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Evaluation of Weed Diversity and Density in White Cabbage Fields in Sakarya Province of Türkiye: A New Record for *Orobanche* spp.

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Abstract

Weeds significantly influence yield and quality in white cabbage production, which has been a longstanding practice in the Sakarya province. In 2022–2023, weed surveys were conducted across 73 randomly selected fields in the districts of Adapazarı, Erenler, Kaynarca, and Pamukova, ensuring coverage of at least 1% of the total cabbage cultivation area. These surveys identified 71 weed species belonging to 27 different plant families. Among the weeds present, *Stellaria media* (L.) Vill. and *Veronica hederifolia* L. were the most dominant in both survey periods. In the first period, *Capsella bursa-pastoris* (L.) Medik. showed the highest density (5.3907), followed by *Sonchus oleraceus* L., *Stellaria media* (L.) Vill., and *Veronica hederifolia* L., all with 100% frequency of occurrence. In the second period, *Stellaria media* had a density of 39.17, while *Veronica hederifolia* had 8.50. Regarding frequency of occurrence, *Portulaca oleracea* L., *Convolvulus arvensis* L., and *Sonchus oleraceus* L. were the most frequent species, with 83.75%, 75.11%, and 75.07%, respectively. The study concluded that *Lamium amplexicaule* L. was the most abundant species (in terms of density) in the first period, while *Veronica hederifolia* L. was the most abundant in the second. However, species dominance varied depending on observation time and whether frequency or density was considered. Additionally, *Orobanche* spp. was identified for the first time in Türkiye as a parasitic weed on white cabbage during the second survey period.

Keywords: Brassicaceae, *Brassica oleracea* var. *capitata, Orobanche* spp., Parasitic weed, Survey.

Introduction

White cabbage (Brassica oleracea var. capitata), a member of the Brassicaceae family, is among the crops native to Türkiye (Al-Shehbaz et al., 2006). It holds a significant place in global agriculture, particularly within the widely cultivated Brassica genus. Türkiye ranks tenth worldwide in white cabbage production, contributing 860,123 tons (FAO, 2023). Valued for its high nutritional content and low caloric value, white cabbage is a staple in healthy diets.

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In Türkiye, the Marmara region, especially Sakarya province, plays an important role in cabbage production. Sakarya, contributing 7,857 tons annually, ranks seventh nationally. Its favorable location and proximity to major markets enable efficient distribution (TUIK, 2024). Global demand for white cabbage is rising due to population growth. In countries with limited arable land, maximizing yield per unit area is essential. However, plant protection challenges, particularly weeds, significantly hinder productivity (Mehdizadeh et al., 2024). Weeds compete with crops for nutrients, water, light, and space, reducing yield and quality (Tepe, 2014; Horwath et al., 2023). In cabbage cultivation, as in other crops, weeds pose a major threat (Akshatha et al., 2019; Thakur et al., 2023), potentially cutting yields by 50% or more if unmanaged (Al-Khatib & Libbey, 1992). Weeds can also degrade market value due to head deformities or reduced size.

Beyond direct competition, weeds can host pests and pathogens, facilitating their spread (Kızılkaya et al., 2001; Akça & Işık, 2016). Pathogens such as Alternaria, Pythium, and Sclerotinia may cause diseases like damping-off or white mold in adjacent cabbage crops, while pests like aphids and whiteflies often shelter and feed among weedy areas.

Numerous weed species have been identified as particularly problematic in vegetable-growing. Key examples include *Amaranthus retroflexus, Chenopodium album, Convolvulus arvensis, Echinochloa crus-galli*, *Orabanche* spp., *Setaria verticillata, Sinapis arvensis*, and *Solanum nigrum*, all reported to severely reduce crop yields (Aksoy, 2003; Gürbüz & Uygur, 2007; Aksoy & Uygur, 2008).

This study was conducted in 2022 and 2023 in the white cabbage-growing districts of Adapazarı, Erenler, Kaynarca, and Pamukova in Sakarya province. Weed surveys were performed in two periods to identify prevalent species, their densities, and frequencies. This research represents the first documented weed survey in white cabbage fields in Türkiye, providing essential data for developing effective weed management strategies to sustain yield and crop quality.

2. Materials and Method

This study was conducted in two periods: October 2022 and January 2023, covering key white cabbage-producing districts in Sakarya—Adapazarı, Erenler, Kaynarca, and Pamukova. Districts were selected based on 2022 cabbage cultivation data from TURKSTAT. Fields were randomly chosen to represent at least 1% of the total cultivated area (Bora & Karaca, 1970), and the number of sampled plots per district is provided in Table 1.

In Pamukova, due to the discontinuation of cabbage farming, only one field was available for sampling. Environmental variables such as field size, soil type, irrigation, and crop management were recorded to aid interpretation of weed distribution patterns. Meteorological data, including temperature, rainfall, and humidity, were obtained from the Sakarya Provincial Directorate of Meteorology for both seasons.

During the 2022 season, Sakarya experienced moderate temperatures and variable rainfall. From March to October, average temperatures ranged from 8.7 °C (March) to 23.4 °C (July–August), with mean maximum temperatures peaking at 29.5 °C in July–August. March recorded the lowest minimum temperature at 4.6 °C. Rainfall varied between 49.5 mm in July and 78.3 mm in October, with 5.84 to 10.84 rainy days per month.

