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Common ragweed: An emerging threat for sunflower production and human health in Turkey

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Common ragweed invasion poses serious risks to human health, biodiversity and agricultural production throughout the world. Although ragweed has an enormous potential to expand its range in Turkey, studies on ragweed have only concentrated on the Black Sea region. An exploratory survey was conducted to observe the level of ragweed occurrence on the nodes of predecided 10 × 10 km grids in the Thrace region of Turkey. Ragweed populations were observed in 44 out of 129 sites in a wide range of habitats, including roadsides, pastures, agricultural fields and non-agricultural areas. The highest levels of ragweed infestation were recorded in the agricultural fields, followed by the roadsides. The most-invaded crop was sunflower. The sunflower fields had the highest ragweed coverage as well and invasion even resulted in crop failure alongside the field borders. A spatial analysis of the data indicated that ragweed exhibited an aggregated pattern over the Thrace region. Ragweed distribution was not associated with the characteristics of the soils, which had a varying range of pH, electrical conductivity and texture. The results revealed that ragweed invasion can arise as a serious weed problem, interfering with the sustainability of sunflower production in Thrace and other sunflower-producing regions of the country. A high degree of ragweed infestation also will contribute to the pollen level counts for the most crowded cities in the region, posing a serious danger to human health.

Keywords: common ragweed, human health, invasion, sunflower, Turkey.

Common ragweed (*Ambrosia artemisiifolia* L.) is an invasive weed that originated from North America and is considered to be among the 100 most-noxious invasive plants of Europe (DAISIE 2015). Common ragweed (ragweed, hereafter) has multidimensional negative impacts on biodiversity, the environment, crop production, as well as human health (Makra *et al.* 2005; Peternel *et al.* 2005; Testi *et al.* 2009; Tokarska-Guzik *et al.* 2011; Smith *et al.* 2013). Ragweed causes severe yield reductions, even at low densities, in several crops, such as sunflower, soybean, maize, sugar beet and wheat (Mutch *et al.* 2003; Kazinczi *et al.* 2008). Moreover, the pollen of ragweed is considered to be among the most dangerous allergens of the world (Jager 2000).

The first record of ragweed in Turkey dates back to 1998 in the Black Sea region (Byfield & Baytop 1998). Therefore, studies on ragweed population dynamics have only concentrated on the Black Sea region (Onen *et al.* 2013, 2014) and no other report exists indicating the presence of ragweed in other regions of the country. Studies concerning the pollens of weedy species up to 2011 also have not reported any presence of ragweed pollen, especially in the Marmara–Thrace region (Bicakci 2006; Erkan *et al.* 2010, 2011). However, Zemmer *et al.* (2012) recently have reported the pres-

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ence of ragweed pollen in the Marmara region. The authors were unable to detect any ragweed population; rather, they asked the question: Are there regional populations around the Marmara? The authors argued that ragweed pollen might come from multiple sites, probably from neighboring countries or transported locally from a distant source (Zemmer *et al.* 2012).

The European part of Turkey is known as the "Thrace peninsula" and >73% of sunflower is produced there (Suzer 2008). Sunflower is a poor competitor, especially in the early stage of growth, and weed control options are limited, especially for broad-leaved weeds. Therefore, weed management is an important component of successful sunflower production (Pfenning *et al.* 2008). The development of imidazilinone herbicide-tolerant sunflower cultivars (CLEARIFIELD technology), in combination with an imazamox-based herbicide, enables effective control of a wide range of broad-leaved weeds and broomrape (*Orobanche* spp.) (Tan *et al.* 2005; Pfenning *et al.* 2008). The technology is being used in different countries, including Turkey since 2003 (Bozic *et al.* 2012; Jursik *et al.* 2014). Although ragweed is a real problem in sunflower production because of the absence of selective herbicides as both plants belong to the same family (Bertrand & Maupas 1996), imazamox is used to control the weed species that are related to sunflower, like ragweed and cocklebur (*Xanthium strumarium* L.) (Pfenning *et al.* 2008; Fernández-Martínez *et al.* 2009). Conversely, it has been demonstrated that imazamox alone is not enough to control ragweed in sunflower (Nagy *et al.* 2006) and that imazamox-resistant ragweed populations have been detected in different crops (Heap 2015).

The management of invasive plants is an extremely challenging task for land managers and researchers due to the limited available spatial distribution data (Rodgers *et al.* 2014). The early detection of newly introduced invasive plants and distribution data or maps of established populations are crucial to stop or minimize their spread and to control their further invasion in a specific region or country (Welch *et al.* 2012; Liang *et al.* 2014; Padalia *et al.* 2014; Rodgers *et al.* 2014). Therefore, the collection of such data is necessary in order to create invasive species inventories, to know their initial intrusion point and the route of spread and to implement effective management strategies (Rew & Pokorny 2006; Padalia *et al.* 2014; Rodgers *et al.* 2014). However, the occurrence data on invasive plant species over a region or country scale are generally poorly documented and mostly compiled from a variety of sources with varying degrees of sampling intensities (Padalia *et al.* 2014; Rodgers *et al.* 2014). Integrating spatial analyses into weed distribution studies is of great importance for predicting the rates of weed invasion (Smolik *et al.* 2010) and for planning management strategies at different landscape scales (Dauer *et al.* 2009).

The current study was planned to: (i) document the distribution and abundance of ragweed in order to establish an inventory for further studies; (ii) investigate the relationship between ragweed invasion and the soil properties; and (iii) answer the question about the source of ragweed pollen reported in the Thrace region.

METHODS

Study area

The present study was carried out in the Thrace Region, Turkey, which has a surface area of 67 000 km^2. This is the smallest, but most densely populated, region of Turkey. The region has a hybrid Mediterranean climate (humid subtropical) on the Aegean Sea and the south Marmara Sea coasts, an oceanic climate on the Black Sea coast and a humid continental climate in the interior (Unal *et al.* 2003).

Field survey

An exploratory field survey was conducted in the ragweed-growing seasons of 2013 and 2014 to observe the ragweed distribution. The region was divided into 10 km × 10 km grids and surveys were carried out on the nodes of each grid (except for the forests and residential areas) (Brocklehurst *et al.* 2007). A total of 129 sites were selected randomly to avoid any bias in the data (Elzinga *et al.* 2001). The exact locations of the sampling sites were recorded with a global positioning system receiver. The presence of ragweed in the agricultural and non-agricultural areas was detected along 1000 m of each surveyed site (Fig. 1). Soil samples were taken from each surveyed site to correlate the distribution and abundance of ragweed with the soil properties. Data regarding the ragweed density (plants per m^2) in the infested sites, total land covered by ragweed (%) and the various habitats were recorded. The survey sites were grouped according to different ecosystems, representing roadsides, agricultural areas, pastures and non-agricultural areas (Fig. 2). The level of ragweed infestation in each group was recorded and expressed as the occurrence percentage. Most of the survey points had more than one ecosystem that was infested by ragweed; therefore, each site represents more than one ecosystem. The interpolated meteorological data (long-term average for the ragweed season) for all of the surveyed sites were obtained from the Turkish State Meteorological Service (2015).

