et al., 2020a, 2006). Therefore, it is necessary to identify the weed species and determine their potential impacts on hazelnut orchards to develop management strategies. For these reasons, data on some native and alien weed species and their impacts, which were reported in line with the producers' complaints, are presented in this study. The study was aimed at drawing attention to the problems of hazelnut producers and to provide basic data for weedy taxa and their management. In addition, it is aimed to contribute to the development of appropriate management programs for the risk status of related taxa not only for agricultural but also non-agricultural habitats.

## 2. Materials & methods

### 2.1. Study species

Hazelnut originated in Asia Minor and included the genus *Corylus* of the subfamily Coryleae in Betulaceae family of the order Fagales. More than 25 taxa have been identified in the genus *Corylus* (Zaman, 2004).

Among the available hazelnut species in the world, *Corylus avellana* L. and *Corylus colurna* L. are native to Turkey. The hazelnuts produced in Turkey are the hybrids of taxa presented in Table 1, and the varieties used are classified according to the shape and characteristics of the fruit. According to this classification, the varieties are grouped as (a) tumbul (vernacular: Tombul, Palaz, Mincane, Gök, Kalinkara, Kan, Cavcava, and Delisava/Çakıldak), (b) beaked (vernacular:

**Table 1.** *Corylus* taxa in Turkey, their life forms and origin

Family	Latin name	Turkish name	Form	Status to Turkey
Betulaceae	<i>Corylus avellana</i> L.	Adi fındık	Bush or Shrub	Native
	<i>Corylus avellana</i> var. <i>avellana</i> L.—variety	Findik	Bush or Shrub	
	<i>Corylus avellana</i> var. <i>pontica</i> (K. Koch) H.J.P.Winkl.—variety	Findik	Bush or Shrub	
	<i>Corylus colurna</i> L.	Türk Fındığı	Tree (15–25 m)	
	<i>Corylus maxima</i> Mill.	Tombul fındık	Bush or Shrub	NW Balkan Peninsula

Sivri, İncekara, Kuş) and (c) other (vernacular: Badem, Foşça, Kargalak, Ordu İkizi) in Turkey (İslam, 2018; Kılıç et al., 2009; Zaman, 2004).

Hazelnut varieties cultivated are shrubs, adapted to the mild, humid regional climate and can grow to 2–2.5 m in barren—south-facing lands and up to 6–7 m in humid, cool soils. Annual precipitation regimes must be regular, evenly distributed throughout the seasons, and above 750–800 mm or more than 1300–1400 mm for the plant to reach its full potential. Dry summer conditions may lead to early ripening of the fruit, significantly decreasing yield (Doğanay, 2012; İslam, 2018; Mennan et al., 2020a; Zaman, 2004). Hazelnut production is extremely sensitive to deviations from the optimum temperature. Hazelnut produces no yields and fruit when grown in regions with temperatures higher or lower than optimum. The regions with winter temperatures between 0°C and 6–7°C and summer temperatures not exceeding 20–25°C are very suitable for hazelnut cultivation. Furthermore, minimum temperatures should not fall below –10°C and maximum temperature should not exceed 37°C (Erdogan, 2018; Zaman, 2004). Two hours of severe frost during female flowers' growth could significantly reduce yield. It has been indicated that the frost events, common in orchards at 250–300 m may affect 40%–80% yield. Relative humidity <60% during the ripening period (June and July) may reduce the fullness of hazelnut fruits (Zaman, 2004). Soil properties such as structure, composition, temperature, and depth are also important in hazelnut cultivation. High soil humus content and depth provide optimum growing conditions, while high lime, sand, and clay contents may adversely affect yield (Doğanay, 2012; Zaman, 2004).

## 2.2. Study area

Düzce province (40°50'25.9"N 31°09'45.2"E) is located in the western part of the Black Sea coastal mountains. While Düzce plain constitutes an area of approximately 360.5 km<sup>2</sup> of the 2.593 km<sup>2</sup> area of the province, the remaining 86% area is mountainous and rough. The hill with an altitude of 1.830 m on Kardüzü plateau located in the east–west part of the province is the highest point of the province (Tatar, 2005). In addition, Düzce has a 30 km coastal line with the Black Sea in the North along the Akçakoca district. The center of Düzce is established on a plain. This plain is a subsidence basin formed by the impact of ground movements in the North Anatolian fault zone and is generally filled with alluvial accumulation. Düzce province includes a total of eight districts with varying altitudes. It is under the influence of a humid and moderately severe climate, which is observed in the coastal areas of the Black Sea region. Furthermore, it is influenced by the climate of the neighboring Marmara region, to its western part. The mean yearly temperature is 13.2°C, the coldest month is January (3.7°C), and the hottest is July (22.6°C—Table 2). The mean total annual precipitation is 823.7 mm/year, and the average relative humidity is reported to be 75% (<https://www.mgm.gov.tr>).