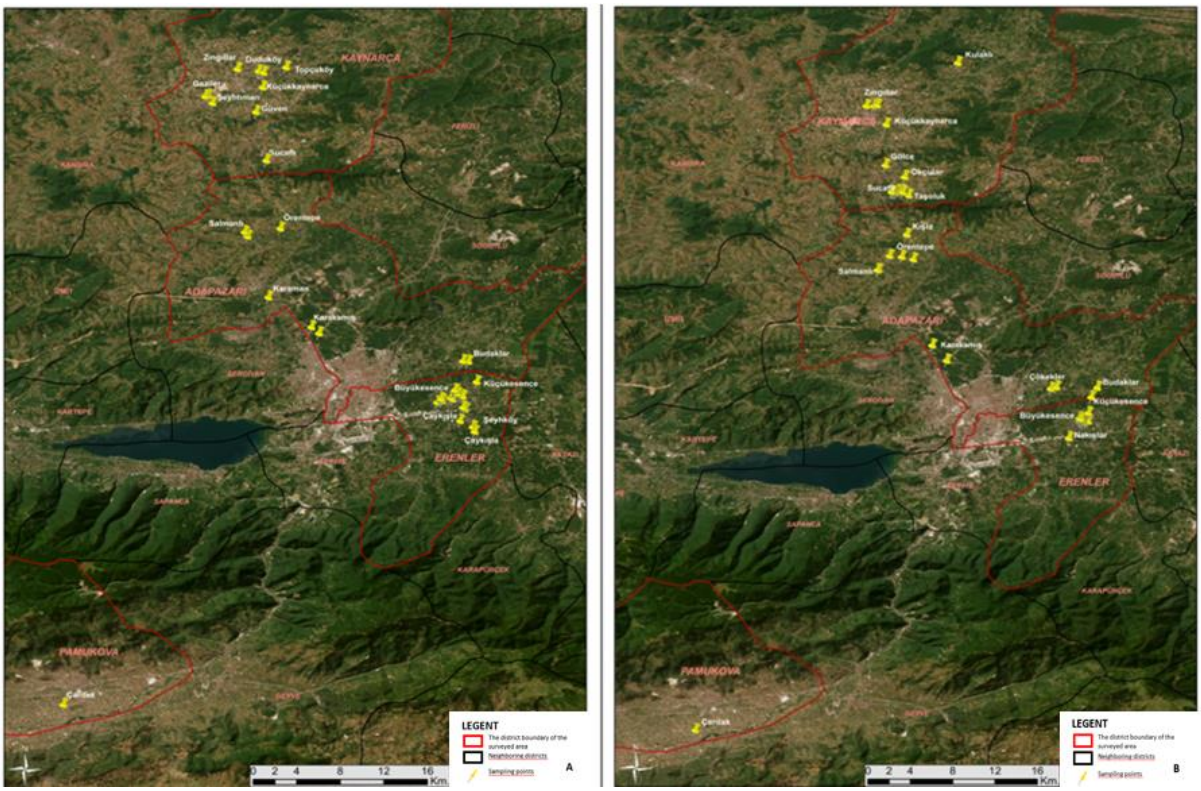

Figure 1. Sampling locations map in white cabbage fields in Sakarya. First period (A) and second period (B).

The data collected in each visited cabbage field included information on the species of weeds present, their densities, and the frequency of occurrence within each sampled area.

Table 1. The sampling locations and number of samples collected from white cabbage growing areas in Sakarya province.

Districts	Number of samples	
	1. Period	2. Period
Adapazarı	8	11
Erenler	15	12
Kaynarca	10	15
Pamukova	1	1
Total	**73**	

Additionally, the density of each weed species was measured by counting the number of individuals per unit area (¼ m² quadrates). To eliminate edge effects during the survey studies, ¼ m² quadrates were placed diagonally starting from 10-15 meters inside the field. The number of quadrate placements was determined based on the size of the area, with 12 quadrate placed in areas of 0-0.3 hectar, 20 quadrate in areas of 0.3-0.7 hectar, and 22 quadrate in areas larger than 0.7 hectar (Boz et al., 1993; Boz et al., 2000; Boz, 2000; Sırma and Kadıoğlu, 2010). Weeds within the frames were recorded. Care was taken to ensure that the counting points were not too close to each other. The frequency of occurrence of weeds was calculated using the following formula from Odum (1971). The values obtained from the counts of each weed species in a given area were divided by the total area counted to determine the density of weeds (plants/m²) (Güncan, 2019). The frequency of occurrence was calculated with the following formula as the percentage of sampled fields in which each species was found. The heat map representing the abundance of weeds in districts were generated with XLSTAT software.

Frequency of occurance (%) = n/m x 100 (Odum, 1971)

FO: Frequency of Occurance (%)

m: Total number of surveyed fields

n: The number of fields where weed species is detected

Density = B/n

B: The total number of surveyed fields

n: The number of samples collected

Most weeds were identified directly in the field at the species level, while others required further identification in the laboratory using herbarium specimens. For this purpose, samples were collected and dried at room temperature, then mounted on sturdy cardboard sheets. Each specimen was labeled with its species name, collection location, date, and relevant data. Identification was performed using taxonomic keys from Flora of Turkey (Davis, 1965–1989; Hanf, 1983), and Turkish names were based on Uluğ et al. (1993).

To assess weed community structure in cabbage fields, several diversity indices were calculated: Shannon-Weiner diversity index (H′), Pielou's evenness index (J′), and species richness index (R), following standard methods (Pielou, 1966; Neher & Darby, 2009).

$H' = -\sum(pi \times \log pi)$, where pi is the proportion of individuals of the ith species.

$J' = H'/\ln(S)$, representing the uniformity of species distribution (S = total number of species).

$R = (S-1)/\ln(N)$, where N is the total number of individuals, indicating species richness relative to population size.

Results

As a result of these surveys, a total of 71 weed species belonging to 27 families were identified. Among these, Poaceae ranked first in species diversity with 14 species, followed by Asteraceae with 10 species. Fabaceae, Brassicaceae, and Solanaceae each had five species.

