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ARAŞTIRMA MAKALESİ RESEARCH ARTICLE

Changes in the weed flora of cotton fields in the Eastern Mediterranean region of Turkiye

Türkiye'nin Doğu Akdeniz bölgesinde yer alan pamuk tarlalarında yabancı ot florasındaki değişimler

Ahmet Tansel SERIM[1], Mine OZKIL[2], Ilhan UREMIS[3], Ahmet ULUDAG[4]

[1]*Bilecik Seyh Edebali University, Faculty of Agriculture and Natural Sciences, Department of Plant Protection, Bilecik, Turkiye.*
[2]*Biological Control Research Institute, Adana, Turkiye.*
[3]*Hatay Mustafa Kemal University, Faculty of Agriculture, Department of Plant Protection, Hatay, Turkiye.*
[4]*Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Plant Protection, Çanakkale, Turkiye.*

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Corresponding author/Sorumlu yazar:
Mine OZKIL
mineozkil@hotmail.com

ABSTRACT

Cotton is the most dominant field crop, especially in higher soil saline parts of the Eastern Mediterranean region of Türkiye. This study aims to determine the current statues of weed flora of cotton fields in the East Mediterranean region, to compare it with weed flora in 1991-1992 and to understand whether a weed flora shift has occurred in these fields. Eighty-two cotton fields were surveyed during the growing season (July and August) in 2018, and thirty-seven weed species distributed in 17 families were found in the survey fields, where 18, 23, 17, and 33 of them were recorded in the Kahramanmaraş, Hatay, Mersin, and Adana provinces, respectively. Canonical correspondence analysis revealed that the phytosociological composition of the cotton fields was significantly related to the P content of the soil, average temperature, and cumulative rainfall. The current weed survey also indicated that these fields were under the threat of some invasive alien plant species that had not been found in previous surveys, such as *Ipomoea triloba* L., *Amaranthus palmeri* L., and *Cucumis melo* var. *agrestis* Naudin. Although cotton fields in the region were reduced by two-thirds in 2018 compared to 1991-1992, weed richness increased. Weed flora shifts were influenced by crop, crop rotation, herbicide use, irrigation, and landscape factors of cotton fields in the East Mediterranean Region of Türkiye.

ÖZET

Pamuk, özellikle Türkiye'nin Doğu Akdeniz Bölgesi'nin yüksek tuzlu topraklarının bulunduğu alanların en yaygın tarla bitkisidir. Bu çalışmanın amacı, Doğu Akdeniz bölgesindeki pamuk tarlalarının mevcut yabancı ot florasını belirlemek, 1991-1992 yılları arasındaki yabancı ot florası ile karşılaştırmak ve bu tarlalarda yabancı ot florası bir değişiklik olup olmadığını anlamaktır. 2018 yılı yetiştirme sezonunda (Temmuz ve Ağustos), Kahramanmaraş, Hatay, Mersin ve Adana illerinde, sırasıyla 18, 23, 17 ve 33 olmak üzere 82 pamuk tarlasında sürvey yapılmış olup burada 17 familyaya dağılmış 37 yabancı ot türü tespit edilmiştir. Kanonik uygunluk analizi, pamuk tarlalarının fitososyolojik bileşiminin, toprağın P içeriği, ortalama sıcaklık ve kümülatif yağışla önemli ölçüde ilişkili olduğunu ortaya koymuştur. Mevcut araştırmada, bu alanlarda önceki çalışmalarda rastlanmayan *Ipomoea triloba* L., *Amaranthus palmeri* L. ve *Cucumis melo* var. *agrestis* Naudin'e rastlanılmıştır. Bölgedeki pamuk tarlaları 2018'de 1991-1992'ye göre üçte iki oranında azalmasına rağmen yabancı ot zenginliği artmıştır. Yabancı ot florası değişimleri, Türkiye'nin Doğu Akdeniz Bölgesi'ndeki pamuk tarlalarının ürün, ürün rotasyonu, herbisit kullanımı, sulama ve peyzaj faktörlerinden etkilenmiştir.

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INTRODUCTION

There are only a few crops that are used as raw materials, such as fiber, lint and seed, in many industrial branches, including fabric, oil, towel, medicine, furnishing and animal feed, and cotton is one of them. Although the balance between the production and consumption of cotton was broken in favour of production because of the COVID-19 pandemic, the annual demand of the world for cotton is nearly 25 mt, and it is expected that this demand will gradually increase until 2030 (OECD FAO, 2021). Turkey is one of the major world cotton producers, with 631.000 t in 2021; however, this production amount has supplied two-thirds of domestic consumption (CWMT, 2022; TUIK, 2022). Cotton production in Turkey remained at the same level during the time period because of the use of new cotton varieties with greater yield potential and intensive use of inputs such as agricultural chemicals, although cotton acreage has steadily declined in recent decades in Türkiye. Adana, located in the Çukurova region, was the province where cotton cultivation in the Mediterranean region of Turkey was launched and then spread to other provinces, especially along the Mediterranean coasts (Yaktı, 2013).

The Mediterranean region is covered by the most fertile soils of Turkey, and with adequate precipitation, a quarter of the region is allocated to crop cultivation (TADPORTAL, 2022; TUIK, 2022). The region is located in the southern part of Turkey and has many agricultural basins that may cultivate a variety of crops and orchards. Therefore, it has special importance in terms of providing the domestic demand of the country and bringing in currency via exportation (Durmuş & Yiğit, 2014). Although the region has only 7.2% of the arable fields of the country, the yield harvested from it reached half of the domestic production for oilseed crops and some fruits and vegetables, including tomato, citrus, cucumber, and strawberry (TUIK, 2022). In recent studies conducted in the different province located in the region, it has been reported that agricultural crops were severely affected by weeds and parasitic plants belonging to different species (Soylu et al., 2017; Üremiş et al., 2020; Üremiş et al., 2022). Cotton production has been compromised by many abiotic and biotic factors, including weeds (Shahrajabian, 2020).