NOTE: These are the lowest and highest temperature values. Actually, we can write these dark values as normal.

**Table 2. The maximum, minimum, and average temperatures (°C) measured in the long period (1959–2021) of Düzce province**

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Avg. Temp.	3.7	5.1	7.7	12.1	16.5	20.3	22.6	22.3	18.6	14.1	9.4	5.7	13.2
Avg. Max. Temp.	8.2	10.4	13.7	18.9	23.4	27.1	29.1	29.2	25.9	20.8	15.6	10.3	19.4
Avg. Min. Temp.	0.5	1.4	3.5	7.2	11.3	14.7	16.9	16.9	13.4	9.8	5.2	2.4	8.6
Maximum Temp.	26.1	26.9	32.2	34.7	39.5	39.0	42.4	42.0	38.7	38.2	30.2	29.2	42.4
Minimum Temp.	-20.5	-17.3	-13.6	-3.0	0.4	6.6	8.8	7.6	4.5	-1.2	-6.8	-16.5	-20.5

Approximately 39% of the provincial land is agricultural, 47% is occupied by forest and shrubs, 3% by meadows and pastures, and 11% is non-agricultural. The largest share of agricultural land (45%) is invested in hazelnut production. Coastal areas consist of maquis shrubland, while the mountains behind the shore are covered with forests of hornbeam, beech, chestnut, and oak. Forests in the lower altitudes of the mountains surrounding the Düzce plain mostly consist of broad-leaved trees, while the forests in the higher altitude consist of coniferous species such as black pine, Scotch pine, and fir (Tatar, 2005).

### 2.3. Data collection

Weeds are one of the most important factors in hazelnut production and product loss (Demir & Işık, 2020; Işık et al., 2014; Mennan et al., 2020a, 2020b). For this reason, mechanical (mowing, hoeing), physical (cover crop, burning, grazing) and chemical control methods are applied in the fight against weeds in hazelnut production areas (Demir & Işık, 2020; Işık et al., 2014; Mennan et al., 2020a). However, these practices vary according to hazelnut production area, such as orchards size and slope, and producer preferences/possibilities (author's personal observations). Individual control practices are also carried out especially for dominant taxa. In this study, which is handled by considering the complaints of the producers in Düzce against dominant weeds and the control methods that are the subject of these complaints, the data were obtained through face-to-face interviews with 30 hazelnut producers between 2018 and 2020. The surveys were carried out between May and July each year. Producers were randomly selected through stratified sampling to obtain a balanced number of interviewees from different sociocultural variables. Their age ranged from 28 to 65 years.

General questions including problematic “dominant plant taxa”, impacts of these taxa and management methods, etc. were asked (for all questions: Table 3). All taxa were recorded with photos from Plants of the World Online (Plants of the World Online (POWO), 2021), DUOF (Düzce University Virtual Herbarium—<http://www.duof.duzce.edu.tr/>) and personal weed photos archive, shown with the producer's description and/or direct plant showing by the producers. Further, additional information was used for general information about the hazelnut production situation of ~8525 registered hazelnut producers in Düzce (*personal interview with Ferrero company representative N. Büyükkurt in Düzce*).

The environmental and socioeconomic impacts (Yazlık et al., 2018) status of relevant taxa was primarily determined from this study data (Table 3), additionally, national (Ulakbim—<https://ulakbim.tubitak.gov.tr/>) and international (Web of Science and Scopus) journals were also considered. The Plant List (<http://www.theplantlist.org/>) and IPNI (<https://www.ipni.org/>) were used in the name control of the plant species, USDA (<https://www.usda.gov/>) for the determination of the plant characteristics, Bizim Bitkiler (national database—(Güner et al., 2012) for the use of Turkish names, and POWO (2021) for the determination of the plant species native ranges (Table 4).

The taxa determined in line with the complaints of the producers (Table 4) were compared with the data of weed survey studies (Figure 1) carried out in hazelnut orchards in the West and Central Black Sea region (Başaran & Adıgüzel, 2001; Mennan et al., 1999). The raw data of the earlier reports were extracted and compared with the dominant taxa recorded in the current study. Chord diagram (Figure 2) in Origin Pro software was used to indicate the differences.

### 3. Results and discussion

According to the results, 32 taxa belonging to 19 families were defined as “robust/dominant weeds” by the producers, particularly because of difficult control. Asteraceae (5 taxa), Rosaceae (4), Apiaceae (4), Fabaceae (3), and Araliaceae (2) families included more than one taxon, while other families represented with only one taxon.

