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DergiPark AKADEMİK

Dergimiz Hakkında/ About Our Journal

Journal of Agriculture, hakemli uluslararası bir dergidir ve 2018 yılında yayın hayatına başlamıştır. DergiPark bünyesinde açık erişimli olarak, tarım ve yaşam bilimleri alanında hazırlanmış araştırma ve derleme makalelerini yayınlamak üzere Mayıs-2018 yılında faaliyete başlamıştır. Derginin desteklediği diller Türkçe ve İngilizce'dir. Yılda 2 (iki) sayı yayınlanır. Dergiye gönderilen makaleler önce editör tarafından şekil ve içerik yönünden incelenir. Uygun olmayanlar sorumlu yazara geri gönderilir. Gönderilen makaleler yazarlar tarafından kaynaklar hariç olmak üzere intihale karşı kontrol edilmektedir. Yapılan kontrollerde benzerlik oranının %20'nin altında olması zorunludur. İntihal raporları incelenerek %20 üzerinde olan yayınlar reddedilir. Yayınlanması istenilen eserlerin herhangi bir yerde yayınlanmamış veya yayınlanmak üzere herhangi bir dergiye gönderilmemiş olması zorunludur. Editörün onayladığı makaleler konu ile ilgili 2 (iki) hakeme gönderilir. Hakem incelemesi ve düzeltme süreci tamamlanan makaleler yayınlanır.

Journal of Agriculture is a refereed international journal and started its publication in 2018. DergiPark started its activities in May-2018 in order to publish research and compilation articles prepared in the field of agriculture and life sciences with open access. The languages supported by the journal are Turkish and English. 2 (two) issues are published annually. Articles submitted to the journal are first reviewed by the editor in terms of shape and content. Unsuitable ones are sent back to the responsible author. Submitted articles are checked against plagiarism by the authors, excluding the sources. It is mandatory that the similarity rate is below 20% in the controls. Publications over 20% are rejected by analyzing plagiarism reports. It is mandatory that the works to be published have not been published anywhere or sent to any journal to be published. Articles approved by the editor are sent to 2 (two) reviewers. Articles whose referee review and correction process are completed are published.

Amaç/Aim

Dergimiz bahçe bitkileri, bitki koruma, bitkisel ve hayvansal üretim, biyosistem mühendisliği, gıda mühendisliği, moleküler biyoloji ve genetik, peyzaj mimarlığı, su ürünleri, tarım ekonomisi, tarımsal mekanizasyon, tarımsal yapılar ve sulama, tarla bitkileri, toprak bilimi ve bitki besleme ve zootekni alanında hazırlanan araştırma ve derleme çalışmalarını Türkçe ve İngilizce dillerinde yayımlamayı amaç edinmiştir.

The articles that can be sent to the journal are horticulture, plant protection, plant and animal production, biosystem engineering, food engineering, molecular biology and genetic, landscape architecture, fisheries, agricultural economy, agricultural mechanization, agricultural structures and irrigation, field crops, soil science and plant nutrition and animal science. The journal aims to publish research and compilation studies in Turkish and English.

Kapsam/Scope

Journal of agriculture, Haziran ve Aralık aylarında yılda iki kez yayınlanan hakemli, akademik, bilimsel, uluslararası bir dergidir. Türkçe ve İngilizce makaleler kabul edilir ve çevrimiçi olarak yayımlanır.

Journal of agriculture is a refereed, academic, scientific, international journal published twice a year, in June and December. Turkish and English articles are accepted and are published online.

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DÜZELTME NOTLARI / CORRECTION NOTES

DÜZELTME

Journal of Agriculture Dersisi 2023 yılı 6. cilt 2. Sayı'sında "Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions" başlıklı makale bir tezden üretilmiş olup, tezin eş danışmanı olan Prof. Dr. Rafet ASLANTAŞ 3. Yazar olarak, sorumlu yazar tarafından unutularak eklenmemiştir. Makale yazarları aşağıdaki şekilde düzeltilmiştir.

Makalenin DOİ numarası: https://doi.org/10.46876/ja.1380024

Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions

Sadiye Peral EYDURAN *[1] | **Zeynebi Kubra AZITI[2]** | **Rafet ASLANTAŞ[3]**

ERRATUM

The article titled "Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions" in Volume 6, Issue 2 of the Journal of Agriculture Dersisi 2023 was produced from a thesis, and Prof. Dr. Rafet ASLANTAŞ, who is the co-advisor of the thesis, was not added as the 3rd author by the responsible author. The authors of the article have been corrected as follows.

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Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions

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ARAŞTIRMA MAKALESİ

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Tuz Stresi Altındaki Kişniş Bitkisinin (*Coriandrum sativum*) DNA Metilasyon Modlarının RAPD Markırları ile Belirlenmesi

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Sorumlu Yazar
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Özet: Epigenetik, gen ifadesi ve fonksiyonundaki kalıtsal değişiklikleri tanımlayan bir alanı ifade eder, ancak DNA baz değişimi olmaksızın gerçekleşir. Bitkilerde en çok incelenen epigenetik mekanizmalar, DNA metilasyonu ve histon proteinlerindeki kimyasal modifikasyonlardır. Epigenetik araştırmalarda, düşük ve yüksek işlem hacimli DNA metilasyon tespiti için çeşitli teknikler kullanılmaktadır. Düşük işlem hacimli tekniklerden biri, enzim tabanlı DNA sitozin metilasyonunu belirleme yaklaşımıdır. Bu yöntem, biyolojik aktiviteleri ve terapötik potansiyeli olan tuz uygulaması yapılan kişniş (*Coriandrum sativum*) fidelerinde rastgele genlerdeki DNA sitozin metilasyonunu incelemek amacıyla kullanılmaktadır. Bu çalışma, bitki genotiplerindeki epigenetik değişiklikleri anlamamıza ve bu değişikliklerin biyolojik etkilerini değerlendirmemize olanak tanır. Bu çalışmada tuz stresine maruz kalan kişniş fidelerinden 12. ve24. Saatlerde alınan doku örnekleri arasındaki sitozin metilasyon polimorfizmini ortaya koymak için touch-down polimeraz zincir reaksiyonları metilasyon duyarlı-rastgele arttırılmış polimorfik DNA (TD-MS RAPD) tekniği uygulanmıştır. Kişniş fidelerinden (Cemre) genomik DNA örnekleri izole edilmiş ve DNA izolatı touch- metilasyona duyarsız olan MspI restriksiyon enzimi ve metilasyona duyarlı HpaII restriksiyon enzimi ile kesilmiştir. Kullanılan 9 oligonükleotid primerinden üç primer (OPA 05-OPD 01-OPH 10) uygulamalar ve saatlik alınan örnekler arasında metilasyon polimorfizmleri belirlenmiştir. TD-MS-RAPD-PZR metodu, basit ve temel cihazlar gerektiren ekonomik bir yaklaşımdır. Bu yöntem, standart bir DNA termal döngü cihazı ve DNA jel elektroforezi sistemi kullanılarak kolayca uygulanabilir. Bu metotla belirlenen sitozin metilasyon polimorfizmi uygulamalar arsında oldukça düşüktür. İki farklı tuz uygulaması arasında (100mM-200mM) düşük düzeyde polimorfizm olduğu sonucuna varılmıştır. Saatlik alınan kişniş fidelerinden elde edilen doku örneklerindeki metilasyona bakıldığında ise 12'nci ve 24'üncü saatlerde alınan örnekler arasında bir metilasyon farkı tespit edilmemiştir.

Anahtar kelimeler: Kişniş, DNA metilasyonu, MspI-HpaII

Determination of DNA Methylation Modes of Coriander Plant (*Coriandrum sativum*) Under Salt Stress Using RAPD Markers

Abstract

Epigenetics pertains to heritable alterations in gene expression and function that occur without modifications to the DNA base sequence. Among the extensively researched epigenetic mechanisms in plants are DNA methylation and chemical modifications in histone proteins. In the realm of epigenetic exploration, a variety of techniques are employed for both low- and high-throughput DNA methylation detection. One low-throughput approach involves the utilization of an enzyme-based method for detecting DNA cytosine methylation. This technique was applied to investigate DNA cytosine methylation in randomly selected genes within salt-treated coriander (*Coriandrum sativum*) seedlings, renowned for their biological activities and therapeutic potential. The study facilitates comprehension of epigenetic modifications in plant genotypes and an assessment of the biological implications of these alterations. The research employed the touch-down polymerase chain reaction methylation-sensitive-randomly amplified polymorphic DNA (TD-MS RAPD) technique to unveil cytosine methylation polymorphism between tissue samples collected at 12 and 24 hours from coriander seedlings subjected to salt stress. Genomic DNA samples extracted from coriander seedlings (Cemre) underwent treatment with the methylation-insensitive MspI restriction enzyme and the methylation-sensitive HpaII restriction enzyme prior to touch-down polymerase chain reactions. Methylation polymorphisms were identified using three primers (OPA 05, OPD 01, OPH 10) out of the 9 oligonucleotide primers employed, with samples taken at hourly intervals. The TD-MS-RAPD-PCR method presents an economical approach requiring basic equipment. Implementation involves a standard DNA thermal cycler and DNA gel electrophoresis system. Notably, cytosine methylation polymorphism determined by this method exhibited minimal variance across applications. The findings indicate a low level of polymorphism between two distinct salt treatments (100mM-200mM). Moreover, when scrutinizing methylation in tissue samples obtained from coriander seedlings at hourly intervals, no discernible methylation differences were observed between the samples collected at the 12th and 24th hours.