Conventional cotton production has presented an opportunity to increase cotton yield with the use of irrigation and herbicides and fertilizers. Indeed, it is not a surprising result when the impacts of a new herbicide are considered as they may destroy some of the weeds while others stand and spread in the agricultural fields (Andreasen et al., 1996). Following a selective herbicide treatment, controlled weeds may result in the occurrence of some ecological niches in the field, and these niches are rapidly filled with the stands (Andreasen & Streibig, 2011). Fertilizers also have the potential to shape weed flora or weed shifts, especially N, P, and K (Andreasen & Skovgaard, 2009; Erviö et al., 1994), but their impact might be less significant compared to the site, crop species, herbicide, and irrigation, following Andersson & Milberg (1998) and Swanton et al. (1999). Moreover, irrigation has a crucial impact on arable weeds when growers intend to repeat the same crop. Bükün (2005) found that irrigation reshaped the weed flora of cotton fields in the Harran Plain in Turkey and that the frequency of some species changed, whereas new species joined irrigated cotton fields, such as *Physalis* species. Similar results have been shared by Arslan (2018) in Turkey and Ramôa et al. (2017) in Portugal. However, the growers are intended to regrow the same crop again and again using irrigation facilities. Hence, the behaviour of farmers results in the salinity of soil or a reduction in biodiversity (Sans et al., 2011; Storkey & Westbury, 2007).

However, more factors might affect weed composition, such as tillage, crop species, crop rotation, temperature, site, and edaphic conditions, and herbicide-resistant biotypes have directly influenced this composition (Bükün, 2005; Andreasen & Streibig, 2011). Moreover, the combination of the aforementioned factors may increase weed diversity in arable fields (Fried et al., 2019). Although there is not a consensus about the impact of tillage on weed density (Swanton et al., 1999), the biodiversity parameters, including weed abundance, evenness, and density, were generally higher in the area where no-tillage systems were performed than in the fields that were applied in tillage systems or conventional systems (Mulugeta et al., 2001). These practices may also trigger a weed shift between annual weeds and perennial weeds (Pollard et al., 1982) or wind-dispersed species (Pardo et al., 2019).

Furthermore, the effects of site and crop species on the weed flora were higher than those of nitrogen application and crop rotation (Andersson & Milberg, 1998).

Sustainability of the cotton production in the East Mediterranean depends on the factors that were affected by abiotic stressors and abiotic agents including plant diseases, pests, and weeds. Weed flora of the cotton fields of the East Mediterranean has been under suppression of intensive agricultural production systems depending on high input use for 25 years; therefore, the switch from vegetables to field crops or vice versa has been experienced each year. This study aims to determine the current weed flora of cotton fields in the East Mediterranean region, to compare it with weed flora in 1991-1992 and to understand whether a weed flora shift has occurred in these fields for 25 years.

MATERIALS and METHODS

Study area

A weed survey was carried out to determine the weed flora of cotton fields of the Adana, Hatay, Kahramanmaraş, and Mersin provinces in the eastern Mediterranean region of Turkey (Figure 1). The region has a typical Mediterranean climate with Csa based on Köppen's climate classification (MGM, 2022). The annual total rainfall in the region varies between 615.5 (Mersin Province) and 1163.5 (Hatay province) mm, and the mean temperatures are 16.7 °C (Kahramanmaraş province) and 19.2 °C (Adana and Mersin provinces), respectively (MGM, 2022). Terra Rossa soil is the most common soil type of the region and may be derived from marl and conglomerate parent materials.

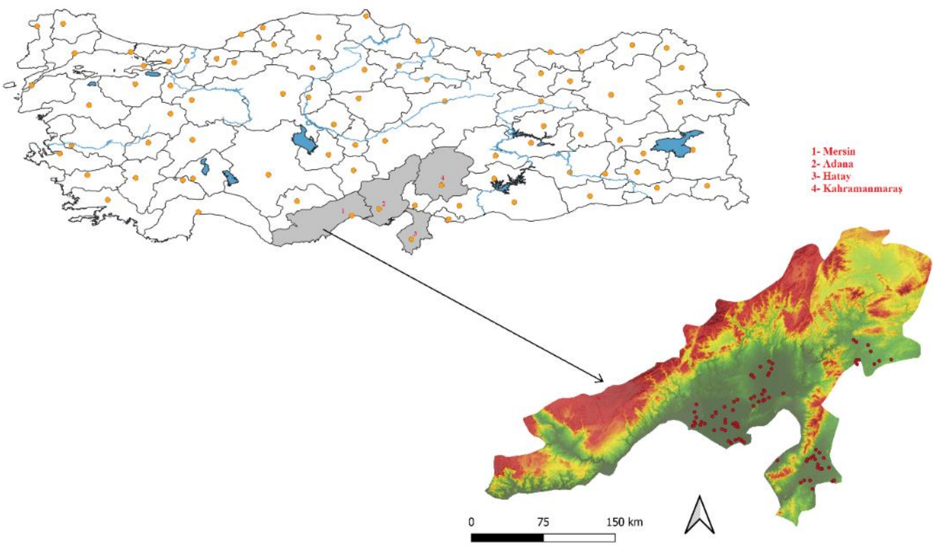

Figure 1. Cotton survey fields of the Mediterranean region of Turkey. Red dots indicate the cotton fields visited during the surveys

Şekil 1. Türkiye'nin Akdeniz bölgesindeki pamuk survey alanları. Kırmızı noktalar, survey yapılan pamuk tarlalarını göstermektedir

Data collection

The survey in cotton fields was carried out along roadsides with a stop in every 10 km. A total of 82 cotton fields, 8 in Kahramanmaras, 20 in Hatay, 7 in Mersin, and 47 in Adana, were visited during the cotton growing season in 2018.Weed surveys were carried out in zigzag patterns to determine weed species, density, and coverage area of the fields. The survey plots were placed in cotton fields at least 10 m from the boundary to avoid edge effects. A wooden frame quadrat which was 1 m x 1 m in size was used five times to count the weeds in each cotton field. The weed specimens in quadrats were botanically identified and counted in the field. The specimens, which could not be identified in the field, were collected and transferred to the laboratory for identification using diagnostic keys (Davis, 1965-1985; Davis et al., 1988). Soil data of the cotton fields were obtained from the soil databank of the Turkish Ministry of Agriculture and Forestry (TADPORTAL, 2022). The status of the weed species was also presented in the tables, as “old” is a species already found in 1991-1992 and as “new” is a species not found in 1991-1992 but found in 2018.