Based on life cycle, 23 of the identified taxa were perennial, 8 annual and one taxon was biennial. Most taxa had herbaceous (19 taxa, 60%) life forms, while the others were shrubs (7, 22%), vine (2, 6%), herb/vine (3, 9%), and herb/shrub (1 taxon, 3%). Only one of the taxa (*Erigeron*

**Table 3. Questions asked for hazelnut producers about weeds and their impacts in hazelnut orchards**

No	Questions
1	What are the general characteristics of the most problematic plant species in hazelnut production? *Please show these taxa.
2	Do you regularly manage weeds in the hazelnut orchards?
3	What are the control methods implemented against these weeds?
4	What economic impacts do you encounter from weeds?
5	How do you think these taxa are spread/reproduce?
6	What is your preference to use the herbicide for the management of these plants?
7	Do you think these taxa are spread more every year?
8	Do you know anything about Integrated Pest/Weed Management (IPM/IWM)?
9	Would you use these taxa for different purposes (ethnobotanical, kindling ... etc.)? Please explain.
10	Have you ever had a health problem (allergy, injury, toxicity) caused by these plants?

*canadensis*) is in the North American native range, while the others are native to Turkey (Plants of the World Online (POWO), 2021). The general status (life form, lifetime, native range) of these taxa and impacts is presented in Table 3.

The main problem in the producer's responses to the dominant weed taxa was socioeconomic impacts caused by the perennial weeds (Table 4), which are reproduced with both seeds and vegetative propagules. Especially, the most important taxa were *Rubus* spp. and *Hedera* spp. considering the difficulty faced in their control, the time spent the management, and the impacts on human well-being (social life and health). However, all reported taxa have socioeconomic impacts in different directions. These impacts: (i) the difficulty of the management (e.g., *Calystegia sepium*, *Coronilla varia*, *Dioscorea communis*, *Hedera* spp., *Rubus* spp.), (ii) the limited control methods, (iii) the necessity of the management more than one time, (iv) high management costs, (v) the effect of time spent on management on social life, (vi) injuries experienced during garden maintenance and weed control activities (For example, *Caucalis platycarpus* and *Sanicula europaea* seeds, *Cornus sanguinea* leaves, *Rubus* spp. stems), (vii) injuries caused to grazing animals and (viii) unrest caused by the inability to achieve the desired control despite the management. In addition, producers also faced environmental impacts originating from the related plants. These impacts are (i) the competition of weeds with hazelnuts (nutrient, water, and light) and (ii) the damage caused by ivy-form weeds, such as *Hedera* spp., climbing hazelnut trees by suffocating them and/or making harvesting difficult. According to the information obtained from the producers in Düzce (Table 5—Q9 and Q10), the plants presented in Table 4 also have ethnobotanical (fuel, ornamental, food, raw food, natural dye, human health, repellent) uses in different aspects. For example, a natural yellow dye is obtained from *Genista tinctoria*, *Eupatorium cannabinum* is used as an ornamental plant, *Heracleum sphondylium* subsp. *ternatum* and *H. platytaenium* are used as fuel and *Pulicaria dysenterica* is used as an insect repellent. Although ethnobotanical use is attractive to producers, some taxa also have some important impacts, such as *Rubus* spp., *Urtica dioica*, *Trachystemon orientale*, *H. sphondylium* subsp. *ternatum*. For instance, producers or workers working in the production area are exposed to allergies due to *U. dioica* and *H. platytaenium*, and difficulties and injuries are experienced in the pruning and cleaning of ivy, especially in sloping

**Table 4. Robust weeds detected in hazelnut orchards and their families, native ranges, living characteristics, and impacts**