Key words: Coriander, DNA methylation, MspI-HpaII

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GİRİŞ

Apiaceae (*Umbelliferae*) familyasına ait olan kişniş (*Coriandrum sativum*) dikotiledonlu bir bitkidir. Bitkinin tüm kısımları yenilebilir ancak genellikle taze yaprakları ve kurutulmuş tohumları kullanılır (Önder, 2018). Besleyici ve tıbbi özelliklere sahip bir bitki olmasının yanı sıra en çok kullanılan baharatlardan biridir (Yılmaz ve ark., 2022). Bitkinin ilk tıbbi kullanımları eski Mısırlılar tarafından rapor edilmiştir. Kişniş başta monoterpenler, pinen, limpen, borenol, citronellol, geraniol, koriandrin, dihidrokoriandrin, kişniş A-E, flavonoidler ve uçucu yağlar olmak üzere birçok aktif madde içerir. *Coriandrum sativum'*un antifertilite, antihiperglisemik, antihiperlipidemik, antioksidan, antiproliferatif, hipotansif ve sindirim uyarıcısı gibi çeşitli farmakolojik etkilere sahip olduğu da rapor edilmiştir(Almasi 2021). Kişniş aynı zamanda detoks diyetinde de kullanılmaktadır. Cıva ve kurşun gibi toksik mineral kalıntılarının atılmasına yardımcı olmasının yanı sıra kan basıncınıda düşürme özelliğine sahiptir (Leena ve ark., 2012). Ayrıca antibakteriyel ve antifungal etkileri de mevcuttur (Önder, 2018).

Kişniş, Güney Avrupa'ya, Kuzey Afrika'ya ve Asya'nın bazı bölgelerine (örneğin İran) özgüdür; geniş bir adaptasyonu bulunmaktadır ve farklı türdeki toprak ve iklim koşulları altında iyi büyüyen bir güce sahip bir bitkidir. Ancak bu bitkinin verimi ve fizyolojisi tuzluluktan olumsuz etkilenmektedir (Moradi ve Zauareh, 2013; Mishra ve ark., 2017; Al-Garni ve ark., 2019).

Tuzlu topraklar ve tuzlu sulama suları tıbbi bitki üretiminde ciddi sorunlara neden olmakta ve bitki büyümesini engellemektedir. Tuzluluk, bitki türlerinin üretimini olumsuz yönde etkileyen önemli bir abiyotik faktördür. Tuz stresi bitkilerde çeşitli biyokimyasal ve fizyolojik süreçleri etkilemektedir. NaCl, doğrudan ozmotik veya iyonik mekanizmalar yoluyla ve gen ifadesine etki ederken dolaylı olaraktan hücre içi etkilerini aracılar yardımıyla da gerçekleştirebilir (Türkoğlu ve ark., 2023a; Thomas ve ark., 1992). Bitkiler çevresel stresler altında oksidatif hasara maruz kalır (Türkoğlu ve ark., 2023b; Eren ve ark., 2023). Reaktif oksijen türleri (ROS), tuzluluğun bozucu etkilerine katkıda bulunan ana faktörlerden biri olarak kabul edilmektedir (Ashraf ve Ali, 2008). ROS sitotoksik olduğundan lipitlerle, proteinlerle ve nükleik asitlerle reaksiyona girebilir ve proteinin denatüre olmasına, lipit peroksidasyonuna ve DNA mutasyonuna neden olabilir (Ashraf ve Ali, 2008; Kulak ve Aydın 2023). Plazmalemmanın peroksidasyonu hücresel içeriğin sızmasına, hızlı kurumaya ve hücre ölümüne yol açar (Scandalios, 1993). Bitkiler, ROS'un olumsuz etkilerini azaltmak için antioksidan moleküllerle donatılmıştır. Süperoksit dismutaz, H_2O_2 üretmek için süperoksit radikaliyle reaksiyona girer. H_2O_2 katalaz ve peroksidaz tarafından temizlenir (Berwal ve Ram, 2018). Ali ve ark., (2004) bitki başına verimin, klorofil konsantrasyonunun, doğurganlık yüzdesinin, verimli kardeş sayısının, salkım uzunluğunun ve pirinç salkımı başına birincil dal sayısının tuzluluk nedeniyle azaldığını bildirmiştir.

Kurak mevsim ve toprak tuzluluğu gibi iklimsel sorunlar, dünya genelinde her zaman en önemli bitkisel üretim kısıtlamaları olmuştur. Tuzluluğun bitki morfolojisi ve fizyolojisi üzerindeki etkilerinin olmasının bilinmesinin yanında metilasyonu değiştirdiği bilinmektedir. Tuz stresi altında, bitkilerde DNA metilasyon profili değişebilir. Bazı araştırmalar, tuz stresinin bitki genomundaki DNA metilasyon desenlerini etkileyebileceğini göstermiştir. Tuz stresine maruz kalan bitkilerde, belirli genlerin metilasyonu durumunda değişiklikler meydana gelebilir. Bu değişiklikler gen ekspresyonunu etkileyebilir, çünkü DNA metilasyonu gen transkripsiyonunu düzenlemede önemli bir rol oynar.

Tuz stresinin DNA metilasyonu üzerindeki etkisi, özellikle bitkilerde stresle başa çıkma mekanizmalarını düzenleyen genlerle ilgili olabilir. Bazı genlerin metilasyon durumundaki değişiklikler, bu genlerin aktivasyonunu veya inhibisyonunu etkileyebilir, bu da bitkilerin tuz stresine karşı adaptasyonunu etkileyebilir. (Al-Lawati ve ark., 2016).

Bu çalışmada, sodyum klorür (NaCl) uygulamasının bireylerdeki DNA metilasyon veya demetilasyon üzerindeki etkilerini değerlendirmenin yanı sıra, eski ve basit bir yöntem olan touch down

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tabanlı metilasyona duyarlı rastgele amplifiye polimorfik DNA markör (TD-MS-RAPD-PCR) yönteminin güvenilirliğini araştırmayı amaçlamaktayız. Bu bağlamda, epigenetik bir mekanizma olan DNA sitozin metilasyonunu kişniş bitkisinde uygulayarak elde edilen veriler, NaCl stresinin genetik materyal üzerindeki etkilerini anlamamıza ve potansiyel epigenetik değişiklikleri belirlememize yardımcı olacaktır. TD-MS-RAPD-PCR yöntemi, genetik çeşitliliği belirlemek ve DNA metilasyon durumunu analiz etmek için yaygın olarak kullanılan bir moleküler teknik olup, bu çalışmada NaCl stresinin neden olduğu potansiyel değişiklikleri belirlemede güvenilir bir araç olabilir. Bu yöntem sayesinde, homozigot ve heterozigot bireyler arasındaki genetik farklılıkları ve stresin bu farklılıkları nasıl etkilediğini anlamak mümkün olacaktır. Ayrıca, kişniş bitkisinde DNA sitozin metilasyonunu uygulayarak elde edilen veriler, bu epigenetik mekanizmanın bitki stres yanıtlarında oynadığı rolü daha iyi anlamamıza imkan tanıyacaktır. Bu, NaCl stresinin bitki genomunda potansiyel değişikliklere yol açabilecek ve bitkinin adaptasyon mekanizmalarını etkileyebilecek epigenetik düzenlemeleri ortaya koymak için önemli bir adım olabilir.

MATERYAL ve YÖNTEM

Çalışmada kişniş (Cemre) (*Coriandrum sativum*) genotipi kullanılmış olup kontrol grubunda saf su ve deney gruplarında 100 ve 200 mM olmak üzere iki farklı NaCl konsantrasyonu uygulanmıştır. 4.2 lt hacmindeki her bir saksıya 10'ar tohum ekilmiştir. Tuz uygulaması, gerçek yapraklar çıktıktan 5 gün sonra uygulanmış ve her bir saksıya iligili çözeltiden 50 ml eklenmiştir. Uygulama yapıldıktan sonra 12 ve 24'üncü saatlerde yaprak doku örnekleri alınmıştır.

DNA izolasyonu

Genomik DNA izolasyonu için uygulamaların ardından elde edilen fidelerden yaprak dokusu alınmıştır. Daha sonra, Aydın ve ark. (2018) tarafından geliştirilen DNA izolasyon protokolü modifiye edilerek uygulanmış olup bu süreç sıvı nitrojen kullanılarak gerçekleştirilmiştir. Elde edilen genomik DNA örnekleri, miktar ve kalite analizleri için spektrofotometrik değerlendirme ve agaroz jel elektroforezi yöntemleri ile detaylı bir şekilde incelenmiştir.

Restriksiyon enzim kesimi işlemi

Enzim kesim reaksiyonları 0,2 ml hacmindeki mikro tüplerde gerçekleştirilmiştir. Her bir reaksiyon karışımı için 1 µg genomik DNA, 10 ünite *Msp*I veya *Hpa*II restriksiyon enzimi ve 2 µL 10x DNA tampon çözelti (Tango buffer, Thermo Scientific) içerecek şekilde hazırlanmıştır (Demirel ve ark., 2023; Türkoğlu ve ark., 2023c). Bu karışım, 37ºC'de 16 saat boyunca inkübe edilmiştir, bu süreç Karaca ve ark. (2005) tarafından belirtilmiştir. İnkübasyonun ardından, her numuneye 107,5 µL su eklenmiş ve bu karışım TD-MS-RAPD-PCR deneyleri için önce iyice homojenleştirilmiştir.