The phytosociological parameters used to identify the cotton fields in each province were frequency (F, %), density (D, plant m-2), abundance (A), relative frequency (RF, %), relative density (RD, %), relative abundance (RA, %), and importance value index (IVI), formulas 1-7.

F=(Number of frames containing the species)/(Total number of frames surveyed) (1)
D=(Total number of individuals in the frames per species)/(Total weed surveyed area) (2)
A=(Total number of individuals in the frames per species)/(Total number of the frames containing the species) (3)
RF=(Frequency of per species)/(Total frequency of per species) (4)
RD=(Density of species)/(Total density of species) (5)
RA=(Abundance of species)/(Total abundance of species) (6)
IVI=RD+RF+RA (7)

The floristic composition of the cotton fields was compared within the province and the time using the Sørensen coefficient index (similarity index: SI), Shannon-Weiner diversity index (H’), and Simpson dominance index (D) described by Nkoa et al. (2015), formulas 8-10.

$$\mathbf{SI} = \frac{2J}{a+b} \times 100 \quad (8)$$
$$\mathbf{H'} = -\sum_{j=1}^{n}(pi \times \ln(pi)) \quad (9)$$
$$\mathbf{D} = \frac{\sum n(n-1)}{N(N-1)} \quad (10)$$

where J is the number of species common to all sites; a is the species number of species site a; b is the species number of species site b; N is the number of all specimens of all species; pi is the relative abundance of the i-th species in the community; and n is the number of species of a given species.

Survey study in 1991-1992 and 2018

Eighty-four cotton fields, eight in Kahramanmaraş, twenty-four in Hatay, ten in Mersin, and forty-two in Adana, were surveyed twice during the growing season (June, July, and August) in 1991-1992 (Kadıoğlu et al., 1993). The first survey was conducted before the first hand-hoeing, whereas the latter was carried out after the first irrigation. These surveys in cotton fields were carried out along roadsides with a stop every 3 km, and the plots were placed at least 15 m from the nearest boundary to avoid the edge effect. A classification scale was used to determine weed density in the fields ranging from A to E; these classes represented >10 plant/m2, 1-10 plant m-2, 0.1-1 plant m-2, 0.01-0.1 plant m-2, and <0.01 plant m-2, respectively. The results of the second survey were used to compare the results of the 2018 survey because the survey times overlapped.

Statistical analysis

Canonical correspondence analysis (CCA) was separately performed to understand the relation between the weed flora and the variables related to the soil, geographic, and meteorological variables obtained in 2018. To investigate the variance, the vegan package (Oksanen et al., 2013) was used in the R statistical software program (R Core Team 2022). The significance of CCA constraints was tested with the analysis of the variance using a CCA permutation test function (n=999) in the Vegan package. A total of 23 weed species whose frequencies were less than 5% were considered rare species and were removed from the original data (Fanfarillo et al., 2020) because these species have had low inputs and low productivity in arable species (Solé-Senan et al., 2014). Prior to the analysis, the data were normalized by log transformation, y=log(x+1). A variance inflation factor (VIF) was detected to measure the degree of multicollinearity in the regression analysis for cumulative rainfall, average temperature, and P content (Soil) because other variables were not significant.

RESULTS and DISCUSSIONS

Weed flora in 2018

A total of 37 weed species were identified in the survey fields, 18, 23, 17, and 33 of which were recorded in the Kahramanmaraş, Hatay, Mersin, and Adana provinces, respectively. Most of these weeds were dicotyledonous weeds belonging to 17 families, including Brassicaceae, Ranunculaceae, and Amaranthaceae. Monocotyledonous weeds were from the Poaceae and Cyperaceae families. There were 29 annual species and 8 perennial species (Table 1 to 4). Previous research indicated that Mediterranean basins became foregrounding in terms of weed richness compared to other basins to provide suitable growth conditions for the weeds because of climatic conditions and geological factors (Ramôa et al., 2017; Glemnitz et al., 2006). This richness was more apparent in the survey fields when the number of rare or less frequent species were considered. The weeds were only being in Kahramanmaraş cotton fields in 1991-1992: *Chenopodium album, Phragmites australis, Alhagi pseudalhagi, Paspalum paspalodes.* In Hatay cotton fields, the weeds were only found in 1991-1992: *Corchorus olitorius, Glycyrrhiza glabra, Heliotropium europaeum, Hypericum perforatum, Phragmites australis, Setaria verticillata, Amaranthus viridis, Digitaria sanguinalis* and *Physalis lanceifolia*. Some weeds were only observed in Mersin cotton fields in 1991-1992 such as *Abutilon theophrasti, Heliotropium europaeum, Hypericum perforatum, Paspalum paspalodes, Solanum nigrum,* and *Physalis lanceifolia*. *Corchorus olitorius, Euphorbia macroclada, Hypericum perforatum, Paspalum paspalodes, Amaranthus viridis,* and *Physalis lanceifolia* were only found in Adana cotton fields in 1991-1992.