Latin name	Family	Origin	Life form	Lifetime	Type of reproduction
<i>Calystegia sepium</i> (L.) R.Br.	Convolvulaceae	Native	H/V	P	S/R
<i>Caucalis platycarpus</i> L.	Apiaceae	Native	H	A	S
<i>Cornus sanguinea</i> L. subsp. <i>australis</i> (C.A. Mey.) Jáv.	Cornaceae	Native	Sh	P	S/St
<i>Coronilla varia</i> L.	Fabaceae	Native	H/V	P	S/R
<i>Dioscorea communis</i> (L.) Caddick & Wilkin	Dioscoreaceae	Native	H/V	P	S/R
<i>Dipsacus laciniatus</i> L.	Caprifoliaceae	Native	H	B	S
<i>Erigeron canadensis</i> (L.) Cronquist	Asteraceae	North America	H	A	S
<i>Eupatorium cannabinum</i> L.	Asteraceae	Native	H	P	S
<i>Galega officinalis</i> L.	Fabaceae	Native	H/Sh	P	S
<i>Genista tinctoria</i> L.	Fabaceae	Native	Sh	P	S
<i>Geranium columbinum</i> L.	Geraniaceae	Native	H	A	S
<i>Hedera colchica</i> (K. Koch) K. Koch	Araliaceae	Native	V	P	S/St
<i>Hedera helix</i> L.	Araliaceae	Native	V	P	S/St
<i>Heracleum platytaenium</i> Boiss.	Apiaceae	Native	H	A	S
<i>Heracleum sphondylium</i> subsp. <i>ternatum</i> (Velen.) Brummitt	Apiaceae	Native	H	A	S
<i>Hypericum calycinum</i> L.	Hypericaceae	Native	Sh	P	R
<i>Ilex colchica</i> Pojark.	Aquifoliaceae	Native	Sh	P	S
<i>Ornithogalum sphaerocarpum</i> A.Kern.	Asparagaceae	Native	H	P	Geophyte
<i>Pallenis spinosa</i> (L.) Cass.	Asteraceae	Native	H	A	S
<i>Potentilla reptans</i> L.	Rosaceae	Native	H	P	S/St

(Continued)

**Table 4. (Continued)**

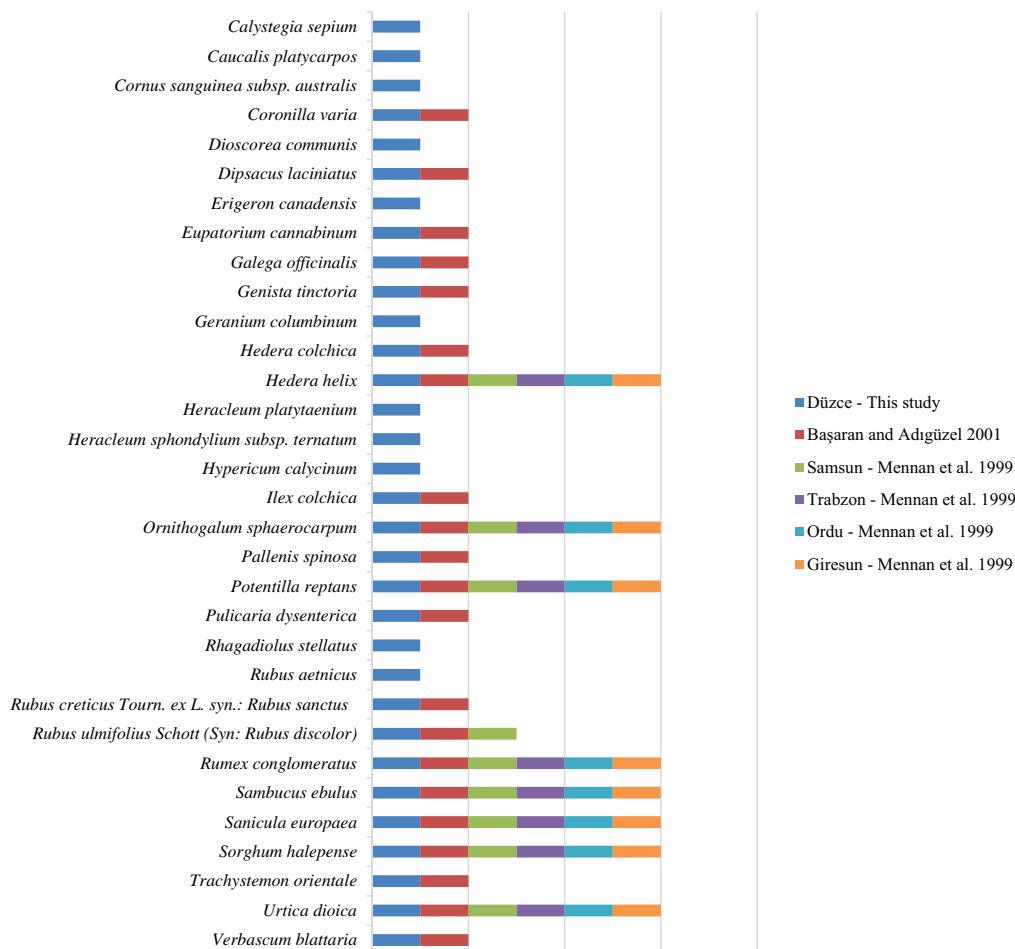
Latin name	Family	Origin	Life form	Lifetime	Type of reproduction
<i>Pulicaria dysenterica</i> (L.) Bernh.	Asteraceae	Native	H	P	S/R
<i>Rhagadiolus stellatus</i> (L.) Gaertn.	Asteraceae	Native	H	A	S
<i>Rubus aetnicus</i> (Syn.: <i>Rubus canescens</i> DC. var. <i>glabratus</i> (God.) Davis & Meikle)	Rosaceae	Native	Sh	P	S/St
<i>Rubus creticus</i> (Tourn.) L. (Syn.: <i>Rubus sanctus</i> )	Rosaceae	Native	Sh	P	S/St
<i>Rubus ulmifolius</i> Schott (Syn: <i>Rubus discolor</i> )	Rosaceae	Native	Sh	P	S/St
<i>Rumex conglomeratus</i> Murray	Polygonaceae	Native	H	P	S/R
<i>Sambucus ebulus</i> L.	Adoxaceae	Native	H	P	S/R
<i>Sanicula europaea</i> L.	Apiaceae	Native	H	P	S
<i>Sorghum halepense</i> (L.) Pers.	Poaceae	Native	H	P	S/R
<i>Trachystemon orientale</i> (L.) G. Don	Boraginaceae	Native	H	A	S
<i>Urtica dioica</i> L.	Urticaceae	Native	H	P	S/R
<i>Verbascum blattaria</i> L.	Scrophulariaceae	Native	H	B	S