Touch-down Polimeraz zincir reaksiyonu (TD-PCR)

PCR işlemleri SimpliAmp (Thermo Scientific) cihazında gerçekleştirilmiştir. Çalışmada, 25 mikrolitrelik bir reaksiyon karışımı oluşturulmuştur. Bu karışım, kalıp DNA, primerler, 10x reaksiyon tamponu, $MgCl_2$, dört farklı dNTP ve Taq DNA polimerazını içermektedir, detayları Çizelge 1'de gösterilmiştir. RAPD PZR reaksiyonlarının spesifikliğini artırmak amacıyla, hedefleri çoğaltmak için Çizelge 2'de belirtilen bir "touch-down PZR" yöntemi kullanılmıştır. Kişniş otu örneklerinde *Msp*I ve *Hpa*II enzimleri (Çizelge 3'te belirtildiği gibi) ile kesilmiş olan numuneler, toplamda 9 oligonükleotid primer kullanılarak çoğaltılmıştır (Çizelge 4).

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Çizelge 1. *TD-MS-RAPD için PZR reaksiyon karışımı (Karaca ve ark. 2016)*
Table 1. *PCR reaction mixture for TD-MS-RAPD (Karaca et al., 2016)*

Kullanılan Kimyasallar		Stok	Miktar	Final
Genomik DNA			8.5 µl	100-120 ng
Steril-H_2O			3.5 µl	
İleri Primer ("Forward")		20 µM	3.0 µl	2.4 µM
Steril-H_2O			4.6 µl	
10X Reaksiyon Çözeltisi	TRIS-HCI (pH 9.1) KCI Triton X-100	100 mM 100 mM %0.1	3 µl	12 mM 60 mM %0.012
$MgCl_2$		50 mM	1.5 µl	3 mM
dNTP		10 mM	0.7 µl	0.28 mM
***Taq* DNA Polimeraz**		5 ünite/ µl	0.2 µl	1 ünite
Toplam Hacim			25 µl	

Çizelge 2. *TD-MS-RAPD-PZR profili (Karaca ve ark. 2016)*
Table 2. *TD-MS-RAPD-PZR profile (Karaca et al.,. 2016)*

PZR Profili		Zaman	Döngü Sayısı	Aşama
Hot Start	94ºC	5 dakika	1 döngü	Ön-denatürasyon
Ön PZR	94ºC	1 dakika	10 döngü	Denatürasyon
	42ºC→37ºC	1 dk 20 sn		Renatürasyon
	72ºC	2 dakika		Sentez
PZR	94ºC	2 dakika	30 döngü	Denatürasyon
	37ºC	1 dk 20 sn		Renatürasyon
	72ºC	2 dakika		Sentez
Final	72ºC	10 dakika	1 döngü	Final Sentez
	4ºC	1 saat		

Çizelge 3. *CCGG bölgelerindeki metilasyona MspI ve HpaII restriksiyon enzimlerinin tepkileri*
Table 3. *Response of MspI and HpaII restriction enzymes to methylation at CCGG sites*

Hedef Bölge	Msp I	Hpa II	Metilasyon Durumu
CCGG/GGCC	Keser	Keser	İki DNA sarmalında da metil grubu yoktur.
$C^{m}CGG$/ $GG^{m}CC$	Keser	Kesmez	İçteki Sitozin bazları tamamen metillidir
$^{m}C^{m}CGG$/ GGCC	Kesmez	Keser	Bir DNA sarmalı tamamen metillidir.
$^{m}CCGG$/GGCC	Kesmez	Keser	Bir DNA sarmalı yarı metillidir
$^{m}C^{m}CGG/GG^{m}C^{m}C$	Kesmez	Kesmez	Her iki DNA sarmalıda tam metillidir

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Çizelge 4. *Çalışmada kullanılan oligonükleotid primer dizileri (Aydin ve Özden 2021)*
Table 4. *Oligonucleotide primer sequences used in the study (Aydin ve Özden 2021)*

NO	Primer ID	Primer sequence 5'→ 3'	100Mm (12.saat)	100Mm (24.saat)	200Mm (12.saat)	200Mm (24.saat)
1	**OPA-05**	AGGGGTCTTG	2	2	2	4
2	**OPC-08**	TGGACCGGTG	2	2	2	4
3	**OPC-09**	CTCACCGTCC	2	2	2	2
4	**OPD-01**	ACCGCGAAGG	6	6	6	6
5	**OPD-02**	GGACCCAACC	4	4	4	4
6	**OPF-16**	GGAGTACTGG	7	7	6	7
7	**OPG-04**	AGCGTGTCTG	2	2	2	2
8	**OPH-07**	CTGCATCGTG	4	4	4	4
9	**OPH-10**	CCTACGTCAG				

Analizlerin ardından, ürünler %2 çözünürlüklü agaroz jellere yüklendikten sonra 3-6 saat boyunca sabit voltajda (5 V/cm) elektroforez işlemi gerçekleştirilmiştir.

Sitozin metilasyon skorlaması

Msp I ve Hpa II enzimleri ile kesilmiş olan genomik DNA'larının farklarını belirlemek amacıyla, iki ayrı uygulama ve farklı saatlerdeki örnekler üzerinde yapılan TD-MS-RAPD-PCR analizleri "var" (1) ve "yok" (0) olarak skorlanmıştır. Bu PZR markörlerinin yokluğu, her iki hedef dizisinde de (5'-CCGG-3'/3'-GGCC-5') metil içermediğini göstermektedir. Öte yandan uygulanan bu PZR yöntemine ait markörlerin olması her iki hedef dizisinin metilli (5'-mCmCGG-3'/3'-GGmCmC-5') olduğunu söylemektedir. Diğer durumlar ise MspI' de var, HpaII' de yok olması durumunda, DNA zincirinin tamamen metillenmiş (5'-mCmCGG-3'/3'-GGCC-5') ya da yarı metillenmiş (5'-mCCGG-3'/3'-GGCC-5') olduğu düşünülmüştür. MspI kullanılan TD-MS-RAPD-PCR markörlerinde, markör bulunmazken; ancak aynı markör HpaII kullanıldığında, içteki sitozin bazlarının tamamen metillendiği kabul edilmiştir (5'-CmCGG-3'/3'-GGmCC-5'). Bu çalışmada, 1 ve 0 puanlama sistemi uygulanmış olup, 1 puan hedefin enzim tarafından kesilmediğini; 0 puan ise hedefin enzim tarafından kesildiğini ifade etmektedir (Çizelge 3).

BULGULAR VE TARTIŞMA

Bu araştırmada, kontrol ve tuz uygulamasına maruz kalan kişniş fidelerinde DNA sitozin metilasyonunu belirlemek amacıyla TD-MS-RAPD-PCR tekniği kullanılmıştır. TD-MS-RAPD-PCR tekniği, MspI ve HpaII enzimleri aracılığıyla uygulanan, aynı tanıma bölgelerine sahip ancak DNA metilasyonuna karşı farklı hassasiyet gösteren izoşizomerleri içeren bir yönteme dayanmaktadır. Bu metodoloji, DNA'nın spesifik bölgelerindeki metilasyon durumunu yüksek çözünürlükle belirleyerek genetik materyalin epigenetik modifikasyonlarını analiz etmeyi mümkün kılmaktadır (Karaca ve ark. 2019). Bu çalışma, metilasyon profillerinin belirlenmesindeki yüksek hassasiyetiyle önemli bilgiler sunmaktadır. Kontrol ve tuz stresine maruz kalan kişniş fidelerindeki genetik değişiklikleri ve bitki yanıtlarını anlamak ve tarım alanında kullanışlı uygulamalar geliştirmek için kapsamlı bir anlayış sağlamaktadır. Bu enzimler, belirli bir tanıma dizisi olan 5'-CCGG-3' üzerinde etkileşim gösterirler. HpaII enzimi, tek bir DNA zincirinde metilasyon gerçekleştiğinde (hemimetillenmiş durumda), dıştaki sitozinleri algılar ve keser. Öte yandan, MspI enzimi, her iki DNA zinciri de tamamen metillendiğinde içteki sitozinleri tanır ve böyle durumlarda hedef diziyi keser. Ancak, her iki DNA zinciri de metillenmediğinde, her iki enzim de hedef tanıma dizisini etkiler.

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Bu enzimatik özellikler, DNA'nın metilasyon durumuna bağlı olarak kesme aktivitesindeki değişiklikleri vurgular. MspI ve HpaII enzimleri, genetik materyal üzerindeki metilasyonun incelenmesinde kullanılarak, epigenetik düzenlemelerin anlaşılmasına ve genetik ifadenin karmaşıklığının çözülmesine katkıda bulunur (Demirel et al., 2023; Türkoğlu et al., 2023c). Çizelge 3 *MspI* ve *HpaII*'nin kesme özelliklerini anlatmaktadır. Farklı uygulamalara veya değişen doz uygulamalarına maruz bırakılan bitki fidelerine ait genomik DNA örnekleri, MspI ve HpaII enzimleri ile işlendiğinde, 5'-CCGG-3' hedef bölgelerinde çeşitli metilasyon paternlerine sahip olabilir. Bu durum, genetik materyalin çevresel streslere tepkisi veya farklı uygulama koşullarının bitkilerin epigenetik düzenlemeleri üzerindeki etkisini değerlendirmek için değerli bir araç sağlar. Hedef dizilerin tamamen metillenmiş veya metillenmemiş olduğu durumlarda, MspI ve HpaII'nin kesme aktiviteleri arasındaki farklar belirgin olmayabilir. Bu durumda, her iki enzimin de hedef diziyi benzer şekilde kesmesi, metilasyon paterninde benzerliklere işaret edebilir (Salmon ve ark., 2008).