In the first period of the surveys conducted in white cabbage fields across Sakarya province, a total of 52 weed species were recorded (Table 2). Province-wide, *Stellaria media* (L.) Vill. had the highest density (35.188 plants/m²), followed by *Veronica hederifolia* L. (12.0905). In terms of frequency, *V. hederifolia* had 100% occurrence, while *Lamium amplexicaule* L. followed with 93.5%.

In Adapazarı, *S. media* showed the highest density (25.22), and both *V. hederifolia* and *S. media* were found in 100% of surveyed plots. In Erenler, *S.media* again ranked first in density (32.16), while *Capsella bursa-pastoris* (L.) Medik. and *V. hederifolia* had 100% frequency. In Kaynarca, *V. hederifolia* had both the highest density (15.66) and 100% frequency. *Mercurialis annua* L. and *L. amplexicaule* L. were also found in all plots. In Pamukova, *S. media* was the most dominant species, with 100% occurrence and a remarkably high density of 77.66 plants/m².

148 **Table 2.** Density and frequency of occurrence of first season weeds in the districts where white
149 cabbage is intensively cultivated in Sakarya province.

First Period Weed Species, Density and Frequency of Occurrence in Sakarya Province											
No.	Weed species	Regions								The Average Density in Sakarya	
		Adapazarı		Erenler		Kaynarca		Pamukova			
		Plant/m^2	FO	Plant/m^2	FO	Plant/m^2	FO	Plant/m^2	FO	Plant/m^2	FO
1.	*Abutilon theophrasti*	0,03	12,5	0	0	0,06	20	0	0	0,0244	8,125
2.	*Alopecurus myosuroides*	0,48	37,5	0,33	20	0,93	70	0	0	0,4399	31,875
3.	*Amaranthus retroflexus*	0,51	12,5	0,10	33,33	0,30	30	6,33	100	1,8141	43,958
4.	*Anagallis arvensis*	0	0	0	0	2,42	60	0	0	0,6060	15
5.	*Anethum graveolens*	0	0	0,05	13,33	0	0	0	0	0,0127	3,333
6.	*Avena fatua*	0,51	37,5	0,28	20	3,84	80	0	0	1,1637	34,375
7.	*Capsella bursa-pastoris*	7,74	37,5	11,45	100	1,12	20	0	0	5,0798	39,375
8.	*Cardamine tenera*	0,14	12,5	2,05	13,33	0	0	0	0	0,5497	6,458
9.	*Chenopodium album*	0,33	12,5	0,66	53,33	0,48	30	0	0	0,3697	23,958
10.	*Cirsium arvense*	0,59	25	0,66	26,66	0	0	0	0	0,3134	12,916
11.	*Cnicus benedictus*	0	0	0,03	13,33	0,18	60	0,66	100	0,2205	43,333
12.	*Conium maculatum*	0,03	12,5	0	0	0,06	20	0	0	0,0244	8,125
13.	*Convolvulus arvensis*	0,11	25	0,50	33,33	0,63	20	0	0	0,3139	19,583
14.	*Conyza canadensis*	0,03	12,5	0	0	0	0	0	0	0,0092	3,125
15.	*Crepis sancta*	0,07	25	0,05	6,66	0,96	40	0	0	0,2736	17,916
16.	*Cynodon dactylon*	0,81	25	0,22	26,66	0,18	10	0	0	0,3042	15,416
17.	*Cyperus rotundus*	0	0	0,32	6,66	0	0	0	0	0,0805	1,666
18.	*Datura stramonium*	0	0	0	0	0,06	20	0,33	100	0,0984	30
19.	*Daucus carota*	0	0	0	0	0,03	10	0	0	0,0075	2,5
20.	*Echinochloa crus-galli*	0,03	12,5	0,01	6,66	0,03	10	0	0	0,0210	7,291
21.	*Equisetum arvense*	0	0	0	0	0,15	10	0	0	0,0378	2,5
22.	*Euphorbia peplus*	0,14	25	4,61	80	2,57	90	0	0	1,8335	48,75
23.	*Fumaria officinalis*	0,85	50	0,33	33,33	0,24	30	0	0	0,3583	28,333
24.	*Galium aparine*	0,88	25	0,06	13,33	1,69	40	0	0	0,6634	19,583
25.	*Geranium pusillum*	0,11	25	0,06	20	1,57	70	0	0	0,4386	28,75
26.	*Lamium amplexicaule*	4,40	87,5	2,61	86,66	14,21	100	0,33	100	5,3907	93,541
27.	*Lolium temulentum*	0	0	0	0	0,24	20	0	0	0,0606	5
28.	*Malva sylvestris*	0,03	12,5	0	0	0,27	50	0	0	0,0774	15,625
29.	*Matricaria chamomilla*	0,03	12,5	0,01	6,66	0	0	0	0	0,0134	4,791
30.	*Medicago sativa*	0	0	0	0	0,42	10	0	0	0,1060	2,5
31.	*Mercurialis annua*	0,51	50	1,06	73,33	4,15	100	0	0	1,4344	55,833
32.	*Papaver rhoeas*	0,88	12,5	0,20	13,33	0,69	40	0	0	0,4473	16,458
33.	*Physalis angulata*	0	0	0,05	13,33	0,03	10	0	0	0,0202	5,833
34.	*Poa annua*	3,62	50	0,37	20	1,87	20	0	0	1,4703	22,5
35.	*Polygonum aviculare*	0,40	12,5	5,96	46,66	0	0	0	0	1,5933	14,791
36.	*Ranunculus repens*	0,81	12,5	0,03	13,33	0,21	20	0	0	0,2652	11,458
37.	*Raphanus raphanistrum*	0,11	25	0,18	33,33	0,27	40	0	0	0,1425	24,583
38.	*Rumex obtusifolius*	0,22	25	0,54	60	0,39	50	0	0	0,2896	33,75