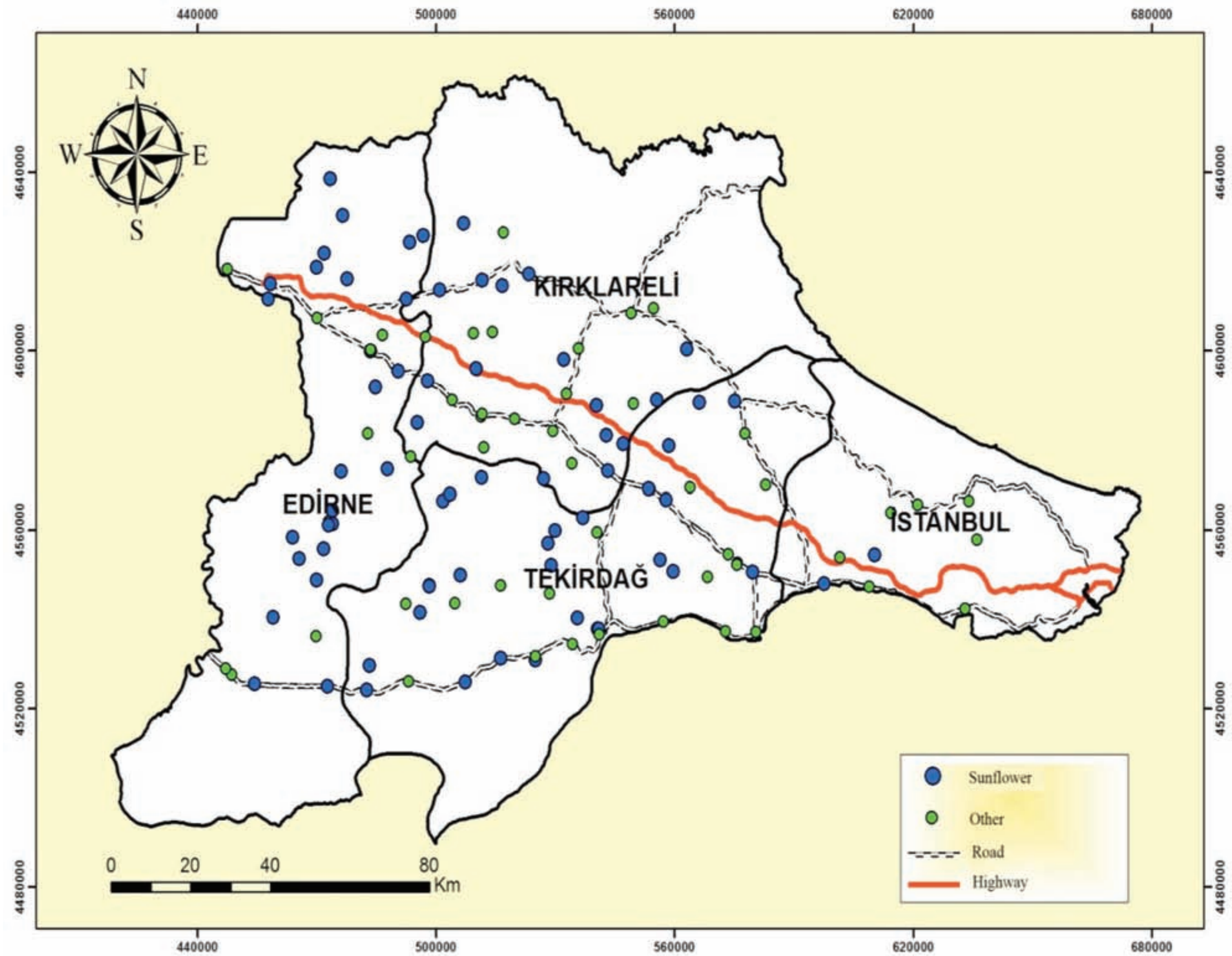

Fig. 1. Survey locations within the Thrace region, Turkey.

Soil analysis

The soil samples were air-dried and passed through a 2 mm sieve in order to carry out the soil analysis. The amount of organic matter was determined by the Walkley and Black method (Nelson & Sommers 1982). The particle size distribution was determined by the hydrometer method in a sedimentation cylinder, using sodium hexametaphosphate as the dispersing agent (Gee & Bauder 1986). The soil reaction (pH) and electrical conductivity (EC) were measured in a saturated paste (Rhoades 1982). The level of $CaCO_3$ was determined by using the calcimeter method, as mentioned by Allison and Moodie (1965).

Data processing

The data analysis for each of the soil properties was conducted in three steps: (i) the frequency distribution was examined and the normality tests were conducted. The soil pH and sand and clay content had normal distributions, but the distributions of all the other variables were not normal; therefore, these were log-transformed prior to the spatial analyses: (ii) an exploratory data analysis was carried out to calculate the minimum, maximum, arithmetic mean, standard deviation and coefficient of variation for each of the soil attributes; and (iii) correlations between the soil properties and the ragweed percentages were calculated. The statistical analyses were carried out by using SPSS statistical software (IBM Corporation 2012).

The spatial patterns of ragweed and the soil properties were characterized quantitatively by a semivariogram. The experimental semivariogram was obtained by calculating one-half of the average squared difference in the data values for every pair of data locations along a specified direction and plotting these values against the dis-