Bu araştırmada, MS-RAPD-PCR markırlarının amplifikasyonu, artefak olarak isimlendirilen spesifik olmayan bölgelerin amplifikasyon oranını düşürmek bir touch-down PZR profili (TD-MS-RAPD-PCR olarak adlandırılır) kullanılmıştır. RAPD tekniğinde, farklı laboratuvarlarda veya farklı zamanlarda tekrarlandığında tekrarlanabilirlik sorunlarına yol açabildiği için ve hedeflenmeyen DNA bölgelerinin de amplifikasyonunu içerir ve istenmeyen bantların oluşmasına neden olduğu için RAPD tekniğinin dezavantajlarındandır (Karaca ve ark., 2019).

Doğru bir şekilde yorumlanabilecek çoğaltılmış ürün sayısı 9 primerde farklılık göstermiştir (Çizelge 4). Örneğin OPA-05 oligonükleotid primeri 2 TD-MS RAPD-PCR markırı üretirken OPF 16 markırı en yüksek değeri yedi (7) üretmiştir. Bu çalışmada iki farklı tuz uygulaması ve iki farklı saatlerde alınan örnekler arasında TD-MS-RAPD-PCR markırların sayasıda değişiklik göstermiş olup toplam 100mMm NACl ve 12. saatte alınan örnekte 26, 100mMm NaCl ve 24. Saatte 26, 200mMm NaCl ve 12. Saatte 25, 200Mm NaCl ve 24. Saatte33 markır tespit edilmiştir.

Kullanılan 9 primerden sadece üçünde (OPA 05-OPD 01-OPH 10) Şekil 1 'de gösterildiği gibi tuz uygulaması yapılan kişniş fideleri arasında metilasyona duyarlı polimorfizmler saptanmıştır. Primer OPA 05 ile amplifiye edilmiş lokus 100 mM 12. saat, 100 mM 24. saat ve 200 mM 12. saatte bant oluşturmadığı için bu uygulamaların her iki DNA sarmalının metilsiz (CCGG/GGCC) olduğu düşünülürken diğer uygulamada (200 mM 24. saat) içteki sitozin bazlarının tamamen metilli (CCmGG/GGCmC) olduğu tespit edilmiştir (Fu ve ark.. 2012). Aynı durum OPC-08 lokusunun 200 mM tuz uygulamasının 24. saat örnekleri içinde geçerlidir. MspI ve HpaII enzimleri ile kesilen kontrol tuz (100mM ve 200mM) uygulaması olan kişniş fide genomik DNA'lar ile OPC-09 primeri PZR işlemine tabi tutulmuştur. OPC-08 lokusunun PZR sonucunda hem MspI hem de HpaII enzimi tüm uygulamalarda kesim yapmış olduğu için jel görüntüsünde bantlar görülmemektedir (0 0). Bu durum CCGG/GGCC bölgesinin (her iki sarmalda) sitozinlerinin metillenmediğini ispatlamıştır. Uygulamalar arasında da değişiklik olmayıp ne NaCl metillenmeyi arttırmış ne de örneklerin alındığı saatler metillenme durumunu değiştirmiştir.

MS-RAPD-PCR markırı olan OPD-01 lokusunda 1. allelde tuz uygulamasından sonra farklı saatlerde alınan örneklerde metilasyon polimorfizmi ortaya çıkmıştır (Şekil 1). Metilasyon poliforfizmi görülen diğer bir lokusumuz OPD 02 markırının 200 mM tuz uygulamasında 24. saatteki örnek dışında diğer uygulama ve saatlerde allelin görülmemesi durumu MspI ve HpaII enzimlerinin aktivitesi ile açıklanmaktadır. Bu durum CCGG/GGCC bölgesinin (her DNA iplikçiğinde de) sitozinlerinin metil grubu içermediğini göstermektedir. 200mM tuz uygulamasından sonra ki örnekte hem Msp I hemde HpaII enziminin kesmemesi her iki DNA sarmalının da tam metilli olduğunu göstermektedir.

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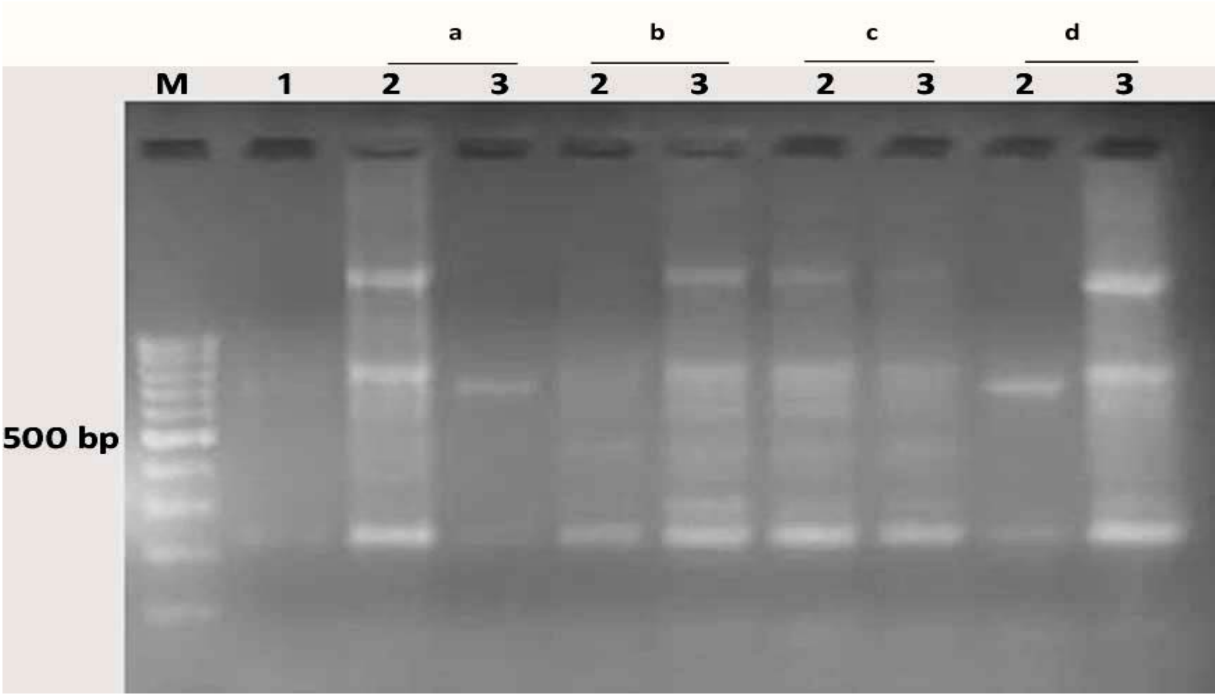
OPH lokusu için ayrı ayrı uygulamalara ve uygulama sonrası sürelere bakıldığında 100mM ve 200mM tuz uygulamalarının 12. saatteki örnekleri hem *MspI* hemde *Hpa II* tarafından kesilmemesi tam metilli olduklarını gösterirken 24. saatteki örneklerin hem MspI hem de HpaII enzimleri tarafından kesilmeleri her iki sarmaldaki sitosizinlerin metillendiğini göstermektedir. Diğer lokuslarda ise kontrol ve uygulamalar arasında farklılık görülmemiştir.



Şekil 1. *100Mm NaCl ve12.saat, b) 100Mm NaCl ve 24.saat , c) 200Mm NaCl ve12.saat, d) 200Mm NaCl ve 24.saat Genomik DNA'larının MspI ve HpaII enzimleri ile kesim sonrası OPD-01 primeri ile TD-MS-RAPD-PCR sonucu 1) Kontrol, 2) MspI enzim metilasyon desenleri, 3) HpaII enzim metilasyon desenleri.*