Abbreviations: Life form: Herb—H, Shrub—Sh, Vine—V Lifetime: Annual—A, Biennial—B, Perennial—P, Type of the reproduction: Seed—S, Rhizome—R, Stolon—St, Bulb—B.

gardens. In addition, stolon and vine forms weeds (Table 4) pose a hazard to field workers/farmers, leading to fall and ankle sprain.

Most of the producers (77%) regularly perform weed control once a year; however, some (23%) indicated that they are only partially involved in weed control with cover crop and/or animal grazing practices when there are intense weed problems. Regarding the use of cover crops for weed management, the producers responded that they did not use a special cover plant, but only protected some of the high population plants such as *Lamium purpureum* and *L. amplexicaule*, in the relevant fields. The main reasons for the adoption and protection of these taxa by the producers are the prevention of water evaporation and erosion as the soil cover of the related taxa in the hazelnut orchards with high slopes ( $\geq 20$ ), as well as the beekeeping activities. Although these approaches of the producers are considered beneficial, they stated that these plants do not fully cover the gardens and therefore some dominant plants (high habitus and/or ivy-shaped

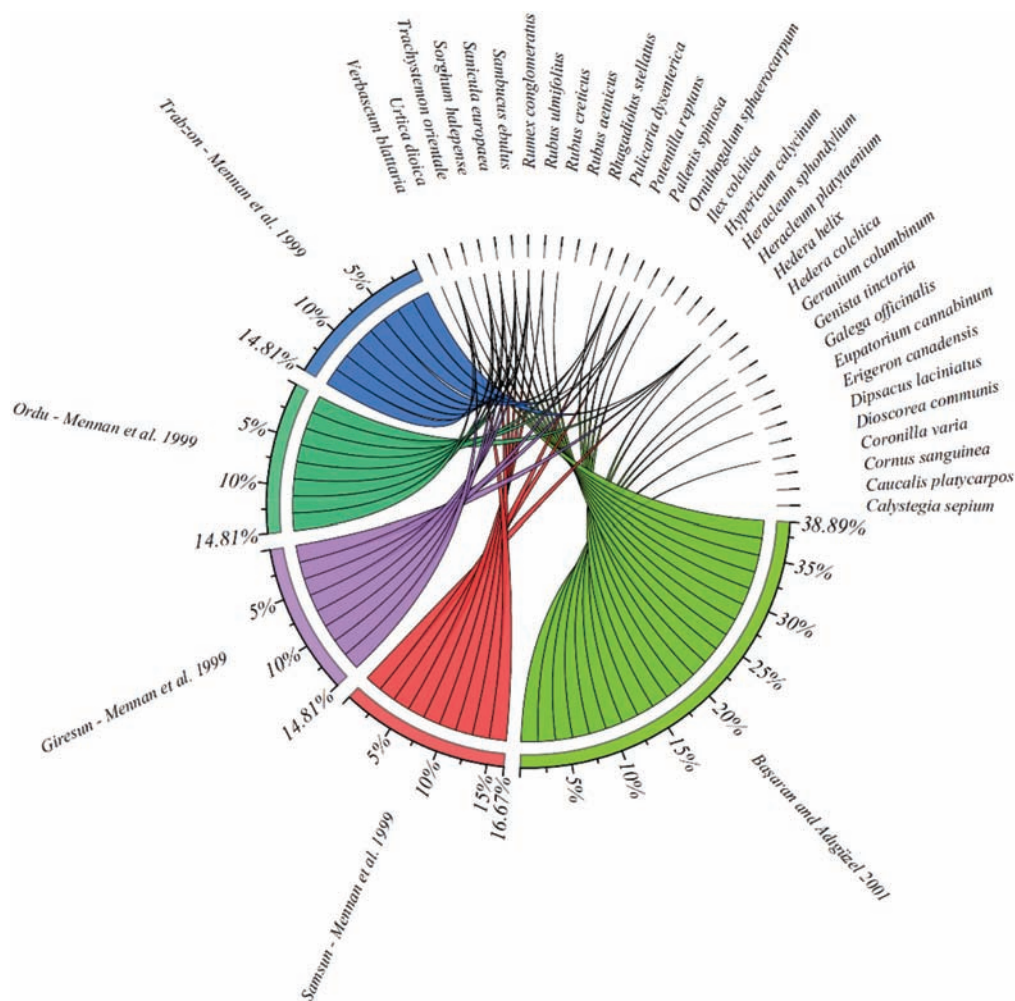
**Figure 1. Comparison of taxa determined in hazelnut production areas with different studies.**