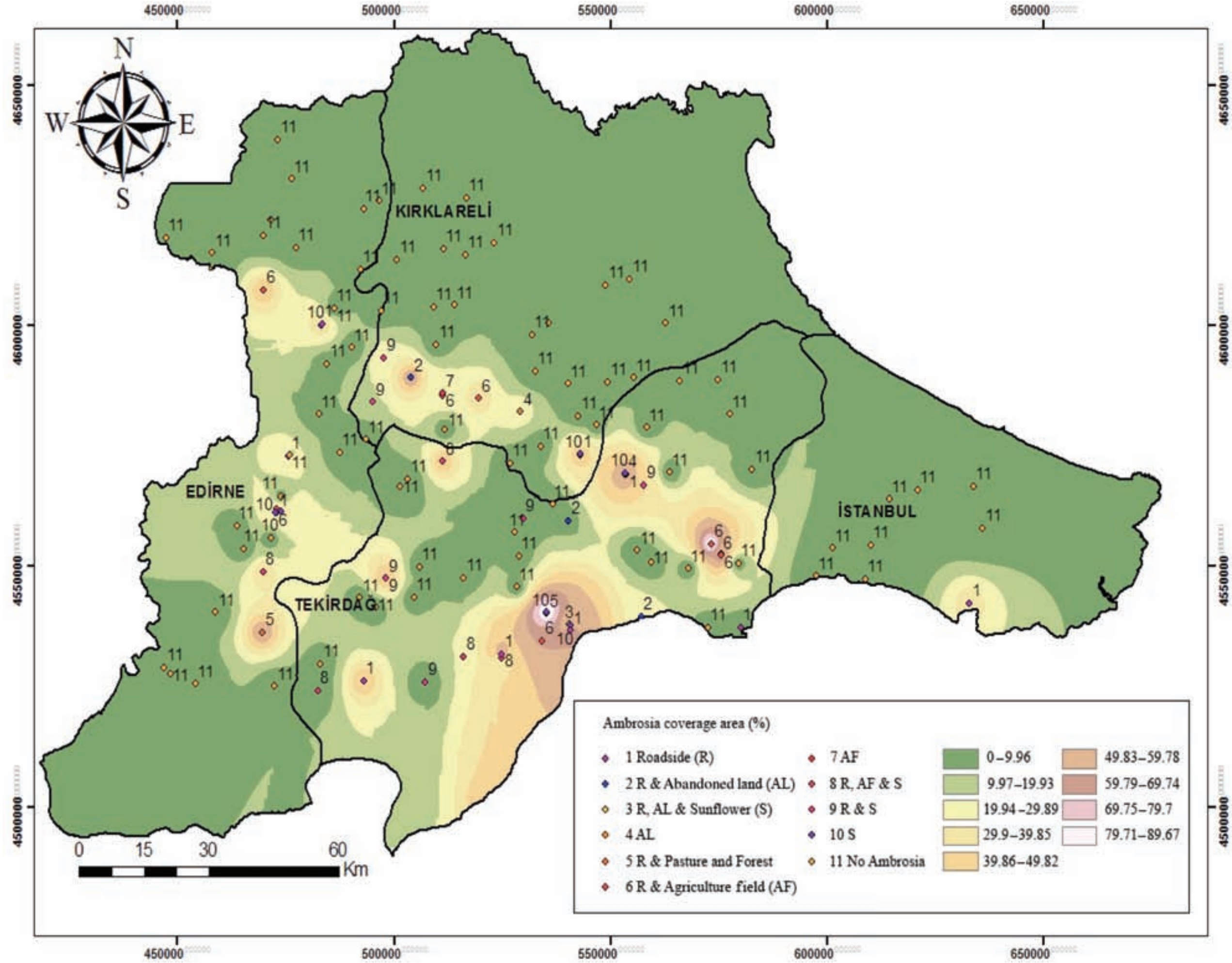

Fig. 2. Spatial distribution of ragweed in the Thrace region, Turkey.

tance between the data pairs. The resulting experimental semivariogram then was used to fit an appropriate theoretical model semivariogram with known mathematical properties. These properties allow semivariogram values to be the inputs for various calculations, including estimations at locations lacking sampling (Isaaks & Srivastava 1989). The spatial representations of ragweed and the soil characteristics were accomplished with ordinary kriging as a geostatistical analytical technique. The ordinary kriging is one of the most commonly used and a basic interpolating method in ecological studies. The method takes both the distance and degree of variation among known points into account when calculating the value of unknown points. The ordinary kriging method provides an estimate of the unsampled-location variables, based on the weighted average of neighbor, measured locations (Yaserebi *et al.* 2009). ArcGIS software was used for the spatial analysis of the level of ragweed occurrence and the soil properties (ESRI 2011).

The nugget-to-sill ratio (Co/[Co + C]) is calculated in order to define the spatial dependence for a given variable (Cambardella *et al.* 1994). If the ratio is <25%, the variable is considered to have strong spatial dependence, while 25–75% is considered as moderate spatial dependence and >75% as weak spatial dependence.

A principal component analysis (PCA) for the soil properties and meteorological indicators (separately) was carried out in order to reduce the data to significant variables explaining the distribution of ragweed in the surveyed region. The PCA was executed on eight soil and seven meteorological variables. The varimax rotation with Kaiser normalization was used to make the interpretation of the soil and meteorological data easier. The SPSS software was used to conduct the PCA, while the graphical representation of the extracted components was accomplished with the CANOCO statistical package (Microcomputer Power, USA).

Table 1. Occurrence of ragweed in different habitats, as observed during the survey

Ecosystem	Total number of survey sites	Number of sites with ragweed occurrence	Occurrence (%)
Agricultural areas†	92	28	30.43
Sunflower fields‡	70	19	27.14
Non-agricultural areas	33	6	18.18
Roadsides	120	35	29.17
Pastures	12	2	16.66

† Agricultural areas with different field crops, including sunflower; ‡ agricultural areas with only a sunflower crop.

Table 2. Coverage area of ragweed and plant population in different habitats, as observed during the survey

Ecosystem	Coverage area (%)				Number of plants (m^{-2})			
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Agricultural areas								
Total	0.00	95.00	12.13	22.64	0	72	5.30	14.12
Infested	1.00	95.00	39.86	24.11	1	72	17.43	21.27
Sunflower fields								
Total	0.00	95.00	9.73	20.05	0	40	3.22	7.89
Infested	1.00	95.00	35.84	23.50	2	40	11.89	11.41
Non-agricultural areas								
Total	0.00	75.00	7.42	18.92	0	100	4.79	17.91
Infested	5.00	75.00	40.83	25.58	1	100	26.33	37.03
Roadsides								
Total	0.00	90.00	12.06	23.05	0	150	8.80	24.22
Infested	1.00	90.00	42.41	24.31	1	150	30.17	37.26
Pastures								
Total	0.00	80.00	11.67	27.58	0	150	15.00	43.38
Infested	60.00	80.00	70.00	14.14	30	150	90.00	84.85

Max., maximum; Min., minimum; SD, standard deviation.