SONUÇ

Bu araştırma çerçevesinde, kişniş genotipine (Cemre) uygulanan 100mM ve 200mM tuz seviyelerinin, 12. ve 24. saatler arasında 5'-CCGG-3' sekans bölgesindeki DNA sitozin metilasyon farklılıklarını belirlemek amacıyla TD-MS-RAPD-PCR yöntemi kullanılmıştır. Hedef genomik DNA örnekleri, tuz uygulamalarının ardından elde edilen kişniş (Cemre) fidelerinden çıkarılmıştır. Kullanılan 9 oligonükleotid primer arasından, epigenetik polimorfizmlerle özdeşleşen yalnızca üç primer seçilmiştir (OPA 05,OPD 01,OPH 10). Bu sonuçlar, kişniş genomlarının 5'-CCGG-3' bölgelerini yüksek oranda içermediğini doğrulamıştır. İncelenen 5'-CCGG-3' bölgelerinin çoğu, kişniş fidelerinden elde edilen genomik DNA örneklerinde yüksek düzeyde DNA sitozin metilasyonları göstermemekte olup, bu bölgelerin farklı şekillerde metillenmediği anlaşılmıştır. Ancak, kontrol ve NaCl uygulamaları arasında yapılan karşılaştırmada, NaCl uygulamasının metilasyonu artırdığı gözlemlenmiştir. TD-MS-RAPD-PCR yöntemi, geniş bir kullanıcı kitlesine hitap eden özelliklere sahiptir. Bu metodoloji, ekonomik olmasıyla birlikte, laboratuvar bütçelerini zorlamadan erişilebilir bir seçenektir. Ayrıca, basit ve temel enstrümantasyon talepleri ile öne çıkar, bu da kullanıcıların karmaşık ekipmanlarla uğraşmak zorunda kalmadan bu yöntemi kullanmalarını kolaylaştırır. TD-MS-RAPD-PCR'nin kolay kullanılabilir yapısı, kullanıcıların hızlı ve güvenilir sonuçlar elde etmelerini sağlar. Bu özellik, herhangi bir laboratuvarda bu yöntemin yaygın olarak benimsenmesine olanak tanımaktadır. Sonuç olarak, ekonomik, basit, ve standart ekipmanlarla kullanılabilir olması, TD-MS-RAPD-PCR metodolojisinin geniş bir araştırma ve analiz alanında tercih edilen bir seçenek haline gelmesine olanak tanımaktadır. Bu çalışmanın sonuçları, NaCl uygulamasının DNA metilasyon seviyelerini arttırdığını belirten polimorfizm seviyeleri ile sağlamlaştırılmıştır.

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TEŞEKKÜRLER

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Pathogenicity of *Beauveria bassiana* (Balsamo) Vuillemin F7-1 on *Sitophilus oryzae* L. (Coleoptera: Curculionidae) Adults and the Effect of Ambient Humidity

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Abstract

Sitophilus oryzae causes considerable damage in stored grain. Considering sustainable agricultural practices biological control plays an important role in the control of this pest. In this study, the pathogenicity of a *Beauveria bassiana* isolate (F7-1) against *S. oryzae* adults and the effect of ambient relative humidity (RH) were investigated. For each experimental unit, fungal spores were applied to 40 gr wheat kernels within a 50 ml centrifuge tube. Thereafter, *S. oryzae* adults were placed in the tube. The tests were conducted at 26±2 °C temperature, 65±5% RH in darkness. The mortality of *S. oryzae* was recorded 7 and 14 later. For the pathogenicity test, spore concentrations were applied at 250, 500, 1000 and 1500 ppm. Increasing with the concentration, lethal effect reached to a maximum of 87.7%. According to the results of the experiment carried out to determine the effect of ambient relative humidity on fungal pathogenicity, adult mortality did not differ statistically at 65-75% RH. However, when RH was increased to 100%, the mortality reached to a statistically higher level of 91.6%. It is concluded that *B. bassiana* F7-1 has a considerable potential providing appropriate concentrations, and ambient humidity did not have a limiting effect except for extreme conditions.

Keywords: Rice weevil; Stored grain; Microbial control; Hypocreales

INTRODUCTION

Cereals and their products constitute an important share in nutrition in Türkiye, mosly due to the fact that the climate zone in which Türkiye is located is suitable for the cultivation of wheat and other cereals (Dizlek, 2012). According to FAO, wheat was cultivated on 6623061 ha area in Türkiye in 2021 (Anonymous, 2023). Harvested wheat needs to be stored and protected due to its consumption over a long period of time. During this post-harvest process, many abiotic and biotic factors have a significant impact on product quality and quantity. Unless appropriate precautions are not taken considering storage conditions and period, 10-20% loss can increase as high as 100% (Yıldırım et al., 2009). One of the biotic factors affecting stored products is insect pests. Rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae), a primary pest, can cause significant losses in wheat warehouses. In order to prevent this, biological, chemical and physical control methods can be applied after monitoring and decision-making processes (Hagstrum, 2014). Due to various negative effects of chemical insecticides, which are frequently used against stored product pests, many studies have been carried out on physical, mechanical and biological control methods as alternatives to insecticides (Yıldırım, 2000; Vincent et al., 2001; Lucas and Riudavets, 2002).

Chemical control is still the most widely used method in stored product insect pest management, but these chemicals have increased problems related with human health, environmental pollution, resistance of pests to pesticides and disruption of the natural balance (Bora and Özaktan, 1998). In addition to efforts to reduce these problems, sustainable agricultural practices, organic farming and activities for the conservation of biodiversity emphasize the use of alternative control methods instead

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of chemical insecticides. Therefore, the importance of biological control and studies in this direction have gradually increased. Among biological control agents, entomopathogenic fungi are considered as promising agents and studies on their development against stored grain pests were reviewed by Batta and Kavallieratos (2018). It was determined that damage and losses in stored products can be reduced with entomopathogenic fungus applications (Mantzoukas et al., 2022).

In the selection of entomopathogenic agents for insect control, initially two features are quite important; high efficacy against targeted pest and tolerance to environmental factors. Among the environmental factors, especially ambient humidity has a significant effect on entomopathogenic fungus activity (Demirci et al., 2011). Ambient humidity affects not only the germination of the fungal spores and crucial for initiation of infection, but also conidiation on dead insects and consequently dissemination of infection (Acheampong et al., 2020). Prior to studies on the utilization of entomopathogenic fungi, efficacy studies at a range of ambient humidity are required (Mishra et al., 2013). In this study, the effect of various concentrations of *B. bassiana* isolate F7-1, selected among 33 *Beauveria* isolates considering its pathogenicity (Şahin, 2015), on *S. oryzae* adults and the effect of ambient humidity on the performance of *B. bassiana* F7-1 were determined.

MATERIALS and METHODS

Insect culture

Rice weevil *Sitophilus oryzae* L. (Coleoptera: Curculionidae) culture in the laboratory of Plant Protection Department of Kahramanmaraş Sütçü İmam University was used. 'Elbistan yazlığı' whole soft wheat (*Triticum aestivum* L.) with 11-13% moisture content was used for the culture of *S. oryzae*. After placing 250 g of clean whole soft wheat kernels in a 1 l capacity glass jar, mixed gender adults were placed inside and the jar was covered with gauze and kept in a climate room at 26±2 ºC temperature and 65±5% relative humidity under completely dark conditions. After three days of oviposition, the adults were removed in jars. When the new generation of adults emerged, they were separated with the help of sieves and transferred to other glass jars containing clear wheat kernels to initiate new cultures. Care was taken to ensure that the adults used in the experiments were of the same age of 7-10 days.

Fungal culture

Beauveria bassiana isolate F7-1 was initially obtained from soil sample taken from a pistachio orchard and kept in fungal culture collection in Plant Protection Laboratory at Kahramanmaraş Sütçü İmam University. The fungal spores used in the experiments were obtained from cultures that completed sporulation after growning on PDA (potato dextrose agar) at 26±2 °C and 16/8 hours light/dark conditions for about one month. As described in Athanassiou and Steenberg (2007), these cultures were kept open overnight to reduce moisture, before collecting spores by vacuuming. They were kept on silica gel at +4 °C for a maximum of two days until use.

Experimental design

The wheat grain to be used for the experiments were sieved and kept at -18 ºC for 10 days to eliminate any possible previous pest infestation. Before used in the experiments the wheat was get to room temperature. For the mortality test with various concentrations of *B. bassiana* F7-1 on *S. oryzae* adults, 50 ml centrifuge tubes containing 40 g of wheat were used as experimental units and the top of the tubes were covered with gauze to ensure ventilation. After adding the required amount of fungal spores for designated concentration to each tube, they were mixing for 20 minutes on a mechanical horizontal shaker. Thereafter, twenty 7-10 days old mixed gender *S. oryzae* adults were placed into the tubes. In the control treatments, the setup was the same without fungal spores. Spore concentrations of 250, 500, 1000, 1500 ppm were used in the experiment. The study was carried out in a completely dark climate room at 26±1 °C temperature and 65±5% relative humidity. The experiment was established according to randomized plot experimental design with three replications and the experiment was repeated three times. Live/dead insect counts were made at the end of one and two weeks, and dead ones were removed from the test in the first count. Prior to the experiment, the germination rate of fungal spores was determined by examining under a light microscope at 40× magnification 24 hours after the spores were spread on PDA medium. The test was carried out under the same conditions as the fungal cultures. The germination rates were determined by counting at least 100 spores, and those with germ tubes at least as long as the spore length were considered as germinated. The process was repeated three times. The germination rate of the spores used in the experiment was 96-98%.

The test to determine the effect of ambient relative humidity on the performance of *B. bassiana* F7-1 was carried out in the same way and under the same conditions as the previous experiment described above. The units prepared with 1000 ppm spore concentration were kept at 65%, 75% and 100% relative humidity conditions during the experiment. 1000 ppm was chosen so that any increase as well as decrease in mortality can be detected under different relative humidity conditions. While 65% relative humidity was provided within the climate room, saturated NaCl solution for 75% humidity and pure water (500 ml each) for 100% relative humidity were ensured in plastic containers (22×20×23 cm) used as humidity chambers The lid of the plastic container was closed and sealed with a flexible tape to prevent air exchange.