Table 1. Phytosociological parameters of the weed species in cotton fields of Kahramanmaraş in 2018 and comparing with the previous survey the previous survey in 1991-1992

Çizelge 1. Kahramanmaraş pamuk tarlalarında 2018 yılı yabancı ot türlerinin fitososyolojik parametreleri ve 1991-1992 yılındaki çalışma ile karşılaştırılması

Species	IVI	D	F	A	RD	RF	RA	Status
Cyperus rotundus L.	77.7	2.325	45.0	5.2	37.2	20.5	20.0	O
Echinochloa colonum (L.) Link.	37.7	1.175	20.0	5.9	18.8	9.1	9.8	O
Convolvulus arvensis L.	31.2	0.425	25.0	1.7	6.8	11.4	13.0	O
Solanum nigrum L.	24.4	0.2	20.0	1.0	3.2	9.1	12.1	O
Physalis angulata L.	24.4	0.2	20.0	1.0	3.2	9.1	12.1	N
Cynodon dactylon (L.) Pers.	21.5	0.8	10.0	8.0	12.8	4.5	4.2	N
Portulaca oleracea L.	20.0	0.25	25.0	1.0	4.0	11.4	4.7	O
Xanthium strumarium L.	15.4	0.275	15.0	1.8	4.4	6.8	4.2	O
Amaranthus retroflexus L.	9.3	0.075	7.5	1.0	1.2	3.4	4.7	O
Sinapis arvensis L.	8.3	0.075	7.5	1.0	1.2	3.4	3.7	N

Table 1 (continued). Phytosociological parameters of the weed species in cotton fields of Kahramanmaraş in 2018 and comparing with the previous survey the previous survey in 1991-1992

Çizelge 1 (devamı). Kahramanmaraş pamuk tarlalarında 2018 yılı yabancı ot türlerinin fitososyolojik parametreleri ve 1991-1992 yılındaki çalışma ile karşılaştırılması

Species	IVI	D	F	A	RD	RF	RA	Status
Echinochloa crus-galli (L.) P. Beauv.	6.4	0.2	5.0	4.0	3.2	2.3	0.9	N
Chrozophora tinctoria (L.) Rafin.	5.4	0.05	5.0	1.0	0.8	2.3	2.3	N
Sorghum halepense (L.) Pers.	4.7	0.075	2.5	3.0	1.2	1.1	2.3	O
Amaranthus albus L.	3.9	0.025	2.5	1.0	0.4	1.1	2.3	N
Sonchus oleraceus L.	2.9	0.025	2.5	1.0	0.4	1.1	1.4	N
Euphorbia nutans Lag.	2.9	0.025	2.5	1.0	0.4	1.1	1.4	N
Hibiscus trionum L.	2.0	0.025	2.5	1.0	0.4	1.1	0.5	O
Euphorbia prostrata Aiton	2.0	0.025	2.5	1.0	0.4	1.1	0.5	N

O: Old; N: New; IVI: Importance Volume Index; D: Density (plant m-2); F: Frequency (%), A: Abundance; RD: Relative Density (%); RF: Relative Frequency (%); RA: Relative Abundancy (%)

Table 2. Phytosociological parameters of the weed species in cotton fields of Hatay in 2018 and comparing with the previous survey the previous survey in 1991-1992

Çizelge 2. Hatay pamuk tarlalarında 2018 yılı yabancı ot türlerinin fitososyolojik parametreleri ve 1991-1992 yılındaki çalışma ile karşılaştırılması

Species	IVI	D	F	A	RD	RF	RA	Status
Cyperus rotundus L.	86.7	1.720	38.0	4.5	42.9	22.6	21.2	O
Convolvulus arvensis L.	58.8	0.550	36.0	1.5	13.7	21.4	23.6	O
Sorghum halepense (L.) Pers.	24.4	0.470	8.0	5.9	11.7	4.8	8.0	O
Alhagi pseudalhagi (Bieb) Desv.	17.0	0.160	13.0	1.2	4.0	7.7	5.3	O
Chrozophora tinctoria (L.) Rafin	15.8	0.150	10.0	1.5	3.7	6.0	6.1	O
Prosopis farcta (Banks and Sol.) Macbrid	15.3	0.110	10.0	1.1	2.7	6.0	6.6	O
Hibiscus trionum L.	11.5	0.080	8.0	1.0	2.0	4.8	4.8	O
Portulaca oleracea L.	9.9	0.110	8.0	1.4	2.7	4.8	2.4	O
Ipomoea triloba L.	9.0	0.080	6.0	1.3	2.0	3.6	3.4	N
Cynodon dactylon (L.) Pers.	8.1	0.180	3.0	6.0	4.5	1.8	1.9	O
Xanthium strumarium L.	7.7	0.070	6.0	1.2	1.7	3.6	2.4	O
Physalis angulata L.	5.8	0.050	4.0	1.3	1.2	2.4	2.1	N
Amaranthus retroflexus L.	4.9	0.040	3.0	1.3	1.0	1.8	2.1	O
Solanum nigrum L.	4.4	0.030	3.0	1.0	0.7	1.8	1.9	O
Echinochloa crus-galli (L.) P. Beauv.	3.7	0.080	2.0	4.0	2.0	1.2	0.5	N
Amaranthus albus L.	3.2	0.020	1.0	2.0	0.5	0.6	2.1	O
Tribulus terrestris L.	3.1	0.030	3.0	1.0	0.7	1.8	0.5	N
Malva spp.	2.2	0.010	1.0	1.0	0.2	0.6	1.3	N
Chenopodium album L.	2.2	0.010	1.0	1.0	0.2	0.6	1.3	O
Xanthium spinosum L.	1.6	0.010	1.0	1.0	0.2	0.6	0.8	N
Sonchus oleraceus L.	1.6	0.010	1.0	1.0	0.2	0.6	0.8	N
Echinochloa colonum (L.) Link.	1.6	0.030	1.0	3.0	0.7	0.6	0.3	O
Cynanchum acutum L.	1.4	0.010	1.0	1.0	0.2	0.6	0.5	O