RESULTS

Frequency and distribution of ragweed

Ragweed was recorded in 44 out of a total of 129 locations that were surveyed and the level of infestation was extensive in the central and south-central parts of the region (Fig. 2). The coverage area of ragweed in the infested ecosystems ranged from 1.0% to 95.0%, with a mean of 14.82%. The highest level of ragweed infestation was observed in the agricultural areas (30.4%), followed by the roadsides (29.2%) (Table 1). The densest populations of ragweed among the agricultural areas were recorded in the sunflower fields. The ragweed was present in 19 fields (27.1%) out of a total of 70 sunflower fields that were surveyed. The coverage area in all the sunflower fields (infested and uninfested) ranged from 0.0% to 95%, with a mean coverage of 9.7%, while in the infested fields, it ranged from 1.0% to 95.0%, with a mean coverage of 35.8% (Fig. 2; Table 2). Next to the agricultural areas, the coverage area of ragweed in all the sites with a roadside habitat ranged from 0.0% to 90.0%, with a mean coverage of 7.4%, while the coverage area in the ragweed-infested roadside habitats ranged from 1.0% to 90.0%, with a mean coverage of 42.4% (Fig. 2; Table 2).

Spatial distribution of ragweed and the soil properties

The descriptive statistics for the soil characteristics and the maps showing the spatial distributions of the soil

Table 3. Descriptive statistics for elevation and some of the soil characteristics of the study area

N = 129	Unit	Min.	Max.	Mean	SD	CV
Elevation	m	2	313	118.40	63.90	53.97
$CaCO_3$	%	1.0	73.0	7.36	9.60	130.42
OM		0.38	7.84	2.00	1.25	62.70
pH		5.48	8.70	7.95	0.56	7.01
EC	mS cm^{-1}	34	11,439	282.83	991.36	350.51
Clay	%	7.5	61.8	32.44	12.69	39.11
Sand		12.5	80.0	47.33	15.88	33.55
Silt		5.0	50.0	20.23	7.30	36.10
Phosphorus	mg kg^{-1}	4.48	187.9	23.14	26.76	115.64

CV, coefficient of variation; EC, electrical conductivity; Max., maximum; Min., minimum; OM, organic matter; SD, standard deviation.

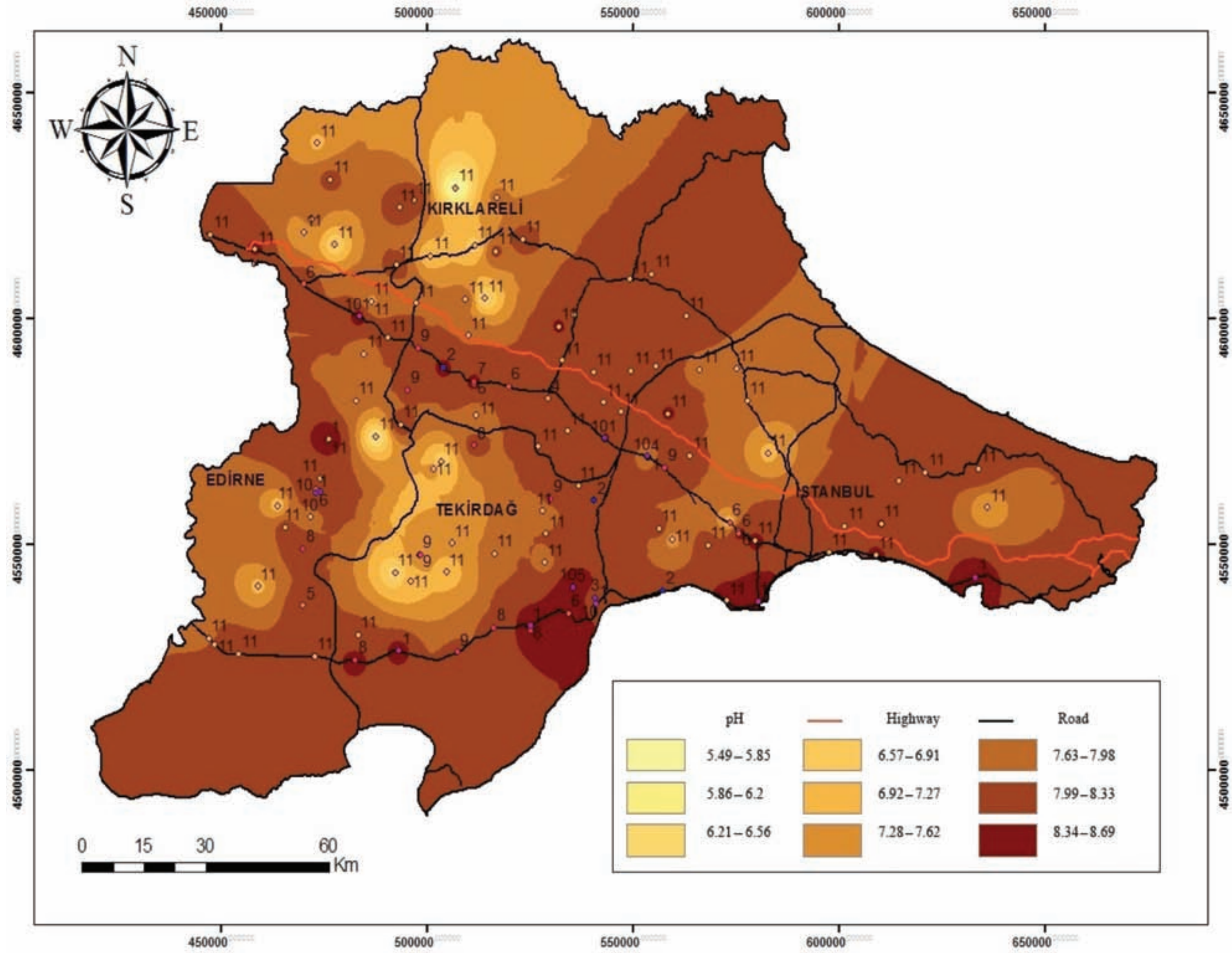

Fig. 3. Spatial distribution of the pH in the Thrace region, Turkey.

characteristics (pH and clay) in the Thrace region are depicted in Table 3 and Figures 3 and 4, respectively. The descriptive statistics characterize the differences in elevation and the soil properties, but do not provide any information on the spatial distribution of ragweed in the area.