39.	*Sambucus ebulus*	0	0	0	0	0,0018	10	0	0	0,00045	2,5
40.	*Senecio vulgaris*	0,34	100	0,13	100	0,03	100	0	0	0,125	75
41.	*Setaria verticillata*	0	0	0,001	6,666	0	0	0	0	0,00025	1,6665
42.	*Setaria viridis*	0,013	75	0,0074	46,66	0,0018	10	0	0	0,0055	32,915
43.	*Solanum nigrum*	0,0046	25	0	0	0,0075	40	0	0	0,0030	16,25
44.	*Sonchus oleraceus*	0,069	100	0,12	100	0,077	100	0,0018	10	0,066	100
45.	*Sorghum halepense*	0	0	0,0021	13,33	0,0037	20	0	0	0,00145	8,33
46.	*Stellaria media*	1.57	100	2.01	100	0,35	100	0,44	100	1,13	100
47.	*Taraxacum officinale*	0	0	0,0074	46,66	0,0056	30	0	0	0,0032	19,165
48.	*Trifolium* spp.	0	0	0,0042	26,66	0,018	100	0	0	0,0055	31,66
49.	*Urtica urens*	0	0	0,0010	6,66	0	0	0	0	0,00025	1,665
50.	*Veronica hederifolia*	1,004	100	0,705	100	0,979	100	0,030	100	0,67	100
51.	*Vicia sativa*	0	0	0	0	0,011	60	0	0	0,0027	15
52.	*Xanthium strumarium*	0	0	0	0	0,0018	10	0	0	0,00045	2,5

The results of the second-period weed surveys conducted in white cabbage fields across Sakarya province are summarized in Table 3. According to the 2023 growing season data, *S. media* (L.) Vill. had the highest density (39.17), followed by *V. hederifolia* L. (8.50) and *Portulaca oleracea* L. (7.55). In terms of frequency, *Convolvulus arvensis* L. was the most widespread species with 75.11%, followed by *Sonchus oleraceus* L. (75.07%) and *L. amplexicaule* L. (69.09%).

At the district level, in Adapazarı, Veronica hederifolia had the highest density (22.56), while Portulaca oleracea had 100% frequency. In Erenler, Stellaria media dominated in both density (133.63) and frequency (100%). In Kaynarca, Stellaria media led in density (11.92), whereas Veronica hederifolia was the most frequent (93.33%). In Pamukova, *C. arvensis* L. was the dominant species with a density of 16.33 and 100% frequency.

Table 3. Density and frequency of occurrence of second season weeds in the districts where white cabbage is intensively cultivated in Sakarya province.

Second Period Weed Species, Density and Frequency of Occurrence in Sakarya Province											
No.	Weed species	Regions								The Average Density in Sakarya	
		Adapazarı		Erenler		Kaynarca		Pamukova			
		Plant/m²	F.O.	Plant/m²	F.O.	Plant/m²	F.O.	Plant/m²	F.O.	Plant/m²	F.O.
1.	*Abutilon theophrasti*	0,40	36,36	0,13	33,33	0,10	13,33	0	0	0,1623	20,7575
2.	*Agropyronrepens*	1,18	54,54	0	0	0	0	0	0	0,2972	13,6363
3.	*Amaranthus retroflexus*	0,75	63,63	0,38	58,33	0,07	6,66	1	100	0,5539	57,1590
4.	*Anagallis arvensis*	0,05	9,09	0,13	25	0,03	13,33	0	0	0,0570	11,8560
5.	*Anethum graveolens*	0,02	9,09	0	0	0	0	0	0	0,0067	2,2727
6.	*Avena fatua*	0,27	9,09	0,02	8,33	0,92	66,66	0	0	0,3069	21,0227
7.	*Beta vulgaris* var. *altissima*	0,27	27,27	0	0	0	0	0	0	0,0675	6,8181
8.	*Capsella bursa-pastoris*	2,83	45,45	3	16,66	0,24	20	0	0	1,5208	20,5303
9.	*Chenopodium album*	0,51	45,45	0,41	50	1,59	46,66	3	100	1,3816	60,5303
10.	*Cirsium arvense*	0	0	6,11	50	0	0	0,33	100	1,6111	37,5
11.	*Cnicus benedictus*	0,02	9,09	0	0	0,14	13,33	0,33	100	0,1251	30,6060
12.	*Convolvulus arvensis*	2,83	45,45	2,91	75	5,98	80	16,33	100	7,0175	75,1136
13.	*Crepis sancta*	0,10	36,36	0	0	0,15	26,66	0	0	0,0665	15,7575
14.	*Cynodon dactylon*	0	0	0,16	33,33	0,17	26,66	0,66	100	0,2521	40
15.	*Cyperus rotundus* L.	0,35	9,09	0	0	0,05	6,66	14,33	100	3,6843	28,9393
16.	*Datura stramonium*	0,32	27,27	0,36	41,66	0,01	6,66	0	0	0,1757	18,9015
17.	*Daucus carota*	0	0	0	0	0,26	33,33	0	0	0,0657	8,3333
18.	*Digitaria sanguinalis*	0,10	27,27	0	0	0,03	6,66	0	0	0,0357	8,4848
19.	*Echinochloa crus-galli*	1,45	54,54	0,13	25	0,01	6,66	0	0	0,4039	21,5530
20.	*Euphorbia peplus*	0,13	36,36	0,97	16,66	0,47	40	0	0	0,3952	23,2575
21.	*Fumaria officinalis*	0,27	27,27	0	0	0,82	33,33	0	0	0,2737	15,1515
22.	*Geranium pusillum*	0,43	36,36	0,16	8,33	1,73	33,33	0,66	100	0,7506	44,5075
23.	*Heliotropium dolosum*	0,37	18,18	0,02	8,33	0,01	6,66	1	100	0,3559	33,2954
24.	*Hibiscus sabdariffa*	0	0	1,36	33,33	0,05	13,33	0,33	100	0,4367	36,6666
25.	*Hordeum vulgare*	0,51	9,09	0	0	2,43	26,66	0	0	0,7380	8,9393
26.	*Lamium amplexicaule*	1,02	36,36	4,44	66,66	5,36	73,33	2	100	3,2099	69,0909
27.	*Lolium temulentum*	0	0	0	0	2,68	6,66	0	0	0,6710	1,6666
28.	*Malva sylvestris*	0,08	27,27	0	0	0,28	46,66	0	0	0,0904	18,4848
29.	*Mentha pulegium*	0	0	0	0	0,21	13,33	0	0	0,0526	3,3333
30.	*Mercurialis annua*	0,40	36,36	2,61	75	5,38	73,33	0	0	2,1006	46,1742
31.	*Orobanche* spp.	0	0	0	0	0	0	7,66	100	1,9166	25
32.	*Papaver rhoeas*	0	0	0,02	8,33	0	0	0	0	0,0069	2,0833
33.	*Phaseolus vulgaris*	0,10	18,18	0	0	0	0	0	0	0,0270	4,5454
34.	*Physalis angulata*	0,10	9,09	0	0	0,82	26,66	0	0	0,2331	8,9393
35.	Plantago major	0,13	9,09	0	0	0	0	0	0	0,0337	2,2727