O: Old; N: New; IVI: Importance Volume Index; D: Density (plant m-2); F: Frequency (%), A: Abundance; RD: Relative Density (%); RF: Relative Frequency (%); RA: Relative Abundancy (%)

Table 3. Phytosociological parameters of the weed species in cotton fields of Mersin in 2018 and comparing with the previous survey the previous survey in 1991-1992

Çizelge 3. Mersin pamuk tarlalarında 2018 yılı yabancı ot türlerinin fitososyolojik parametreleri ve 1991-1992 yılındaki çalışma ile karşılaştırılması

Species	IVI	D	F	A	RD	RF	RA	Status
Cyperus rotundus L.	65.6	2.143	40.0	4.7	32.8	17.0	15.9	O
Cucumis melo var. *agrestis*	34.6	0.371	32.5	1.0	5.7	13.8	15.1	N
Echinochloa crus-galli (L.) P. Beauv.	27.2	0.857	20.0	3.8	13.1	8.5	5.6	N
Portulaca oleracea L.	25.7	0.429	30.0	1.3	6.6	12.8	6.3	O
Echinochloa colonum (L.) Link.	25.3	0.857	10.0	7.5	13.1	4.3	7.9	O
Chenopodium album	23.8	0.257	22.5	1.0	3.9	9.6	10.3	N
Convolvulus arvensis L.	19.8	0.2	15.0	1.2	3.1	6.4	10.3	O
Cynodon dactylon (L.) Pers.	15.7	0.457	7.5	5.3	7.0	3.2	5.6	N
Setaria verticillata (L.) P. Beauv.	14.8	0.429	10.0	3.8	6.6	4.3	4.0	N
Amaranthus viridis L.	12.3	0.143	12.5	1.0	2.2	5.3	4.8	N
Physalis angulata L.	10.8	0.114	10.0	1.0	1.7	4.3	4.8	O
Prosopis farcta (Banks and Sol.) Macbride	5.4	0.057	5.0	1.0	0.9	2.1	2.4	O
Xanthium strumarium L.	4.6	0.057	5.0	1.0	0.9	2.1	1.6	O
Hibiscus trionum L.	4.6	0.057	5.0	1.0	0.9	2.1	1.6	N
Euphorbia prostrata Aiton	3.9	0.029	2.5	1.0	0.4	1.1	2.4	N
Amaranthus retroflexus L.	3.8	0.057	5.0	1.0	0.9	2.1	0.8	O
Euphorbia nutans Lag.	2.3	0.029	2.5	1.0	0.4	1.1	0.8	N

O: Old; N: New; IVI: Importance Volume Index; D: Density (plant m-2); F: Frequency (%), A: Abundance; RD: Relative Density (%); RF: Relative Frequency (%); RA: Relative Abundancy (%)

Table 4. Phytosociological parameters of the weed species in cotton fields of Adana in 2018 and comparing with the previous survey the previous survey in 1991-1992

Çizelge 4. Adana pamuk tarlalarında 2018 yılı yabancı ot türlerinin fitososyolojik parametreleri ve 1991-1992 yılındaki çalışma ile karşılaştırılması

Species	IVI	D	F	A	RD	RF	RA	Status
Cyperus rotundus L.	63.6	1.523	32.3	4.7	31.1	15.1	17.3	O
Convolvulus arvensis L.	34.9	0.430	29.4	1.5	8.8	13.7	12.4	O
Cucumis melo var. *agrestis* Naudin	24.0	0.204	18.7	1.1	4.2	8.7	11.1	N
Ipomoea triloba L.	19.4	0.285	11.5	2.5	5.8	5.4	8.2	N
Portulaca oleracea L.	19.4	0.268	17.0	1.6	5.5	8.0	5.9	O
Echinochloa crus-galli (L.) P. Beauv.	18.6	0.451	11.1	4.1	9.2	5.2	4.3	O
Echinochloa colonum (L.) Link.	16.0	0.391	8.1	4.8	8.0	3.8	4.3	O
Xanthium strumarium L.	15.2	0.170	11.9	1.4	3.5	5.6	6.1	O
Physalis angulata L.	13.0	0.123	10.6	1.2	2.5	5.0	5.6	N
Sorghum halepense (L.) Pers.	7.3	0.170	3.8	4.4	3.5	1.8	2.1	O

Table 4 (continued). Phytosociological parameters of the weed species in cotton fields of Adana in 2018 and comparing with the previous survey the previous survey in 1991-1992

Çizelge 4 (devamı). Adana pamuk tarlalarında 2018 yılı yabancı ot türlerinin fitososyolojik parametreleri ve 1991-1992 yılındaki çalışma ile karşılaştırılması

Amaranthus retroflexus L.	6.9	0.072	6.0	1.2	1.5	2.8	2.7	O
Prosopis farcta (Banks and Sol.) Macbride	6.5	0.068	6.0	1.1	1.4	2.8	2.3	O
Chenopodium album L.	6.4	0.077	6.4	1.2	1.6	3.0	1.9	N
Setaria verticillata (L.) P. Beauv.	4.8	0.128	2.6	5.0	2.6	1.2	1.0	O
Euphorbia prostrata Aiton	4.2	0.072	4.3	1.7	1.5	2.0	0.7	O
Euphorbia nutans Lag.	4.1	0.030	3.0	1.0	0.6	1.4	2.1	N
Heliotropium europaeum L.	3.9	0.047	3.8	1.2	1.0	1.8	1.2	O
Amaranthus albus L.	3.8	0.030	3.0	1.0	0.6	1.4	1.8	N
Solanum nigrum L.	3.6	0.034	3.4	1.0	0.7	1.6	1.3	O
Hibiscus trionum L.	3.3	0.034	3.4	1.0	0.7	1.6	1.0	O
Chrozophora tinctoria (L.) Rafin	3.3	0.038	3.4	1.1	0.8	1.6	0.9	O
Amaranthus spinosus L.	3.1	0.030	2.6	1.2	0.6	1.2	1.3	N
Sonchus oleraceus L.	2.0	0.017	1.7	1.0	0.3	0.8	0.9	N
Malva spp.	1.8	0.034	1.7	2.0	0.7	0.8	0.3	N
Setaria viridis (L.) P. Beauv.	1.6	0.034	1.3	2.7	0.7	0.6	0.3	N
Cynodon dactylon (L.) Pers.	1.6	0.038	0.9	4.5	0.8	0.4	0.4	O
Ipomoea hederacea (Linn) Jacq.	1.5	0.013	1.3	1.0	0.3	0.6	0.6	N
Digitaria sanguinalis (L.) Scop.	1.4	0.034	0.9	4.0	0.7	0.4	0.3	O
Convolvulus betonicifolia Mill.	1.3	0.013	0.9	1.5	0.3	0.4	0.6	N
Ipomoea purpurea (L.) Roth.	1.1	0.009	0.9	1.0	0.2	0.4	0.5	N
Cynanchum acutum L.	0.9	0.009	0.9	1.0	0.2	0.4	0.3	N
Amaranthus palmeri L.	0.9	0.009	0.9	1.0	0.2	0.4	0.3	N
Tribulus terrestris L.	0.8	0.009	0.9	1.0	0.2	0.4	0.2	N