The attributes of the semivariograms for the ragweed coverage area, number of plants per square meter and

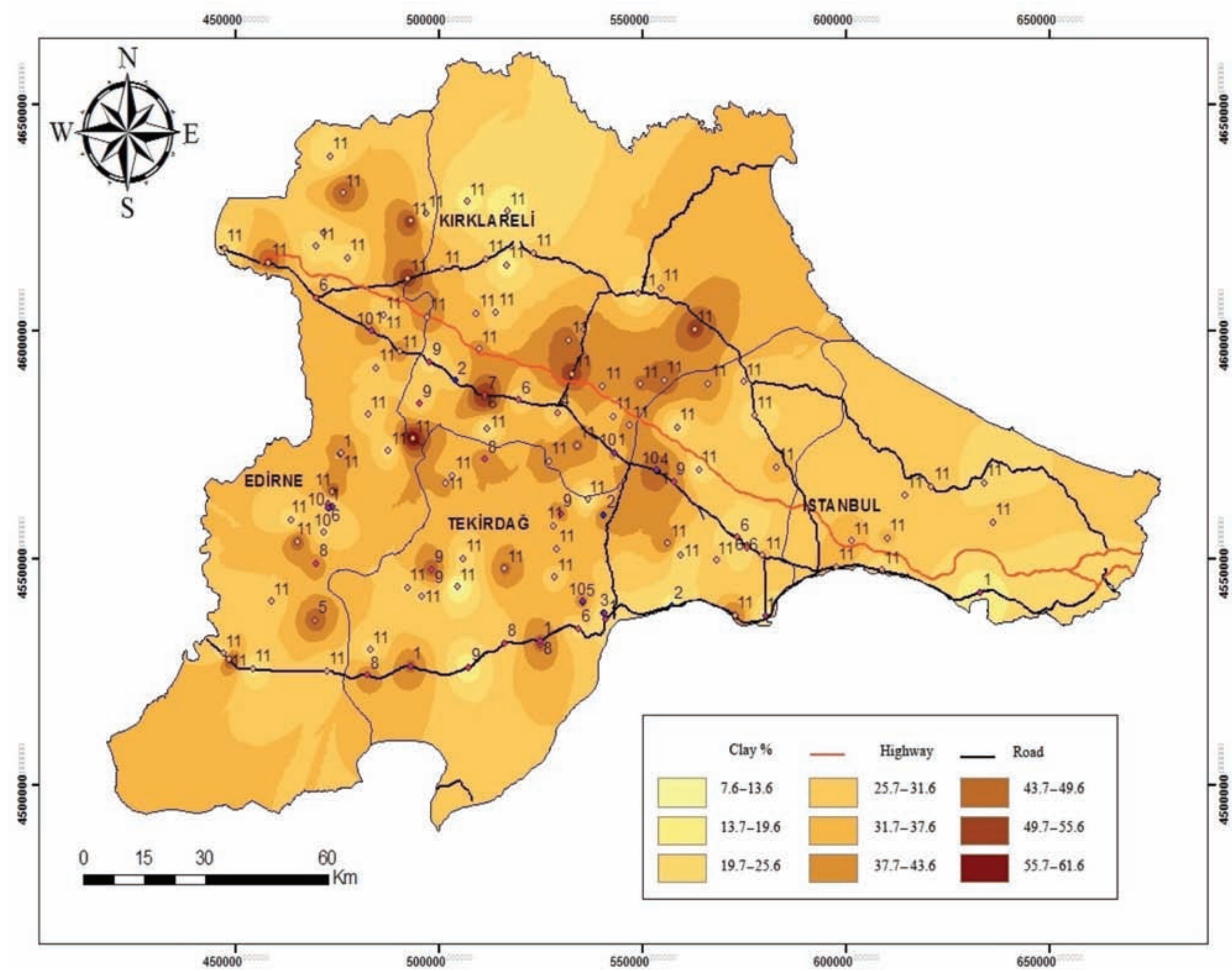

Fig. 4. Spatial distribution of the clay content within the Thrace region, Turkey.

soil characteristics are presented in Table 4. The semivariogram results showed that the spatial structure of the variables was best described with either a spherical or an exponential model (Fig. 5). The spatial autocorrelation structure of ragweed indicates a distinct spatial autocorrelation within the study area. The ragweed exhibited an aggregated pattern over the Thrace region. The range value of ragweed is the distance at which spatial autocorrelation becomes zero, which was 14,700 m. The large aggregation suggests that long dispersal events have occurred in the region.

The spatial dependency of the soil properties ranged from 12.0% for EC to 100% for the phosphorus concentration and clay content, suggesting a strong-to-weak autocorrelation within the study area (Table 4). The pH in the study area ranged from moderately acidic (5.5) to moderately alkaline (8.7) and ragweed was observed in the pH range of 6.9–8.7 (Fig. 3). The non-existence of ragweed below a pH of 6.9 could or could not be related to the adaptability of ragweed, which might even adapt to thrive at pH values outside this range. The central part of the region had the highest clay content, ranging from 7.5% to 61.8%, with a coefficient of variation of 39.1%. The clay content did not correlate with the number of ragweed plants in the surveyed locations (data not given). The ragweed distribution was not specific to the clay content or to the sand and silt content of the soils. The EC of the soils in the study area varied from 34–11.439 mS cm^{-1}, though the EC of the soils where ragweed was observed was between 67.7 mS cm^{-1} and 406 mS cm^{-1}.

The PCA analysis using the varimax rotation and components extraction with Eigenvalues ≥1.0 yielded three principal components (PCs) that collectively accounted for the 72.43% variation in the soil properties (Table 5). PC1 contained four different soil characteris-

Table 4. Attributes of the semivariograms for each of the evaluated parameters

Attribute	Model	Transformation	Model r^2-value	Range	Nugget	Sill	Spatial dependence (%)	RSS
Ragweed coverage area (%)	E	Log	0.824	14,700	1.21	8.206	14.8	1.47
Number of plants per m^2	E	Log	0.865	13,500.0	0.86	6.033	14.3	0.995
$CaCO_3$	S	Log	0.651	19,500.0	0.286	0.918	31.2	0.086
Organic matter	E	Log	0.775	749,400.0	0.282	0.636	44.3	0.014
pH	S	None	0.870	21,500.0	0.090	0.311	28.9	0.004
Electrical conductivity	E	Log	0.581	3,600.0	0.029	0.241	12.0	0.003
Phosphorus	L-P	Log	0.211	194,597.5	0.528	0.528	100.0	0.167
Clay	L-P	None	0.002	187,239.1	159.1	159.1	100.0	2,088
Sand	L	None	0.451	511,000.0	198.0	659.9	30.0	67,054

E, exponent; L, linear; L-P, linear-pure nugget; RSS, residual sum of squares; S, spherical.