36.	*Poa annua*	0,62	27,27	0,11	25	1,96	66,66	0	0	0,6744	29,7348
37.	*Polygonum aviculare*	0,05	18,18	0,02	8,33	0,03	6,66	0	0	0,0292	8,2954
38.	*Portulaca oleracea*	4,62	100	7,02	75	2,57	60	16	100	7,5570	83,75
39.	*Raphanus raphanistrum*	0,10	18,18	0,02	8,33	0,19	26,66	1	100	0,3322	38,2954
40.	*Rumex obtusifolius*	0,21	27,27	0,77	41,66	0,15	20	0	0	0,2879	22,2348
41.	*Scrophularia nodosa*	0,02	9,09	0	0	0	0	0	0	0,0067	2,2727
42.	*Senecio vulgaris*	0,51	27,27	1,08	41,66	0,01	6,66	0	0	0,4035	18,9015
43.	*Setaria verticillata*	0	0	0	0	0	0	0,66	100	0,1666	25
44.	*Setaria viridis*	0,18	18,18	0	0	0	0	0	0	0,0472	4,5454
45.	*Sinapis arvensis*	0	0	0,13	25	0,61	20	0	0	0,1882	11,25
46.	*Solanum nigrum*	0,94	72,72	1,08	41,66	0,36	20	0	0	0,5994	33,5984
47.	*Solanum tuberosum*	0,81	27,27	0	0	0	0	0	0	0,2027	6,8181
48.	*Sonchus asper*	0,13	27,27	0	0	0,03	13,33	0	0	0,0425	10,1515
49.	*Sonchus oleraceus*	1,70	63,63	1,41	83,33	1,01	53,33	5	100	2,2842	75,07575
50.	*Sorghum halepense*	1,27	27,27	1,58	25	0	0	0,66	100	0,8800	38,0681
51.	*Spinacia oleracea*	1,43	9,09	0	0	0,01	6,66	0	0	0,3624	3,93939
52.	*Stellaria media*	11,13	90,90	133,63	100	11,92	66,66	0	0	39,1759	64,3939
53.	*Taraxacum officinale*	0,02	9,09	0	0	0,03	6,66	0	0	0,0155	3,9393
54.	*Trifolium* spp.	0	0	0	0	0,01	6,66	0	0	0,0043	1,6666
55.	*Triticum* spp.	0,02	9,09	0	0	1,10	20	0	0	0,2830	7,2727
56.	*Urtica urens*	0	0	0	0	0,21	6,66	0	0	0,0526	1,6666
57.	*Veronica hederifolia*	22,56	72,72	2,30	66,66	9,14	93,33	0	0	8,5033	58,1818
58.	*Vicia sativa*	0	0	0	0	0,03	13,33	0	0	0,0087	3,3333
59.	*Vicia faba*	0	0	0	0	0,01	6,66	0	0	0,0043	1,6666
60.	*Xanthium strumarium*	0,40	9,09	0,02	8,33	0,49	13,33	0	0	0,2311	7,6893
61.	*Zea mays*	0,02	9,09	0	0	0	0	0	0	0,0067	2,2727

Table 4, categorizes all identified species based on their family, life form, life span, and photosynthetic pathway. Accoring to Table 4 most weeds belonged to Poaceae, Asteraceae, Amaranthaceae, and Brassicaceae. Annual therophytes were dominant, reflecting the disturbed nature of cultivated fields. The majority of species followed the C_3 photosynthetic pathway, while a smaller number (e.g., *Amaranthus retroflexus*, *Portulaca oleracea*, *Setaria* spp.) were C_4 plants, indicating potential competitive advantages under warmer or drier conditions.