O: Old; N: New; IVI: Importance Volume Index; D: Density (plant m-2); F: Frequency (%), A: Abundance; RD: Relative Density (%); RF: Relative Frequency (%); RA: Relative Abundancy (%)

Importance Value Index (IVI) values were used mainly in the discussions because the value represented all distribution parameters, including the relative frequency, the relative abundance, and the relative density, although all indicators related to the population are presented in Tables 1 to 4. *C. rotundus* had the highest IVI values in all the cotton fields, followed by the other species. In Hatay, the five weeds had the highest IVI in the 2018 survey, *Cyperus* sp., *C. arvensis, S. halepense, A. pseudalhagi*, and *C. tinctoria* (Table 2), while four of the first five weeds were the same in Kahramanmaraş (Table 1). In Adana and Mersin, only three of the first five weeds were the same (Table 4). The new weeds with high IVI values were E. crus-galli and C. melo subsp. agrestis in Mersin, I. triloba in Hatay, *C. melo* subsp. *agrestis* and *I. triloba* in Adana, and *P. angulata* in Kahramanmaraş. Some other weeds that had moderate-high IVI values in the survey fields were *A. retroflexus, E. crus-galli, P. angulata, S. halepense, S. nigrum*, and *X. strumarium*. Species richness in the surveyed provinces was closely related to the total cotton fields of each province. Weed species richness was highest in Adana, where most fields were surveyed with 33 species, whereas it was the lowest in Mersin with 17 (Tables 1 to 4). A study conducted by Andersson & Milberg (1998) indicated that the site where crops were grown was the most significant factor in weed flora, whereas crop species were the second most significant factor. The researchers' results may provide insight into why the weed floras of Kahramanmaraş, Adana, Hatay, and Mersin provinces differed, especially for the weed species with low IVI values. CCA was used to understand the reasons for weed diversity in the cotton fields and its relationship to the variables. The variance inflation factors, a measure of collinearity between the aforementioned variables in the CCA, were near 1, indicating that all these variables were independent (Table 5). CCA showed that there was a significant phytosociological difference between the weed species depending on the soil phosphorus content, cumulative rainfall, and average temperature (Table 6 and Fig 2). The total inertia was 2.479, and the constrained soil variables covered only 5.87% of the total inertia, in agreement with the values from earlier studies (Fanfarillo et al., 2020; Nowak et al.,2015). The three CCA axes explained 3.01, 1.97, and 0.89% of the variations, and they were highly correlated with the soil phosphorus content, the cumulative rainfall, and the high average temperature (Table 6 and Figure 2).

Table 5. Values of the variance inflation factor (VIF) in 2018

Çizelge 5. 2018 yılı varyans inflasyon faktörü (VIF) değerleri

Cumulative rain	Average temperature	Phosphorus
1.02	1.032	1.016

Table 6. The contribution of the soil features to the variation in the three axes

Çizelge 6. Toprak özelliklerinin üç eksendeki değişime katkısı

Parameter	CCA1	CCA2	CCA3
Phosphorus	0.6971	0.6440	-0.3153
Average temperature	-0.7898	0.5849	-0.1844
Cumulative rain	0.1372	0.2638	0.9548

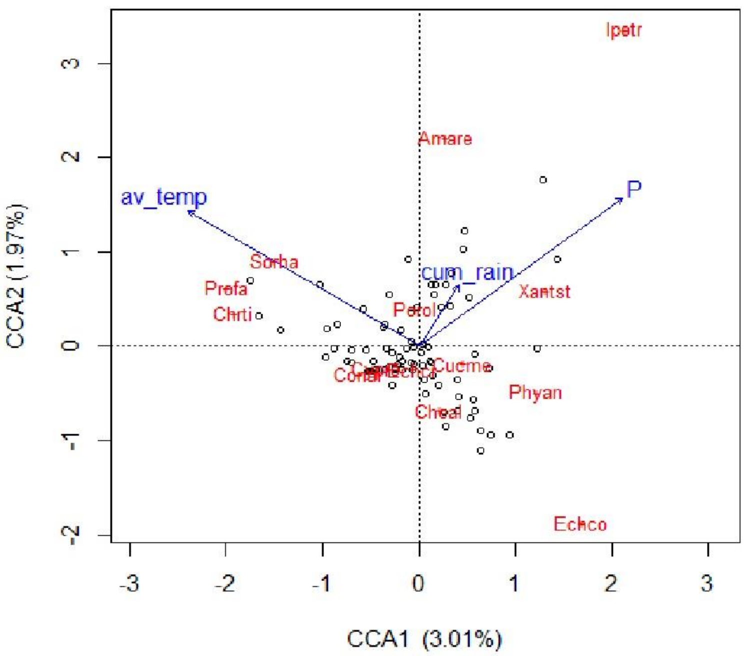

Figure 2. CCA ordination diagram of weed species and the soil and meteorological variables av_temp: Average temperature, cum_rain: Cumulative rainfall, P: Phosphorus content in soil