Statistical analysis

The mortality rates obtained at 7 and 14 days after the treatment were corrected using Abbott's formula (Abbott, 1925) and then arcsine transformation (Zar, 1996) was applied. Data were subjected to one-way and two-way analysis of variance. Differences between treatments were analyzed by Duncan's test at 5% significance level. Where only two treatments were required to be compared, independent samples t test was used. Statistical tests were performed using SAS computer program (Proc GLM; SAS Ins., 2009).

RESULTS and DISCUSSION

The results of the experiment carried out to determine the effects of different concentrations of *B. bassiana* isolate F7-1 on *S. oryzae* adult mortality are presented in Table 1. It is found that as the fungal spore concentration increases, mortality rates also increase. As a result of the two-way analysis of variance, the concentration and exposure time had statistically significant effects on mortality rates (Concentration $F_{4,80}$= 191.50, P<0.0001; exposure time $F_{1,80}$= 89.90, P<0.0001; interaction $F_{4,80}$= 3.30, P<0.05). At the end of the 7th day, all concentrations caused statistically different mortality from each other, but according to the 14th day results, there was no statistical difference between 1000 ppm and 500 ppm in terms of the mortality they caused. The fact that it caused more than 50% mortality at 500 ppm after 14 days of the treatment and a very high mortality at 1500 ppm shows that this isolate is promising for the control of *S. oryzae*.

Table 1. *Mortality rates of Sitophilus oryzae adults on the 7th and 14th day after application of various concentrations of Beauveria bassiana F7-1 spores under three different ambient humidities*

Spore concentration	Mean mortality ± SEM (%)		t and P values
	7thday	14thday	
1500 ppm	75.5±4.5 Ab*	87.7±2.6 Aa	t(16)= 2.42, P=0.028
1000 ppm	46.6±3.8 Bb	66.1±1.3 Ba	t(16)= 4.77, P<0.0001
500 ppm	25.5±2.4 Cb	57.2±3.0 Ba	t(16)= 8.03, P<0.0001
250 ppm	16.1±2.1 Db	42.2±4.1 Ca	t(16)= 5.55, P<0.0001
Control	2.7±0.8 Ea	6.1±1.1 Da	t(16)= 2.08, P=0.054
ANOVA P and F values	$F_{4,40}$= 81.95 P<0.0001	$F_{4,40}$= 118.30, P<0.0001	

*One-way analysis of variance and Duncan test (P≤0.05) were used for spore concentrations. Mortalities on two days were compared by t tests (P≤0.05). Different capital letters in the same column and different lower case letters in the same row are statistically different from each other.

The results of the experiment on the effect of ambient relative humidity on the performance of *B. bassiana* F7-1 are shown in Table 2 and Table 3 for the 7th day and 14th day, respectively. As can be seen from Table 1, mortality rates were almost the same in the first 7 days at 65% and 75% RH, while an increase was noticed at 100% humidity. As a result of the analysis of variance performed on the data obtained at the end of the 7th day, it was determined that humidity had a statistically significant effect on mortality rates (Humidity $F_{2,48}$ =22.98, P<0.0001, Concentration $F_{1,48}$ = 589.27, P<0.0001; and interaction $F_{2,48}$ = 6.34, P<0.01). ANOVA results were similar to those of 7th day data; humidity had a statistically significant effect on mortality rates (Humidity $F_{2,48}$ = 13.79, P<0.0001, concentration $F_{1,48}$ = 740.36, P<0.0001; interaction $F_{2,48}$= 8.62, P<0.001). According to the results at the end of the 14th day, there was no statistical difference between 65% and 75% RH in terms of mortality caused by the fungus. However, 100% RH resulted in a statistically significant high insect mortality.

Table 2. *Mortality rates of Sitophilus oryzae adults 7 days afterapplication of 1000 ppm Beauveria bassiana F7-1 spore concentration under three different ambient humidities*

Treatments	Mean mortality ± SEM (%)			ANOVA F and P values
	% 65	% 75	% 100	
B. bassiana F7-1	46.6±3.8 Ab*	47.2±2.3 Ab	77.7±4.1 Aa	$F_{2,24}$= 24.14 P<0.0001
Control	0.5±0.5 B	2.2±0.8 B	4.4±1.3 B	-
t and P values	t(16) =15.665 P<0.0001	t(16)=14.194 P<0.0001	t(16) =13.416 P<0.0001	

*One-way analysis of variance and Duncan test (P≤0.05) were used for relative humidities. Mortalities of treatment and control were compared by t tests (P≤0.05). Different capital letters in the same column and different lower case letters in the same row are statistically different from each other.

***Table 3.** Mortality rates of Sitophilus oryzae adults 14 days after application of 1000 ppm Beauveria bassiana F7-1 spore concentration under three different ambient humidities*

Treatments	Mean mortality ± SEM (%)			ANOVA F and P values
	% 65	% 75	% 100	
B. bassiana F7-1	66.1±1.3 Ab*	75.5±1.9 Ab	91.6±2.6 Aa	$F_{2,24}$= 24.53 P<0.0001
Control	2.7±0.8 B	5.0±1.4 B	5.0±1.4 B	-
t and P values	t(16)=19.475 P<0.0001	t(16)=16.533 P<0.0001	t(16)=14.421 P<0.0001	

*One-way analysis of variance and Duncan test (P≤0.05) were used for relative humidities. Mortalities of treatment and control were compared by t tests (P≤0.05). Different capital letters in the same column and different lower case letters in the same row are statistically different from each other.

According to the results of the experiment on the relationship between fungal spore concentration and insect mortality rate, it was revealed that the mortality rate increased with increasing spore concentration. According to the 14th day results, while there was no statistical difference between 1000 ppm and 500 ppm, at the highest concentration tested (1500 ppm) 87.7% mortality was recorded. Vassilakos et al. (2006) also used different concentrations (2500, 5000, 10000ppm) and observed that *S. oryzae* mortality increased as the concentration increased. In the study by Ramswamy et al. (2009 two different concentrations were used and 500 ppm resulted in higher insect mortality than 250 ppm. The results obtained in this study confirm the results reported in the literature. Sewify et al. (2014) evaluated the pathogenic effect of *B. bassiana* and found a concentration of 0.35×10^7 conidia.gr^{-1} and found a 64% mortality effect on *S. oryzae*. Bello et al. (2000) recorded 74.17% *S. oryzae* mortality with the combination of *B. bassiana* ARSEF 5500 + *M. anisopliae* ARSEF 2974 + 3 ppm fenitrothion. Although a high mortality rate (80%) was reached in the study conducted by Rice et al. (1999), the fact that immersion method (using suspension of 2×10^8 conidia.ml^{-1}) was chosen for application in their experiment and the evaluation was carried out on the 21st day enabled them to reach a higher mortality rate. In the study of Vassilakos et al. (2006), 95% mortality of *S. oryzae* adults was obtained at a high concentration of 2500 ppm of *B. bassiana*. Considering the results of all these studies, the results obtained in present study show that *B. bassiana* F7-1 is as effective against *S. oryzae* as the isolates reported in the literature, and even higher than those at similar conditions.

In the experiment carried out to evaluate the relationship between ambient humidity and the efficacy of isolate F7-1, significant increase in mortality rate was detected only at the highest humidity (100%). Although the mortality rate at 75% RH was higher than that at 65% humidity, no statistical difference was found, and the treatment at 100% humidity caused statistically higher mortality (96.6%). In a research by Sheeba et al. (2000), the experiment was conducted at 70% RH and mortality rate was found as 75%. In Batta's (2003) study, 73.3-86.7% mortality was reached in *S. oryzae* at 75% RH by using additives (furnace ash, chalk powder, charcoal and wheat flour) to increase *M anisopliae* efficacy. As a result of decreasing the RH from 75% to 55%, an increase in mortality rate was found for *Rhyzopertha dominica* (Wakil et al., 2011) and *Tribolium confusum* (Michalaki et al., 2006).

All the results together indicate that the effect of the fungus on storage pests does not increase in direct proportion to increasing RH. However, in this study, when the RH was increased to 100%, the mortality rate also increase.

CONCLUSION

It was concluded that the *B. bassiana* isolate F7-1 examined in present study is a potential agent for the microbial control of *S. oryzae*, and that except in extreme relative humidity environments, differences in ambient humidity did not make a significant difference in the ability of *B. bassiana* F7-1 to control *S. oryzae* adults. This result indicates that ambient humidity will not be a limiting factor if *B. bassiana* F7-1 can be used against *S. oryzae* in future studies..

CONFLICTS of INTEREST

The authors declare there is no conflict of interest.

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From Fertilizer to Disease Control: Study of the Relationship between Fertilizer Applications and Bacterial Fruit Blotch Disease

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Abstract

In this research, the effects of different doses of nitrogen (Ammonium sulfate) and phosphorus (Triple superphosphate) fertilizers given in combination in melon cultivation on the growth of bacterial fruit blotch caused by *Acidovorax citrulli* were examined. The experiment was conducted with a randomized plot design that consisted of three replications. The study included recommended optimal doses, 25%, 50%, and 100% more than the optimal dose, as well as a control group that did not receive any fertilizer application. The findings of the study revealed that the application of the optimal fertilizer dose caused the least disease severity (27.78%), while 55.56% disease severity was determined in the pathogen (control) application only, while the disease severity was highest when the fertilizer dose was increased by 100% more than the optimal dose. The results indicate a direct association between the amount of fertilizer applied and the intensity of disease severity, where in a greater severity of disease is noted with higher doses of fertilizer.