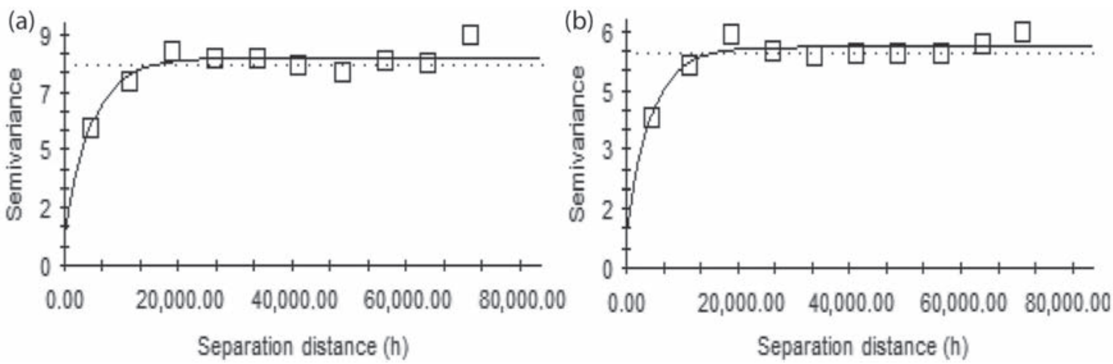

Fig. 5. Semivariogram models for the (a) coverage area (%) and (b) number of plants per m^2 of ragweed.

tics (EC, clay, sand and silt), with correlation coefficients of ≥0.50. PC2 contained three different soil properties (organic matter, clay and phosphorus). PC3 comprised two soil properties ($CaCO_3$ and pH). The correlation coefficients of these soil properties indicated that most of the soil properties significantly affected the first two PCs, accounting for 56.2% of the total variation. These factors were considered to probably affect the ragweed distribution in the surveyed region.

The extracted data from the first two components were used to create the scatter plot of the ragweed and non-ragweed sites in order to test the influence of the soil properties on ragweed distribution (Fig. 6). The scatter plot shows that the ragweed sites are distributed over almost the whole chart. Therefore, all the soil properties affected the ragweed distribution and no specific soil property was responsible for the prevalence of ragweed in the region.

Meteorological data and ragweed distribution

The PCA of the meteorological indicators yielded three PCs with Eigenvalues >1 that collectively accounted for 87.21% of the total variation (Table 6). PC1 comprised three meteorological indicators (rainfall, radiation and relative humidity), with correlation coefficients of ≥0.50. PC2 also comprised three meteorological indicators (total evapotranspiration, average temperature and altitude). PC3 comprised only sunshine hours. Most of the meteorological indicators significantly affected the first two PCs, with a total variation of 62.14%; therefore, these were considered to probably affect the ragweed distribution.

The scatter diagram of the first two components shows that the ragweed sites were distributed over almost the whole chart, as for the soil properties (Fig. 7). It is evident that there exists no relationship among the

Table 5. Principal component analysis results of the soil properties

Soil property	Principal component		
	1	2	3
$CaCO_3$ (%)	−0.089	−0.142	0.834
OM (%)	0.349	0.588	0.383
pH	0.279	−0.478	0.621
EC (mS cm^{-1})	0.576	0.465	0.124
Clay (%)	0.672	−0.623	−0.168
Sand (%)	−0.881	0.420	0.157
Silt (%)	0.751	0.166	−0.051
Phosphorus (p.p.m.)	0.403	0.774	−0.039
Eigenvalues	2.493	2.002	1.300
% variance	31.161	25.031	16.245
Cumulative explanation	31.161	56.192	72.436

EC, electrical conductivity; OM, organic matter.

Table 6. Principal component analysis results of the meteorological indicators

Meteorological indicator	Principal component		
	1	2	3
Total rainfall (mm)	0.630	0.400	0.461
Total evapotranspiration (mm)	0.609	0.658	0.148
Average temperature (°C)	−0.311	0.860	−0.299
Altitude (m)	−0.072	−0.700	0.629
Radiation (MJ m^{-2})	0.969	0.059	0.035
Sunshine hours	−0.406	0.517	0.663
Relative humidity (%)	0.877	−0.323	−0.220
Eigenvalues	2.334	2.017	1.797
% variance	33.338	28.811	25.672
Cumulative explanation	33.338	62.149	87.821

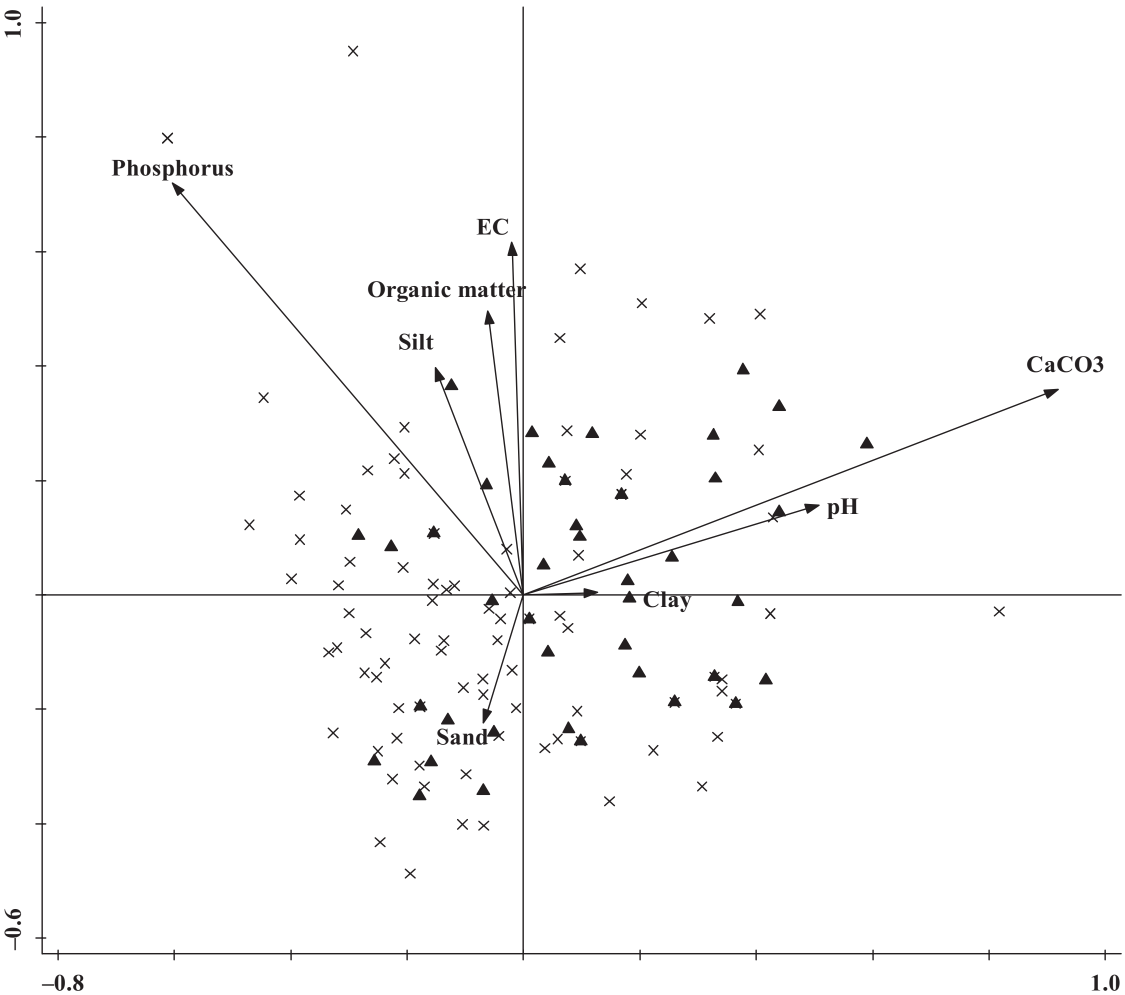

Fig. 6. Principal component analysis scatter diagram showing the distribution of the ragweed sites (▲) and the non-ragweed sites (×) with respect to the soil properties. EC, electrical conductivity.