185 Table 4. The family, life form, life span, and photosynthetic pathway of weeds identified in
186 cabbage fields.

Plant Name	Familya	Life Form	Life span	C3/C4
Abutilon theophrasti	Malvaceae	Th	A	C4
Agropyron repens	Poaceae	G	P	C3
Alopecurus myosuroides	Poaceae	Th	A	C3
Amaranthus retroflexus	Amaranthaceae	Th	A	C4
Anagallis arvensis	Primulaceae	Th	A	C3
Anethum graveolens	Apiaceae	Th	A	C3
Avena fatua	Poaceae	Th	A	C3
Beta vulgarisvar altissima	Amaranthaceae	H	Bi	C3
Capsella bursa-pastoris	Brassicaceae	Th	A	C3
Cardamine tenera	Brassicaceae	Th	A	C3
Chenopodium album	Amaranthaceae	Th	A	C3
Cirsium arvense	Asteraceae	H	P	C3
Cnicus benedictus	Asteraceae	Th	A	C3
Conium maculatum	Apiaceae	Th	A/Bi	C3
Convolvulus arvensis	Convolvulaceae	H	P	C3
Conyza canadensis	Asteraceae	Th	A	C3
Crepis sancta	Asteraceae	Th	A	C3
Cynodon dactylon	Poaceae	G	P	C4
Cyperus rotundus	Cyperaceae	G	P	C4
Datura stramonium	Solanaceae	Th	A	C3
Daucus carota	Apiaceae	H	Bi	C3
Digitaria sanguinalis .	Poaceae	Th	A	C4
Echinochloa crus-galli	Poaceae	Th	A	C4
Equisetum arvense	Equisetaceae	G	P	C3
Euphorbia peplus	Euphorbiaceae	Th	A	C3
Fumaria officinalis	Papaveraceae	Th	A	C3
Galium aparine	Rubiaceae	Th	A	C3
Geranium pusillum	Geraniaceae	Th	A	C3
Heliotropium dolosum	Boraginaceae	Th	A	C3
Hibiscus sabdariffa	Malvaceae	Th	A	C3
Hordeum vulgare	Poaceae	Th	A	C3
Lamium amplexicaule	Lamiaceae	Th	A	C3
Lolium temulentum	Poaceae	Th	A	C3
Malva sylvestris	Malvaceae	H	Bi	C3
Matricaria chamomilla	Asteraceae	Th	A	C3
Medicago sativa	Fabaceae	H	P	C3
Mentha pulegium	Lamiaceae	H	P	C3
Mercurialis annua	Euphorbiaceae	Th	A	C3
Orobanche spp.	Orobanchaceae	Holoparasite	A	C3
Papaver rhoeas	Papaveraceae	Th	A	C3
Phaseolus vulgaris	Fabaceae	Th	A	C3
Physalis angulata	Solanaceae	Th	A	C3
Plantago major	Plantaginaceae	H	P	C3
Poa annua	Poaceae	Th	A	C3
Polygonum aviculare	Polygonaceae	Th	A	C3
Portulaca oleracea	Portulacaceae	Th	A	C4
Ranunculus repens	Ranunculaceae	H	P	C3
Raphanus raphanistrum	Brassicaceae	Th	A	C3
Rumex obtusifolius	Polygonaceae	H	P	C3
Sambucus ebulus	Adoxaceae	G	P	C3
Scrophularia nodosa	Scrophulariaceae	G	P	C3
Senecio vulgaris	Asteraceae	Th	A	C3
Setaria verticillata	Poaceae	Th	A	C4
Setaria viridis	Poaceae	Th	A	C4
Sinapis arvensis	Brassicaceae	Th	A	C3
Solanum nigrum	Solanaceae	Th	A	C3
Solanum tuberosum	Solanaceae	G	P	C3
Sonchus asper	Asteraceae	Th	A	C3
Sonchus oleraceus	Asteraceae	Th	A	C3
Sorghum halepense	Poaceae	G	P	C4
Spinacia oleracea	Amaranthaceae	Th	A	C3
Stellaria media	Caryophyllaceae	Th	A	C3

Taraxacum officinale	Asteraceae	H	P	C3
Trifolium spp.	Fabaceae	H	A/P	C3
Triticum spp.	Poaceae	Th	A	C3
Urtica urens	Urticaceae	Th	A	C3
Veronica hederifolia	Plantaginaceae	Th	A	C3
Vicia faba	Fabaceae	Th	A	C3
Vicia sativa	Fabaceae	Th	A	C3
Xanthium strumarium	Asteraceae	Th	A	C3
Zea mays	Poaceae	Th	A	C4

*Th:Therophyte, G:Geophyte, H:Halophyte, *A:Annual, B:Biannual, P:Perannual

In the second period survey conducted in the district of Pamukova, *Orobanche* spp. (broomrape) was detected (Figure 2). This weed was found at a density of 7.66. The incidence in the district is 100%. This is the first time that broomrape has been identified in the cultivation of white cabbage in Türkiye. Laboratory tests showed that white cabbage acts as a host for broomrape (Figure 3).

Figure 2. Orobanche on non-harvested cabbage plant (A) Orobance on harvested cabbage plant (B).

Figure 3. Binocular view of Orobache attached to cabbage roots (A, B).

The heat map generatet with XLSTAT represents weed abundance in surveyed fields in Sakarya. The colors black, red and green indicates different population densities. In the map red tones represent low density (Fig 4).