Keywords: *Acidovorax citrulli*, Disease severity, Fertilizer dosage, Nitrogen fertilizer, Phosphorus fertilizer

INTRODUCTION

Bacterial fruit blotch disease caused by *Acidovorax citrulli* is a serious and destructive disease that affects various cucurbit crops, particularly melons and watermelons, during seedling and fruiting stages (Schaad et al., 2003). This seed-borne pathogen is responsible for significant economic losses in many parts of the world (Latin and Hopkins, 1995; Demir, 1996; Burdman and Walcott, 2012). Environmentally friendly methods that increase yield and improve product quality are crucial for plant disease control (Batish et al., 2007; Camprubí et al., 2007). Therefore, it is necessary to determine practices that prevent or minimize the occurrence of bacterial fruit spot disease in cucurbit crops during the growing period. Plant nutrition is an integral component of an integrated plant protection program in sustainable agriculture (Dordas, 2008). Proper nutrient application via fertilization is critical for improved agricultural production. While plant resistance to disease is largely genetically controlled, nutrient deficiencies or excesses can also affect resistance. Plant nutrients can function as attractants or repellents for pathogens and can trigger resistance or tolerance mechanisms in the host plant (Agrios, 2005). Furthermore, they influence the growth rate of the host plant, protecting seedlings from infection during the stage when they are most vulnerable to pathogens (Krauss, 1999).

Optimal fertilization is known to reduce plant susceptibility to disease, as fertilization has a significant impact on plant resistance to disease. However, nutrients are also essential for the growth and development of microorganisms, which utilize these nutrients in substantial amounts (Agrios, 2005). Pathogens can cause a reduction in the availability of essential nutrients for the plant they infect, leading to increased plant susceptibility to disease due to nutrient deficiency (Dordas, 2008). The three most important nutrients that influence plant response to microbial pathogens are nitrogen (N), phosphorus (P), and potassium (K), which are directly related to plant resistance (Huber and Haneklaus, 2007; Rahman and Punja, 2007). Nitrogen is a crucial element in the production of essential compounds and

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is used by plants in the production of compounds involved in defense against pathogens, such as phytoalexins and other antimicrobial molecules (Huber and Thompson, 2007). Phosphorus is the second most widely used nutrient in many agricultural crops and is part of many organic molecules of the cell, such as deoxyribonucleic acid (DNA), ribonucleic acid (RNA), adenosine triphosphate (ATP), and phospholipids. It also plays a significant role in many metabolic processes in plants and pathogens (Bolat and Kara, 2017). Potassium (K) is an essential nutrient that plays an active role in most of the biochemical and physiological processes that affect plant growth. It increases the resistance of plants to various biotic and abiotic stress factors (Marschner, 2011; Wang et al., 2013).

Studies have reported that the impact of elements on the development of disease agents can vary, and some elements can have a positive or negative effect depending on the specific forms and concentrations of nutrients (Saygılı et al., 2006; Marschner, 2011). Therefore, it is important to understand the specific effects of nutrients on a particular pathosystem, and it is not possible to directly apply the knowledge from one pathosystem to another. Additionally, determining the optimal nutrient amounts for disease control is crucial. However, there is limited research on the role of nutrients in *A. citrulli* and melon pathosystems (Zimerman-Lax et al., 2016). Thus, the present study aimed to investigate the impact of different doses of nitrogen and phosphorus solutions on the severity of bacterial fruit spot disease in melon seedlings.

MATERIALS and METHODS

Pathogen strain and plant material used in the study

In this study, *Acidovorax citrulli* KVN 21 strain, isolated by İnik (2019) from melon plants showing bacterial fruit blotch symptoms in Iğdır province and determined to have the highest virulence within the scope of his master's thesis study, was selected as the pathogen (İnik, 2019). The commercial Sürmeli F1 melon variety was chosen as plant material.

Soil preparation for pots

Before the study, soil samples were dried in an oven at 105°C until reaching a constant weight. The moisture content of the soil was kept constant by weighing the pots at three-day intervals and adding water when needed to maintain a field capacity of at least 70%. Routine analysis of the pot soils revealed that 2 kg da^{-1} N, 1.6 kg da^{-1} P_2O_5, and 9 kg da^{-1} K_2O were present, and these values were used to determine the appropriate N and P nutrient levels for the melon plants. Soil physical and chemical properties were determined by commonly used methods for calcareous soils (Kacar, 2009). It has been reported that melon plant needs 10 kg da^{-1} N and 9 kg da^{-1} P_2O_5 and 10 kg da^{-1} K_2O nutrients during the growing period (Güçdemir, 2006). As a result of the analysis, potassium fertilizer was not required since the existing soil was sufficient to meet the potassium needs of the plant. In the light of this information, the nitrogen, ammonium sulphate and phosphorus required by the melon were met by using Triple super phosphate fertilizers. The experiment was set up according to the random plot design, arranged to contain 1 kg of soil in each pot, and was carried out in 3 replications. Fertilizers were applied to the soil in combination with planting. The study included 5 different applications: optimum fertilizer dose, 25%, 50%, 100% more than the appropriate fertilizer dose and pathogen (control). The optimum dose for nitrogen fertilizer was determined as 2 g and for phosphorus fertilizer as 2.2 g, and other doses were adjusted accordingly. No fertilizer was given in the pathogen application.

Preparation of pathogen inoculum and determination of disease severity in plants

To prepare the pathogen inoculum, the strains were streaked onto Nutrient Agar (NA) medium and incubated at 27°C for 48 hours. After the melon seeds were disinfected with 2% sodium hypochlorite, two seeds were planted in each pot containing sterile soil and the experiment was set up with 3 replications. Then, fertilizer solutions prepared at different doses were added to the pots. The bacterial colonies were then transferred to Nutrient Broth (NB) medium and incubated overnight at 150 rpm min^{-1} on a shaker at 27°C. The resulting bacterial solution was diluted with sterile distilled water (sdH_2O) to a concentration of 10^8 CFU ml^{-1} using a turbidimeter. Plants were kept under laboratory conditions and inoculated by spraying the pathogen solution with a density of 10^8 CFU ml-1 on the above-ground parts of the plants when they reached the 4-5 leaf stage. The pots were then covered with polyethylene bags for 48 hours. Disease severity values were determined two weeks after pathogen inoculation using the 0-6 scale (0=no symptoms; 1=1-5% symptomatic leaf; 2=6-12% symptomatic leaf; 3=13-37% symptomatic leaf; 4=38-62% symptomatic leaf; 5=% 63-87 symptomatic leaves and 6=88-100% symptomatic leaves or dead plants) developed by Carvalho et al. (2013). The % disease severity in seedlings was calculated according to the equation 1 by Thowsend and Heuberger (1943), and % effect values were determined using the Abbott (1925) formula and compared to the control (Equation 2).

Severity Disease %= Σ[E(scale value×number of plants evaluated on the scale)/ (highest scale value×total number of plants)]x100 (1)

Effect %=[(X-Y)/X]x100

X; Disease Severity in Control, Y; Disease Severity in Application (2)

Statistical analysis

The disease severity data obtained as a result of the experiment were analyzed by one-way ANOVA using R studio program and the difference between the applications was determined by Duncan multiple comparison test ($p \leq 0.01$) Rstudio version 4.3.0 software (R Core Team, 2023).

RESULTS and DISCUSSION

In this study, the effect of different fertilizer doses on the development of bacterial fruit spot disease caused by *Acidovorax citrulli* in melon was evaluated. The data obtained as a result of the experiment are given in Table 1. The severity of the disease was found to be significantly different among the applied fertilizer doses, with the lowest disease severity occurring at the optimum fertilizer dose and the highest at 100% more than the optimum dose. The study showed that disease development increased with increasing fertilizer dose, and the optimum dose was necessary to prevent the development of *A. citrulli*. The % effect of different fertilizer doses on disease development is presented in Figure 1. The control treatment without fertilizer showed 55.56% disease severity, which was considered normal, as plants require the necessary nutrients for growth and development.