weeds) cause problems especially close to the harvest period. Producers emphasized that they carry out individual plant-specific efforts such as manual weeding and/or mowing for these plants, which increases the time spent on the struggle. Therefore, this situation may be evaluated as another socioeconomic impact on dominant weeds. In fact, with the real application of the use of cover crops to combat weeds, this additional labor problem can be eliminated. There are studies on the application of cover crops in hazelnut production areas in Turkey (Demir & Işık, 2020; Işık et al., 2014; Mennan et al., 2020a). In fact, in these studies, it was concluded that cover crops not only contribute to the struggle against weeds but also affect the effects on soil quality parameters and hazelnut yield (Demir & Işık, 2020; Işık et al., 2014). For example, used as cover crops, plants such as *Vicia villosa* and *Trifolium repens* can be incorporated into cropping systems to improve soil quality variables and hazelnut yield (Demir & Işık, 2020). Considering these contributions of the use of cover crops, it is recommended that this practice of combating weeds be extended in all hazelnut production areas.

The use of herbicides is the first preferred control method by producers for weed control (70%). Some producers consider herbicide application, which is the main herbicide glyphosate, as the only suitable solution. This is also evident from the ratio of producers who know integrated pest management (IPM). The awareness level of producers about IPM was not very low (40%). That indicated that producers are aware of different management methods; however, chemical control is preferred because the size of the hazelnut orchards ( $\geq 30$  da) and high slope ( $\geq 20$ ) prevents different control practices, such as mowing.

**Figure 2. Chord diagram indicating the similarities between “dominant taxa” recorded during the current study and earlier studies.**



Almost all producers (90%) believe that the density of “dominant taxa” will increase in the coming years no matter how intensively these robust weeds are managed. Although the producers know the deficiencies or mistakes in some application methods, such as mowing time, they believe that the desired management success cannot be achieved with the majority of opted methods. Moreover, the control practices vary according to the weed type. For example, the control of *T. orientale* is fully provided with ethnobotanical use (Table 4), while the ethnobotanical use of *Rubus* taxa has no contribution to the control of the related plant. It was emphasized that mowing/cutting + herbicide application is done in special individual applications against *Rubus* and *Hedera* taxa. Producers stated that they applied glyphosate to the cutting point left after the stolons of the related taxa were cut and repeated these several times in a season. This situation causes an increase in the workforce. In addition, producers are not aware that such repetitive applications of herbicides can lead to the risk of herbicide resistance.

The similarities between the dominant weed species recorded during the current study and the weed survey studies performed in hazelnut orchards in the West and Central Black Sea region (Başaran & Adıgüzel, 2001; Mennan et al., 1999) conducted earlier are visualized by chord diagram (Figure 2). All the species recorded in the current study are listed on the upper side of chord diagram, and the presence/occurrence of these species in the earlier studies have been indicated by nodes connecting them with the relevant study. The weightage in percentage was used to assess which of the earlier studies had higher resemblance to the current study. The studies conducted by Mennan