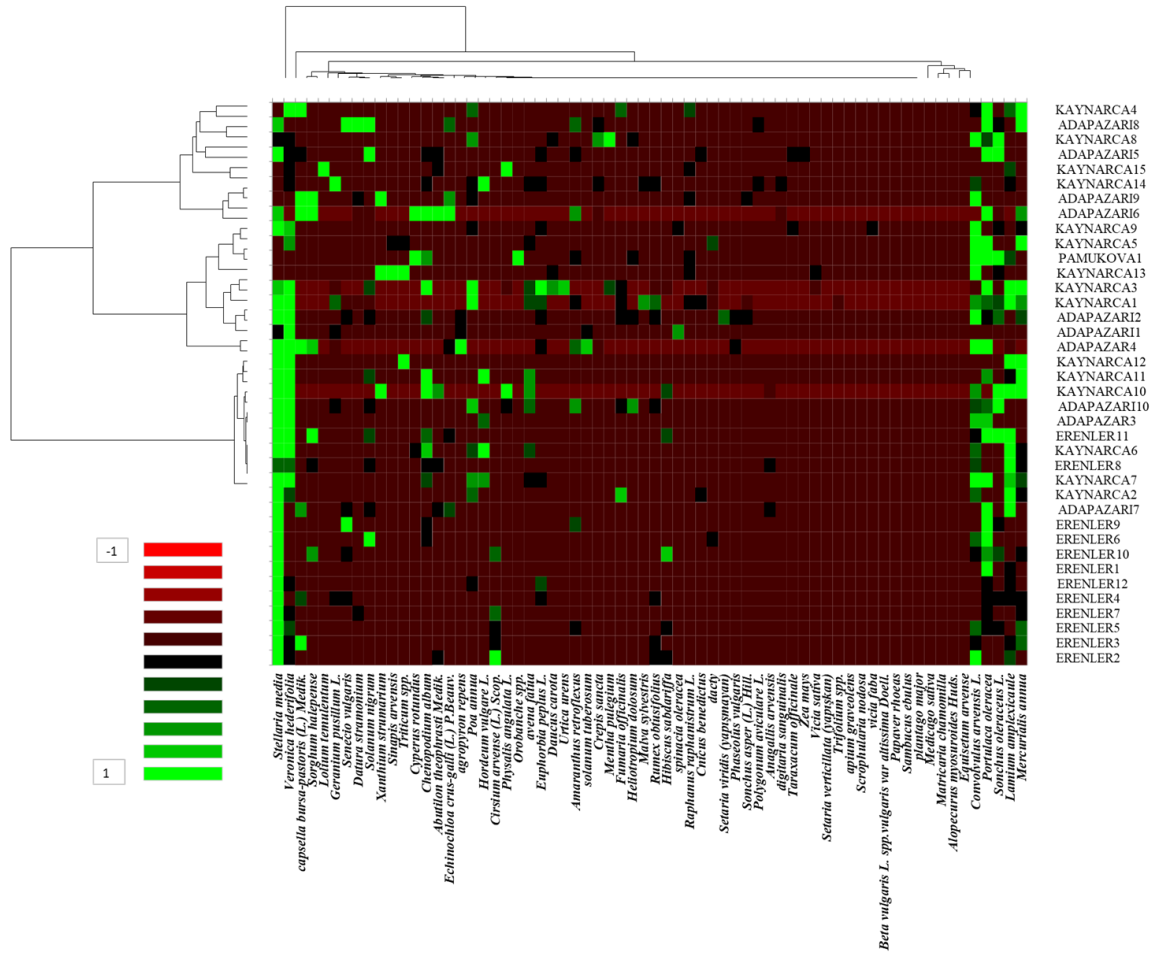

Figure 4. Heat map showing weed abundance in survey areas.

The bar charts in Figure 4. illustrates the biodiversity indices in four districts. Shannon Index (H') values for biodiversity in four districts: Adapazarı, Erenler, Kaynarca and Pamukova. The Shannon Index measures species diversity, with higher values indicating greater biodiversity. Pamukova has the highest Shannon index (2.08), represented by the letter indicating that its biodiversity is significantly higher compared to the other districts. Both Adapazarı (1.757) and Kaynarca (1.717) have similar Shannon Index values, indicating no significant difference in their biodiversity levels. However, these values are lower than those of Pamukova. Erenler has the lowest Shannon Index (1.036), indicating significantly lower biodiversity compared to the other districts. Overall, the graph emphasizes that Pamukova has the highest biodiversity while Erenler has the lowest, with Adapazarı and Kaynarca in between (Figure 5).