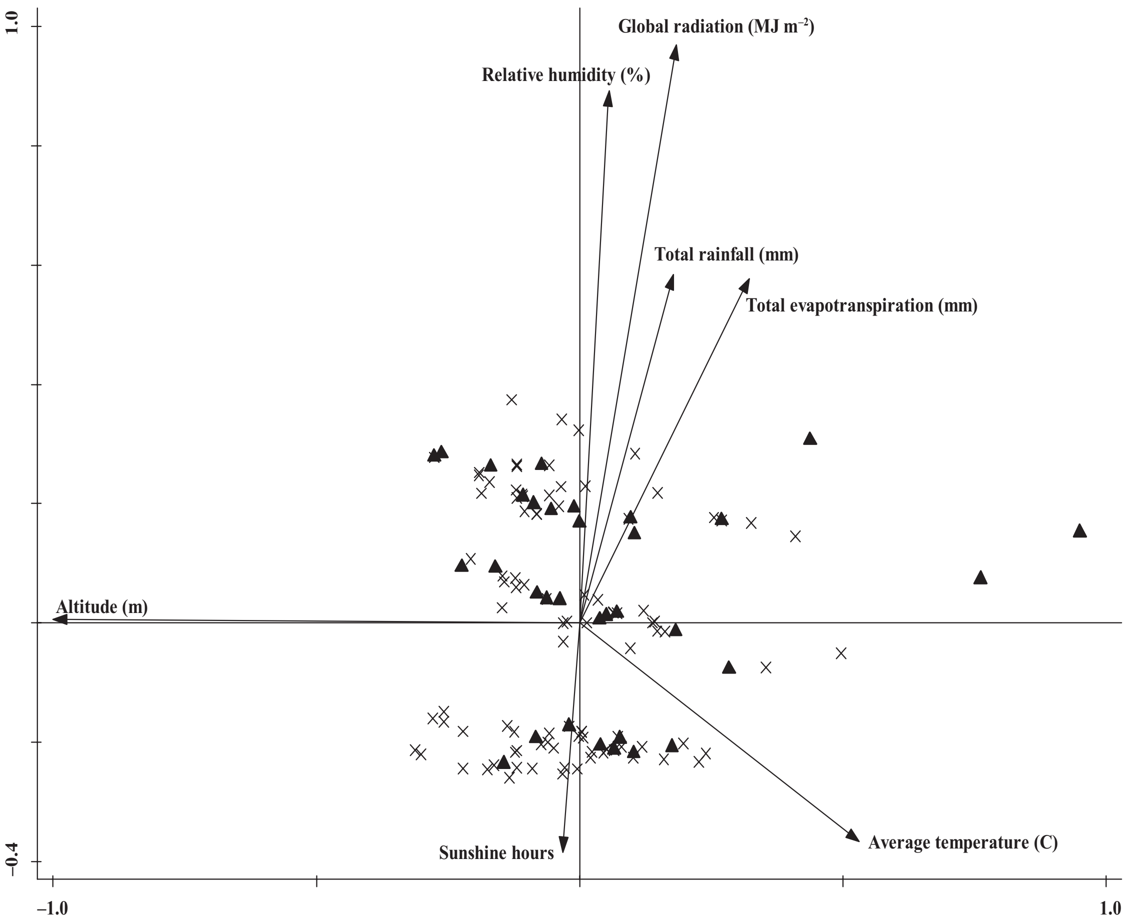

Fig. 7. Principal component analysis scatter diagram showing the distribution of the ragweed sites (▲) and the non-ragweed sites (×) with respect to the meteorological indicators.

meteorological indicators and the ragweed distribution in the surveyed region.

DISCUSSION

The survey results indicated that ragweed has already invaded a variety of habitats, particularly the sunflower-cultivated areas of the Thrace region. The high infestation rate suggests that ragweed is a potential threat for sunflower production in the future if effective management strategies are not chosen. Ragweed occurrence with similar densities in the sunflower fields of Hungary also has been reported (Pinke & Karacsony 2010; Pinke *et al.* 2011), where it has become a noxious weed in those areas. Both sunflower and ragweed belong to the same family and the absence of selective herbicides in sunflower further makes the situation ideal for ragweed spread and invasion (Bertrand & Maupas 1996). Although imidazolinone-tolerant sunflower hybrids are being cultivated and imazamox is used for weed control in the Thrace region (Pfenning *et al.* 2008; Fernández-Martínez *et al.* 2009), the high infestation rate of ragweed in sunflower raises a serious question: Has ragweed already become resistant to the herbicide in the Thrace region?

The presence of ragweed pollen in the Thrace region has been reported previously, but ragweed was not detected (Zemmer *et al.* 2012). This survey clarifies the presence of established local populations in the region that are contributing towards the pollen count. Besides, the extensive ragweed presence in the region suggests that the pollen that has been detected has more local sources than distant sources. Pollen studies in some cities of Thrace did not report the presence of ragweed pollen until 2011 (Bicakci 2006; Erkan *et al.* 2010, 2011). The possible argument as to why pollen was not detected in these studies is that the populations were not large enough to contribute to the pollen count in 2006.