**Table 5. The response of hazelnut producers to the asked questions during face-to-face surveys**

Questions and answers	Response ratio
<b>What are the general characteristics of the most problematic plant species in hazelnut production? *Please show these taxa.</b>	
making maintenance and harvesting processes difficult	100%
causes too much herbicide use	
affecting labor costs	
causes prolongation of working time in the orchard	
causing injury (human or ruminant animals)	
despite the struggle, highly competition (growing very fast and covering large areas)	
competing with the main product (nutrient, water)	
wrapping (due to vine life form) around the hazelnut stem/s and causing the product to suffocate	
<b>Do you regularly manage weeds in the hazelnut orchards?</b>	
Yes, I do regular maintenance every year	77%
No, I only struggle when there is intense trouble	23%
<b>What are the control methods implemented against these weeds?</b>	
Herbicide (1–2 applications after post-emergence—Glyphosate)	90%
Hoing machine in early spring	30%
Mowing three times: early spring, middle summer and before harvest	63%
cover crop	10%
grazing in early spring	60%
<b>What economic impacts do you encounter from weeds?</b>	
Negative impacts: competition, labor costs, extend harvesting, high herbicide use	100%
<b>How do you think these taxa are spread/reproduce?</b>	
Seed transport by rainwater, stream floods, irrigation (especially transport of seeds poured into the soil in sloping orchards), wind, ruminants, birds, or humans.	100%
Vegetative propagation parts (especially plant parts thrown out of the garden/free area after mowing/ cutting application),	
<b>What is your preference to use the herbicide for the management of these plants?</b>	
First	70%
After mowing	20%
After grazing, mowing, cover crop ... etc.	10%
<b>Do you think these taxa are spread more every year?</b>	
Yes	90%
No	10%
<b>Do you know anything about Integrated Pest/Weed Management (IPM/IWM)?</b>	
Yes	40%
No	60%

(Continued)

**Table 5. (Continued)**

Questions and answers	Response ratio
<b>Would you use these taxa for different purposes (ethnobotanical, kindling ... etc.)? Please explain</b>	
Yes, kindling, ornamental plants, food (e.g., <i>O. sphaerocarpum</i> , <i>H. sphondylium</i> subsp. <i>ternatum</i> , <i>T. orientale</i> ... etc.—for more: Table 3)	30%
<b>Have you ever had a health problem (allergy, injury, toxicity) caused by these plants?</b>	
Yes, injuries caused by plant thorns, ivy and/or stolons during gardening maintenance are a serious problem. Injuries also occur in grazing animals (Table 3)	80%

et al. (1999) in Giresun, Ordu, and Trabzon had eight species similar to the current study; therefore, these had similar weightage, i.e., 14.81% in the chord diagram. Similarly, the weed flora reported by Mennan et al. (1999) from Samsun province had nine species in common with the current study and carried 16.67% weightage. The highest number (21 species) of similar species was reported by Başaran and Adıgüzel (2001); thus, it had the highest weightage (38.89%) in Figure 2. These results indicate that the weed flora of hazelnut orchards have differentiated over two decades. The reasons for the changes in the weed flora of hazelnut orchards can be problems in cultivation practices, difficulties in production areas (such as sloping land), regional differences, producer behaviors (unconscious care and weed control practices), and impacts of alien species. For instance, the higher number of common taxa (21 taxa) between this study and Başaran and Adıgüzel (2001) is that these studies were conducted in the same region (A3 grid—for Turkey grid system Bakış et al., 2011). Another reason is that most of the hazelnut orchards in the Western Black Sea region (A3) are established on sloping lands, so weed control is limited. However, common taxa were very low (eight taxa—Figure 1) in this study and those reported by Mennan et al. (1999). The main reason is the Central Black Sea region (A6), where is located on the plains (Alkan & Kılıç, 2007). As can be expected, agricultural activities in orchards located on plain areas are easier than on sloping lands. It is possible that some of the dominant plants in this study in the A6 grid are not distributed in the plains. For instance, *Cornus sanguinea* detected in hazelnut orchards in the A3 grid, although considered as a forest plant, pose a problem in agricultural areas. One of the main reasons for this is the deterioration of the forest areas in the A3 grid and the establishment of a hazelnut orchard instead (*personal observation during this study and personal communication with Düzce Provincial Directorate of Agriculture and Forestry*). Therefore, it is not surprising that many taxa, such as *Heracleum* spp. and *C. sepium* (Figure 1), were not encountered in a plain area. For all of these reasons, the common taxa (at most 21 taxa—Figure 1 and Figure 2) were evaluated as dominant weeds for hazelnut plantations in the Black Sea Region’s main hazelnut production provinces (Bolu, Bartın, Düzce, Giresun, Ordu, Trabzon, Samsun, and Zonguldak) in Turkey.

Comparison of most common families (Asteraceae, Apiaceae, Araliaceae, Fabaceae, and Rosaceae) of this study with earlier studies (Başaran & Adıgüzel, 2001; Mennan et al., 1999) resulted in non-significant differences. Since the recorded families are among the most common families hosting weed plants, the results are non-significant (IPBES, 2019; Linder et al., 2018).

In the meantime, it should be emphasized that weed diversity can be created according to the characteristics of the areas where hazelnut orchards are established (altitude, slope, plain, etc.), and there may be serious differences in weed management according to this situation. In addition, the different demographic structures (such as higher education levels or younger age ranges) of the people living in the plains (Alkan & Kılıç, 2007) play a role in the effective management of the problems in the related agricultural areas.