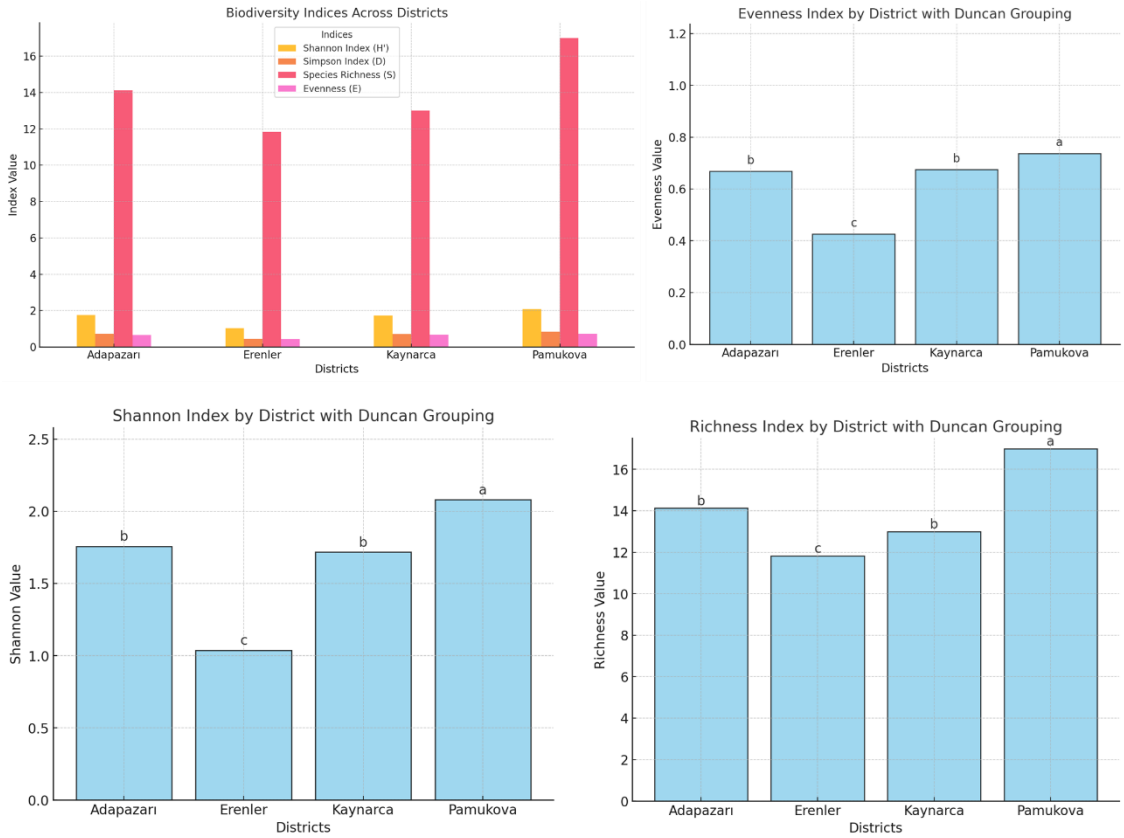

Figure 5. Biodiversity indice values comparisons and Duncan results.

DISCUSSION

Sustainable weed management is becoming increasingly important, as weeds cause significant yield and quality losses across all agricultural sectors. Effective control depends on understanding weed biology, distribution, host relationships, and competitiveness. Although numerous studies focus on major crops, research on weeds in white cabbage fields is limited in Türkiye, despite its role in crop rotation and allelopathic potential. In this pioneering study, 73 fields were surveyed over two growing seasons (2022–2023), marking the first weed survey in Türkiye's white cabbage production areas.

During the surveys in Sakarya, 71 weed species from 27 families were identified, reflecting a diverse and complex weed community that may impact crop performance. These findings are consistent with a study in China that recorded 71 species from 25 families, including 39 annuals, 16 biennials, and 16 perennials. The most common families were Compositae (20 species), Poaceae (8), Cruciferae (6), and Polygonaceae (5). Ten dominant weed species from six families accounted for 50% of the total, with *Portulaca oleracea* (8.07%), *Digitaria ciliaris* (7.54%), and *Chenopodium album* (5.73%) among the most prevalent (Hwang et al., 2024).

In Sakarya, S. media (39.17) and V. hederifolia (100% frequency) were notably competitive. *S. media* is known for competing strongly with plant, reducing crop yield and quality (Kumar et al., 2021), while *V. hederifolia*'s adaptability makes it a persistent problem (Bourgeois et al., 2019). Their dominance, especially in the first period where both appeared in all plots, underscores the importance of integrated weed management (IWM), which combines mechanical, cultural, and chemical methods (Buhler, 2016).

In the second survey, *V. hederifolia* had the highest density in Adapazarı (22.56), and Portulaca oleracea was present in 100% of plots. This aligns with Büyükdemir and Kara (2020), who reported its prevalence in sugar beet due to drought tolerance and high seed production. In Erenler, *S. media* showed the highest density (133.63) and frequency (100%), consistent with its resilience across various soils (Bukun, 2006). Holm et al. (1997) also reported its dominance in cooler climates, as seen in Kaynarca. In Pamukova, *Convolvulus arvensis* was both dense (16.33) and widespread (100%), confirming its persistence as an invasive perennial with a deep root system (Heap, 2023).

District-level differences were evident, such as the dominance of *V.hederifolia* in Kaynarca and the exceptional density of *S. media* in Pamukova. This spatial variability highlights the need for localized management strategies suited to specific ecological conditions (Liebman & Davis, 2000). In Erenler, *C. bursa-pastoris* also reached 100% frequency and is known to host pests that affect cabbage health and yield (Storkey et al., 2012).

Overall, *S. media* and *V. hederifolia* were the most prevalent weeds in white cabbage fields. Similar observations were made by Oerke (2006) in Germany, where *C. album* and *Sinapis arvensis* were dominant. This suggests regional weed dominance varies based on environmental and agricultural practices. Likewise, Zand et al. (2020) in Iran identified *V. hederifolia* as a major weed in vegetable crops, confirming its adaptability across different cropping systems.

Another significant outcome of the study was the first confirmed detection of *Orobanche* spp. parasitizing white cabbage in Türkiye, marking a novel host-parasite relationship. Laboratory analysis verified its root attachment, suggesting risks of nutrient depletion and yield loss. Similar associations have been reported in other *Brassica* crops globally (Qasem & Foy, 2007; Piwowarczyk, 2012), and recent studies note the expanding host range of *Orobanche* spp. (Kaçan, 2019; Chedadi et al., 2021; Güzel & Doğan, 2022).

Conclusions

This study presents the first weed survey in white cabbage fields in Türkiye, identifying 71 species from 27 families across Sakarya province. *S. media* and *V. hederifolia* were the most dominant weeds, with significant densities and frequencies across districts. The results emphasize the need for localized integrated weed management strategies.

A major finding was the first detection of Orobanche spp. parasitizing white cabbage in Türkiye, indicating a novel host–parasite relationship. Given its potential to cause significant yield losses, this finding underscores the importance of regular monitoring and effective control measures.Overall, the study contributes valuable baseline data for sustainable weed management in white cabbage production systems.

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