Şekil 2. Yabancı ot türlerinin ve toprağın CCA koordinasyon diyagramı ve meteorolojik değişkenleri, av_temp: Ortalama sıcaklık, cum_rain: Kümülatif yağış, P: Topraktaki fosfor içeriği

Amare: *Amaranthus retroflexus* L., Cheal: *Chenopodium album* L., Chrti: *Chrozophora tinctoria*, Conar: *Convolvulus arvensis* L., Cpyro: *Cyperus rotundus* L., Echcr: *Echinochloa crus-galli* (L.) P. Beauv., Ipotr: *Ipomoea triloba* L., Porol: *Portulaca oleracea* L., Sorha: *Sorghum halepense* (L.) Pers., Xantst: *Xanthium strumarium* L., Cucme: *Cucumis melo* var. *agrestis*, Profa: *Prosopis farcta* (Banks and Sol.) Macbride, Phyan: *Physalis angulata* L.

Ipomoea triloba, A. retroflexus, and *X. strumarium* had a high correlation degree with the soil phosphorus content, while they had a slight relation with the cumulative rainfall (Fig 2). On the other hand, the average temperature resulted in an increase in some weed species, including *S. halepense*, *C. tinctoria,* and *P. farcta.* Önen et al. (2018) indicated that *X. strumarium* and *S. halepense* were closely associated with the soil phosphorus content in orchard fields of Turkey, but in the present study, *S. halepense* was highly associated with the average temperature, whereas *X. strumarium* had a moderate relationship with the soil phosphorus content. Although previous studies indicated that the density of *C. rotundus*, which was the most important weed species in this study, was closely affected by the soil phosphorus content (Shiratsuchi et al. 2005) or potassium content (Önen et al., 2018), in the cotton fields of the East Mediterranean region, no significant impact of these factors was detected. The soil variables had no significant effect on some weed species that were the most common and had high IVI values, such as *C. album, C. rotundus, C. arvensis, C. album, E. colonum, E. crus-galli,* and *P. angulata* (Table 1-4 and Figure 2).

Changing weed flora of the cotton fields

Weed species richness was 13 (Kahramanmaraş), 25 (Hatay), 14 (Mersin), and 25 (Adana) in 1991-1992 survey (Following first irrigation) (Kadıoğlu et al., 1993), and 18, 23, 17, and 33 weed species were found in the survey conducted in the same provinces in 2018, respectively (Tables 1-4). Weed richness increased in the cotton fields of Kahramanmaraş, Mersin, and Adana provinces but slightly decreased in Hatay. The following weed species were found in four provinces in the 2018 survey: *A. retroflexus, C. arvensis, Cyperus* sp., *E. colonum, P. oleracea, S. halepense, S. nigrum,* and *X. strumarium*. In general, the density and frequency of *C. arvensis, C. rotundus*, and *P. oleracea* increased compared to those of other weeds. This finding is unsurprising because many of these weeds may create a strong weed seed bank in cotton fields (Uludağ et al., 2004; Kadıoğlu et al., 2004), and some of them, including *C. album, C. rotundus, D. sanguinalis, E. colonum, P. oleracea* and *S. nigrum*, have a close relation to cotton from ancient times (Economou et al., 2016). Although *S. halepense* was not in high ranks according to IVI values, except in Hatay province, it also has special importance in cotton fields of Turkey because one weed per 8 m of cotton row may reduce cotton yield by 7.12% (Uludağ et al., 2007).

Ecological indices are also powerful indicators that reflect the change in weed flora in a specific field at various times or at the same time in various fields. The Shannon–Wiener diversity index showed that Hatay had the lowest plant biodiversity compared to the other provinces, while the Simpson dominance index had the highest value in Hatay (Table 7). The geographical position of the cotton fields of Hatay that spread in a plain surrounded by the mountains and far away from the national highways resulted in these unexpected values similar to the findings of Christen & Matlack (2006) (Figure 1).

Table 7. Ecological indices of the cotton fields of the Mediterranean provinces in 2018

Çizelge 7. 2018 yılında Akdeniz illerinin pamuk tarlalarının ekolojik indeksleri

Index	Kahramanmaraş	Hatay	Mersin	Adana
H’	1.18	1.15	1.32	0.44
D	0.199	0.223	0.158	0.132

H’: Shannon-Weiner diversity index (H’), D: Simpson dominance index

The similarity index (SI) is a valuable indicator to compare plant communities at different moments, and values above 25% indicate that compared factors have a similarity to each other (Sørensen, 1948; Santos et al., 2017).

These values of Kahramanmaraş, Hatay, Mersin, and Adana for 1991-1992 and for 2018 are presented in Table 8. The similarities between the provinces were generally lower in 1991-1992 than in 2018, except for SIs between Adana and Hatay and between Adana and Mersin. This case is not a surprising result because of the aforementioned weed shift. SI varied in a narrow range between 64 and 78.95 in 2018. This trend showed that the region's floristic compositions changed and resembled each other over time similar to Fried & Reboud (2007) who indicated weed flora of oilseed rape changed over time because of crop rotation and environmental conditions, and more generalist weed species became prominent.

Table 8. Similarity index values of the cotton fields of the Mediterranean provinces (%)
Çizelge 8. Akdeniz illerinin pamuk tarlalarının benzerlik indeksi değerleri (%)

Province	Kahramanmaraş	Hatay	Mersin	Adana
Kahramanmaraş	-	78.951	68.571	58.821
Hatay	63.162	-	64.871	67.931
Mersin	66.672	61.542	-	64.001
Adana	57.892	84.002	66.672	-

1:SI values of the provinces calculated from the survey that employed in 2018;
2:SI values of the provinces calculated from the survey that employed in 1991-1992.