Lastly, one of the most important issues to be addressed is the restrictions on the use of glyphosate in the coming years; for details on this, please see, Mennan et al. (2020a) and

Pergl et al. (2020). While the most important justification for the planned restrictions is the risks of using glyphosate, I agree with Pergl et al. (2020) on the extent of these risks and the need for glyphosate application to control strong plants with the potential for invasion. In addition, Mennan et al. (2020a) also reported that the use of herbicides in hazelnut orchards, which have high altitudes and slope due to their geographical structure, is the main solution for many producers. Therefore, it would be beneficial to continue glyphosate to be used in such areas, at least until an alternative herbicide is found, provided that ongoing awareness activities are carried out on the correct use time and dose of glyphosate application and necessary inspections are made. In other words, the context and scales should be taken into account against the situations to be encountered in the implementation of such prohibitions (Pergl et al., 2020).

#### 4. Conclusions

The main purpose of this study was to emphasize that weeds recorded in hazelnut orchards are classified by producers according to their morphological and biological characteristics, impacts, and control strategies, and they seek solutions to problematic weeds defined as dominant/robust plants. In a different perspective, selecting the weed species with high environmental and socioeconomic impacts for management could make significant contributions to sustainability and biodiversity. Moreover, producers' perspectives regarding benefit-interest relationship of the "dominant taxa" were examined. For example, producers believe that some of the weed species prevent erosion because they cover the land surface in sloping hazelnut orchards, facilitate harvesting, and even serve as a shelter for beneficial insects. This is important for the producers to perceive that weeds are not only harmful plants. Awareness of the positive effects of weeds, especially in orchards, will benefit the management of relevant areas and the sustainability of biodiversity, which the importance of this situation in agricultural lands are also emphasized in many international reports on biodiversity, e.g., IPBES (2019).

The main herbicide used in hazelnut production areas is glyphosate (*Düzce Provincial Directorate of Agriculture and Forestry and Ferrero—Düzce personal communication*). This situation has also been determined in the interviews with hazelnut producers through this study (Table 5). Although the producers think that they use different herbicides, glyphosate is sold under different trade names. Therefore, awareness on the active substance and mode of action should be created in the producers. In addition, it would be useful to conduct general training studies on possible situations arising from the active substance ratio, herbicide rotation, resistance formation, and/or incorrect application time and dose, which vary according to the companies.

The producers must be educated about the impacts of weeds (injuries, allergies, etc.) and IPM. Although the rate of producers with IPM/IWM knowledge is substantial (Table 4), the success of weed management is not at the desired level due to the mistakes made during the applications. For example, producers who include mowing practice in weed management do not choose the right time and number of mowing, which reduces this practice effectiveness. Producers apply mowing only during the harvest period. Since many weed taxa are in the seed stage at harvest, producers facilitate the seed dispersal of these taxa, especially those belonging to the Asteraceae and Apiaceae families. Further, providing awareness of the impact of plants, especially on human health, will contribute to the protection of the health of both the producers and the seasonal workers in the production area.

Some taxa found in hazelnut orchards established in agricultural areas opened by the degradation of sloping forest areas in the mountain habitat are defined as "weed" instead of "under forest plant". Some weeds (such as *Hedera* spp, *Rubus* spp., and *Cornus* sp.) reported by producers in this study were of this character. For this reason, it would be beneficial to inform the producers of the selection of the areas where they will make agricultural production by considering the long-term

effects. Moreover, local governments should prevent or at least limit the opening of new agricultural areas from forest areas.

Finally, studies on the determination of weeds in the hazelnut orchards show that the demographic structure is effective in the selection of agricultural areas depending on the level of consciousness (Alkan & Kılıç, 2007; Méndez et al., 2015). Therefore, as shown here, plants encountered in the same culture can vary not only according to regional and climatic conditions but also depending on the selection of the production area. For this reason, the long-term effects of the selection of agricultural production areas should be considered.

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#### Disclosure statement

No potential conflict of interest was reported by the author.

#### Data availability

The authors confirm that the data supporting the findings of this study are available within the manuscript.

#### Ethics approval

The author declares that she complies with the ethical standards, and they refrain from misrepresenting research results which could damage the trust in the journal, the professionalism of scientific authorship, and ultimately the entire scientific endeavor. Ethical standards were also complied with in the interviews conducted in this study. In addition, the author has three licenses for human-participated research by the CITI Program: Institutional Review Board Member (IRB - ID 44117788), Social/Behavioural Research (ID 44117789) and Responsible Conduct of Research (RCR - ID 44117790).

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