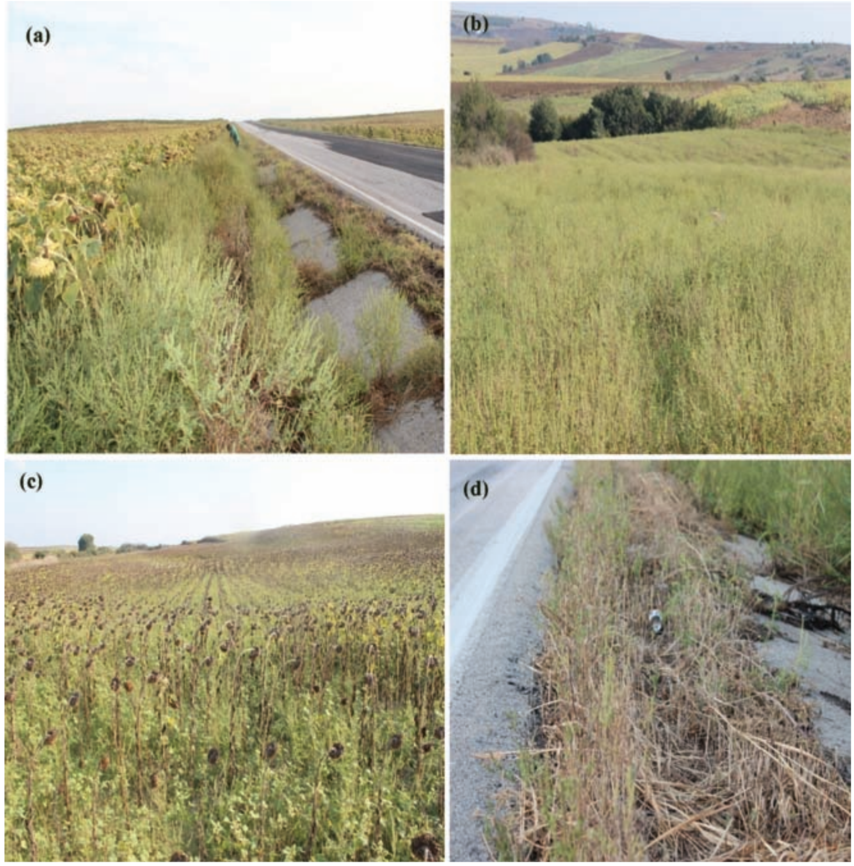

Fig. 8. Heavy infestation of ragweed in the: (a) roadsides, (b) pastures, (c) sunflower fields and (d) mown populations on the roadsides, which are a source of further spread.

Ragweed populations have become established with time and are producing enormous amounts of pollen. A possible reason for the non-detection of ragweed pollen in the other studies that were conducted after 2006 might be the unawareness and non-recognition of ragweed pollen (Bicakci 2006; Erkan *et al*. 2010, 2011).

After the first record of ragweed in 1998 in the Black Sea region (Byfield & Baytop 1998), within a period of 16 years, the distribution area of ragweed in Turkey has extended from the Georgian to the Greek/Bulgarian borders (survey observations). The rising infestations of ragweed probably will present severe challenges to human health and crop production in the near future, similar to other invaded countries (Makra *et al*. 2005; Peternel *et al*. 2005; Testi *et al*. 2009; Smith *et al*. 2013).

The ragweed-infested locations were closer to the main highways (Fig. 8a,b) and it could be considered that ragweed has been transported from Western neighboring countries. Korres *et al*. (2015) also have emphasized the role of roadsides in weed distribution. Moreover, due to the enormous amount of seed production of ragweed, the plant can spread from the roadsides to the agricultural fields with rainwater or the frequently occurring flash floods in the region (Unal *et al*. 2003). It also was observed that the ragweed populations containing ripened seeds along the roadsides were mown in the late ragweed season and were left there (Fig. 8d). These seeds are separated easily from the plants and could be transported over long distances by natural means or human activities (Vitalos & Karrer 2008). Established populations of ragweed that were ≤40 km away from infested highways were observed on the link roadsides. Furthermore, the environmental conditions (Unal *et al*. 2003) and continuous soil disturbance for crop production make the region ideal for further ragweed expansion (Fumanal *et al*. 2008). Some agricultural practices, such as tillage, also amend the distribution of weed communities within the field or its surroundings (Fig. 8a,b,c). Besides, farm machinery, such as seed drills, causes the dispersion of weed seeds for longer distances (Barroso *et al*. 2006).

Understanding the factors that drive the spatial distribution of ragweed is of fundamental importance because the plant potentially can cause severe crop yield losses in agro-ecosystems and health problems due to its aggressive nature and allergenic pollen, respectively. In order to limit the spread of ragweed in the region, a framework is needed to identify the major factors that are contributing to the spatial dispersal of ragweed and dispersal management strategies based on the identified major factors should be proposed. Andreasen *et al.* (1991) indicated that the occurrence of weed species is often correlated with the soil properties, information that could be used to improve the mapping of weed infestations (Heisel *et al.* 1999). In this study, the properties of the soils that were collected from the survey points were characterized in order to understand their effect on ragweed distribution (Table 4; Figs 3,4). However, the correlation analysis between the number of ragweed plants that were counted at each sampling point and the soil properties and the climatic indicators of the sampling locations did not show any relationship. The spatial distribution of weeds depends on seed dispersal mechanisms, as well as on the spatial variability of safe sites to stimulate germination and ensure growth to maturity (Zanin *et al.* 1998). Information on the possible relationship between weed populations and soil properties (safe sites), which is closely related to heterogeneity in the soils' chemical and physical properties, is limited in general (Gaston *et al.* 2001). Soil salinity is considered as an important abiotic stress that can negatively affect important physiological processes of plants (Lambers *et al.* 1998). However, the successful establishment of ragweed in highly saline areas also has been documented (DiTommaso 2004). Several researchers have reported that ragweed thrives best in a wide range of environmental and soil conditions, including roadsides, waterways, railway tracks, urban and waste lands, as well as in cultivated fields, including maize, soybean and sunflower (DiTommaso 2004; Lavoie *et al.* 2007; Fumanal *et al.* 2008; Simard & Benoit 2010; Ngom & Gosselin 2014). The non-selective ecological nature and adaptability to varying soil conditions and micro-environments of ragweed might be responsible for the cosmopolite and regional distribution of ragweed.

CONCLUSIONS

This survey presents the first record of ragweed in the Thrace region of Turkey and suggests that the ragweed pollen that has been detected earlier has a local source of origin, rather than multiple sources, as argued previously (Zemmer *et al.* 2012). The high infestation level of ragweed in the region will contribute to the pollen count in the most crowded city (Istanbul) of Turkey. The climate of the region, which is perfectly suited for ragweed invasion, indicates that there are many vacant niches in the region for further expansion and invasion. Therefore, ragweed is suspected as a potential threat for sunflower production in the Thrace region. Ragweed seeds can be distributed easily to the other parts of the country with contaminated sunflower seeds. The main highways also could provide dispersal corridors for invading populations to the other parts of the country.

In conclusion, a rapid response and concrete efforts are needed to stop further invasion and the range expansion of ragweed. This survey has resulted in some important questions that need to be answered in a very short period of time: What is the status of ragweed in the whole of Turkey? What are the possible expansion areas and effects of the weed in Turkey? Will sunflower production be severely affected by ragweed? What are the current pollen densities in different regions and what are their possible impacts on human health?

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