There was an apparent weed shift in all cotton fields compared to the survey in 1991-1992; four weed taxa were not found in Kahramanmaraş, while nine new weed species were detected (Table 1). A similar trend was observed in Mersin, where nine new weed species were found, while six weed species were not found in the 1991-1992 survey (Table 3). In Adana, a more dramatic change was found with 16 new weed species, whereas six weeds were not found (Table 4). In contrast to other provinces, the number of weed species not found in Hatay was higher than the number of new weeds (Table 3).

Some factors in crop production systems, including crop, crop rotation, irrigation, and herbicide use may change weed flora. Fried et al. (2008) stated that crop type and preceding crop type were the primary driving forces to explain the changing weed compositions in different fields. Crop rotation is another factor that has an impressive effect on arable weeds in crop fields, including cotton. Previous studies showed that crop sequences might increase weed control efficacy without decreasing weed diversity (Ulber et al., 2009). In addition, combining crop sequences with agricultural practices not only enhances weed control but also reduces the adverse impact of tillage (Ruisi et al., 2015). Similar to other factors, irrigation may also change the weed communities of horticultural and field crops including cotton at various degree (Ramôa et al., 2017; Bükün, 2005).

Weed shifts in crop fields also depend on agricultural chemicals such as fertilizers and herbicides. Mennan & Işık (2003) indicated that fertilization in maize fields for a long time had resulted in weed shift in these fields. Indeed, impact of the fertilizers on weed flora was limited compared to the main factors, site and crop species (Andersson & Milbergs, 1998). Another main variable that causes weed shifts in crop fields is the herbicide which may use as a main component and/or as a complementary part of integrated weed management to control weeds. For instance, herbicide use combining with crop rotation can achieve higher control of weed than crop rotation (Daucet et al., 1999). Salonen et al. (2001) stated that using herbicides in a cropping system resulted in a change in weed composition in wheat fields, and weeds that may not be controlled by herbicides were more common than others. *C. rotundus* was found to be the most prominent weed species in both surveys. Furthermore, its importance increased over time because the weed was not successfully controlled with only herbicides if some complementary control techniques, including cultivation and hand hoeing, were not employed, as mentioned in the study of Murray et al. (1992).

Adana may be a good example to understand the impact of crop species and crop rotation on the weed flora because cotton was one of the most common crops in this province until the 1990s; however, cotton was replaced or sequenced with maize, citrus and horticultural crops in the following years, especially in the fields where the soil salinity was above 200 mS m-1 (Bülbül et al., 2013). Cotton husbandry in Adana along the seashore has continued as monoculture because of high soil salinity. As a consequence of this change, IVI, abundance, density and frequency of *C. rotundus* were the lowest in Adana compared to other provinces of the region.

New weed species are another significant problem in cotton fields because most of them have alien plants such as *A. palmeri, C. melo* var. *agrestis, I. triloba,* and *P. angulata*, while some alien plants have almost adopted Turkish flora, including *A. retroflexus, A. spinosus, C. album, C. rotundus, D. stramonium, E. colonum, E. nutans, E. prostrata, X. strumarium,* and *X. spinosum* (Uludağ et al., 2017; Mennan et al., 2018; Arslan & Aksoy, 2017). Üremiş et al. (2010) indicated that invasive *Physalis* species were introduced in the cotton fields of Turkey at the beginning of the 1990s and spread over time. Likewise, *I. triloba* was first found in the cotton fields of Antalya province and then spread to nearly all the cultivation fields of the Mediterranean region (Yazlık et al., 2013; Özkil & Üremiş, 2020). Similarly, *A. palmeri* was first reported in the middle of the 2010s in Turkey, and then it was introduced to other field crops, including cotton fields, in the following years (Mennan et al., 2018). Although nearly all of them completed their naturalization process in Turkish flora, controlling them was a significant problem, especially with herbicides, because a limited number of herbicides were registered to control them (PPPD, 2022). Invasive plants might replace native weed species in some fields due to their high competition ability compared to natural elements of agricultural and forestlands (Kumar et al., 2021). Moreover, there were no restrictive factors, such as intraspecific competition, natural enemies, and competitive natural plants, that may produce allelopathic chemicals in their new environment (May, 2007).

In conclusion, cotton husbandry has nearly two centuries of history in the East Mediterranean region of Turkey. Alternative crops replaced the cotton in the region, and the cotton fields were reduced to two-thirds compared to the previous years; however, cotton production remained nearly stable because of convenient agricultural practices, especially in weed control. To control weed species in cotton fields, weed flora should be well known by cotton farmers who may use proper weed control strategies, including herbicide use. The results of the recent survey showed the importance and increased density of some dominant weed species, such as *C. rotundus, C. arvensis, P. oleracea, P. angulata, S. nigrum*, and *S. halepense,* in all provinces. This increase was considered a threat to the biodiversity of agricultural fields (Krähmer et al., 2020). Management of invasive alien plants in cotton even if they were naturalized is another significant difficulty because no new herbicides have been registered in Turkey for them and they have no natural enemy in their new agroecosystem; therefore, integrated pest management strategies should be employed. Additionally, cotton growers should carefully manage the weed flora of cotton fields because the seeds of dominant weed species in the soil seed bank may decrease in time if precautions are taken.

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STATEMENT OF CONFLICT OF INTEREST

All authors declare that there are no conflicts of interest.

AUTHOR'S CONTRIBUTIONS

Ahmet Tansel Serim created project idea, provided data, interpreted the data, drafted and wrote-reviewed & edited the article; Mine Ozkil created project idea, managed project, provided data, interpreted the data, drafted and wrote-reviewed & edited the article; Ilhan Uremiş; provided data, interpreted the data, drafted the article; Ahmet Uludag interpreted the data, drafted and wrote-reviewed & edited the article.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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