***Table 1.** The influence of nutrient management on Acidovorax citrulli growth and disease development in melon*

Applications	Scale Values	Disease Severity (%)
OFD**	1.67±0.33b*	27.78
25% more than OFD	3.17±0.45ab	52.78
50% more than OFD	4.33±0.17a	72.22
100% more than OFD	4.50±0.29a	75.00
Control	3.33±0.73ab	55.56

*: There is no statistical difference between the values shown with the same letter and the values are the average of three replicates ($p \leq 0.01$)., OFD**: Optimum fertilizer dose

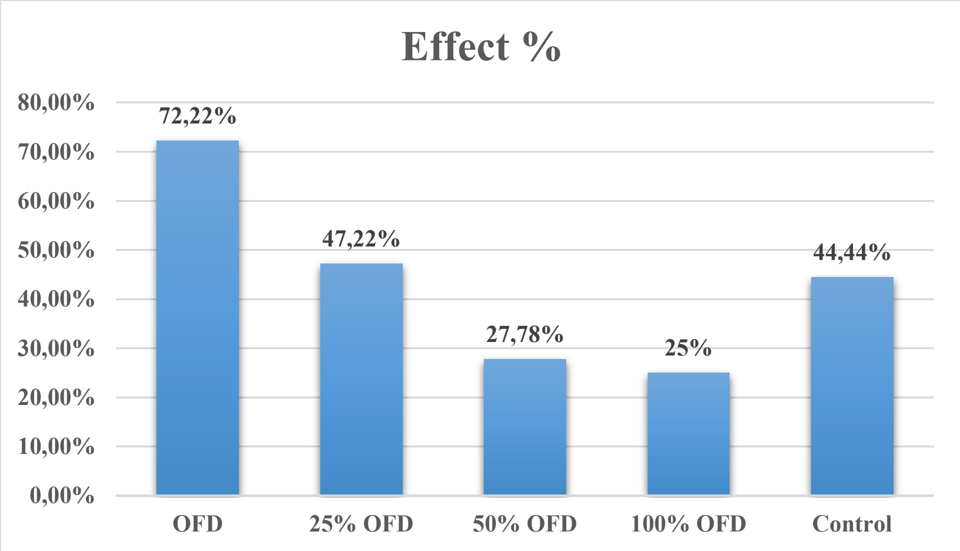

Figure 1 *Effect of different doses of fertilizer applications on bacterial fruit blocth disease in melon.*

In the current study, the optimum fertilizer dose recommended in melon cultivation and the effect of different levels of this dose on the development of *A citrulli* were investigated and it was determined that the optimum dose of fertilizer was the most effective application in suppressing the disease. In the study, the disease severity was determined at a rate of 55.56% in the control application without fertilizer. Since the growth and development problems that occur in plants in the absence of the nutrients needed by the plants are known, this result was accepted as usual. It was determined that as the applied fertilizer dose increased, the disease severity increased and the highest disease severity (75%) occurred in the application where 100% more than the optimum dose was given.

It has been reported in various studies that plant nutrients play a critical role in stress (biotic and abiotic) resistance of plants (Cakmak, 2005; Amtmann et al., 2008; Römheld and Kirkby, 2010) as well as contributing to plant growth by increasing soil fertility (Esringü et al., 2016). Zimerman-Lax et al. (2016) investigated the effect of different nitrogen fertilizer applications against *A. citrulli* and reported that the treatments affected the expression of resistance genes such as HPL (hydroperoxide lyase), PDF1.4 (defensin) and PRX34 (peroxidase) and nitrate fertilization as a nitrogen source significantly reduced disease development. In various studies, it has been reported that the appropriate doses of nutrients required for plants reduce the incidence of disease in plants and this is due to the role of nutrients in the tolerance or resistance mechanisms of the host plant (Celar, 2003; Öborn et al., 2003; Sharma et al., 2005; Dordas, 2008; Nicolas et al., 2019). Therefore, it is necessary to provide sufficient amounts of nutrients necessary for the stimulation and synthesis of antimicrobial compounds present in the plant. Thus, phytoalexins, phenols, flavonoids and other defense compounds with inhibitory effects accumulate around the site of infection (Huber and Haneklaus, 2007).

CONCLUSION

In this study, we aimed to investigate the effectiveness of different fertilizer doses in controlling bacterial fruit spot disease caused by *Acidovorax citrulli* in cucurbitaceae plants, which is known to cause significant yield losses. The results of the study showed that the application of fertilizer at the recommended optimum dose was the most effective in preventing the pathogen. The findings highlight the crucial role of plant nutrients in modulating the interplay between host plant resistance and pathogen virulence and emphasize the importance of maintaining an adequate level of nutrient supply to sustain high levels of disease resistance. Notably, our results also indicate that excessive fertilizer use can lead to increased disease severity, as higher nutrient concentrations can enhance the susceptibility of plants to pathogen attacks. Overall, our findings suggest that careful nutrient management is essential for maintaining plant health and preventing disease outbreaks in Cucurbitaceae crops.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Pupal Parasitoids of the Hessian Fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae) in Cereal Fields in Northern Cyprus

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Abstract

The Hessian fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae), is the primary pest insect affecting barley and wheat fields in Northern Cyprus. This research aimed to identify the pupal parasitoids of *M. destructor*. Field studies were conducted in three locations representing Lefkoşa, Girne, Güzelyurt, Gazimağusa, and İskele during the cereal production seasons of 2012-2013. In each field, 100 plants were uprooted and placed in plastic bags, then kept in boxes covered with nets in the laboratory at 25±1°C and 65±5% relative humidity during the spring season. As a result of the studies revealed *Arthrolytus maculipennis* (Walker), *Meraporus graminicola* Walker (Pteromalidae), and *Eupelmus microzonus* Folster (Eupelmidae) species from the Hymenoptera order (Chalcidoidea). *A. maculipennis*, with a prevalence rate of 59.6%, was found to be widespread and predominant, followed by *M. graminicola* at 22.8% and *E. microzonus* at 17.6%. While *E. microzonus* was newly recorded in the fauna of Cyprus, both *A. maculipennis* and *M. graminicola* were documented for the first time in this study in the Cyprus fauna.

Keywords: Hessian fly, *Mayetiola destructor*, pupal parasitoid, Northern Cyprus

INTRODUCTION

The cereal cultivation has an important share in agricultural areas in Northern Cyprus. Of the 880,446 decares of arable land, 660,380 decares consist of cereal (Anonymous, 2019). Among cereals, barley ranks first with a share of 82.5%, followed by wheat with 17%. Known as the Hesse fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae) is one of the most significant pests in cereal fields in Cyprus.

The Hessian fly is considered a serious pest in all areas where barley and wheat grow. If this pest is not controlled, it can cause significant yield losses in both barley and wheat (Painter, 1951; Lafever et al., 1980; Wellso et al., 1987; Chapin et al., 1989; Lhaloui et al., 1992; Buntin, 1999). Therefore, the population of the Hessian fly is regularly monitored in North America and Western Mediterranean countries. Especially, in Morocco, losses attributed to *M. destructor* have been recorded at 42% in bread wheat (*Triticum aestivum* sub. sp. *aestivum* L.) and 32% in durum wheat (*T. turgidum* sub. sp. *durum* L.) (Lhaloui et al., 1992a; Lhaloui et al., 1992b). Although the biological development of the Hessian fly varies from region to region, the pest produces 2-3 generation per year (Lhaloui, 1995; Konuksal et al., 2016). The females of *M. destructor* live for 1-4 days (Bergh et al., 1990; Harris and Rose, 1990). Larvae, hatched from approximately 250-300 elliptical, red-orange-colored eggs laid on the upper surface of cereal leaves, begin feeding within leaf sheaths within 12-24 hours (Hamilton, 1966).

There are three larval stages, during which the first and second stage larvae feed, and these two stages last approximately 2-3 weeks (Foster and Hein, 2009). The mature larval (third instar) and pupal stages vary between 7 and 35 days, depending on environmental factors. Damaged plants become dark green and remain stunted, causing them to dry out in the future.

The lack of sufficient knowledge about the biology of the insect and uncertainty about the timing of spraying reduce the success of chemical applications. Therefore, methods such as cultivating resistant varieties, late sowing, and controlling weeds should be preferred.

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Alongside these, biological control agents are also important in suppressing the population of the fly. So far, 55 species belonging to the families Aphelinidae (3), Encyrtidae (1), Eulophidae (9), Eupelmidae (6), Eurytomidae (3), Pteromalidae (25), and Torymidae (8) of the order Hymenoptera, superfamily Chalcidoidea, have been identified as egg, larval, and pupal parasitoids of the Hessian fly, which is found in many parts of the world.

This study was carried out to determine the pupal parasitoids of *M. destructor*, which was the main pest in Northern Cyprus cereal fields during the 2012-2013 cereal production season.

MATERIALS and METHODS

The studies were conducted three each fields representing the districts of Lefkoşa, Girne, Güzelyurt, Gazimağusa, and İskele between February and March during the 2012-2013 cereals production season. Samples were collected from 10 different parts of each field with 10 infected plants with their roots. Plants with pupae were distinguished under stereo-microscope. Then, the upper part of these plants was by cut (15 cm above the root collar), only root section was cultured in plastic jars with mesh-covered openings, maintained at a temperature of 25°C and a relative humidity of 60±10% in the laboratory. The obtained adult parasitoids were preserved in 70% ethyl alcohol for diagnostic purposes.

RESULTS and DISCUSSION

A total of 57 parasitoids were reared from pupae of Mayetiola destructor (Say) (Diptera: Cecidomyiidae) from barley fields of Northern Cyprus (Lefkoşa, Girne, Güzelyurt, Gazimağusa, and İskele) in the 2012-2013 cereals production season. The species obtained were *Arthrolytus maculipennis* (Walk.), *Meraporus graminicola* Walker (Pteromalidae), and *Eupelmus microzonus* Folster (Eupelmidae) species of the superfamily Chalcidoidea of Hymenoptera order. *Arthrolytus maculipennis* (Walk.) is known as a parasitoid of both *M. destructor* and *M. avenae* (Marchal) (Graham, 1969). When examining the distribution of this parasitoid worldwide, it is observed to be distributed in Bulgaria (Thuroczy, 1990), the Czech Republic (Kalina, 1989), France (Graham, 1969), Germany (Vidal, 2001), Hungary (Herting, 1978), Italy (Vidal, 1997), Moldova (Boucek, 1965), the Netherlands (Gijswijt, 2003), Russia (Tselikh, 2011), Spain (Garrido & Nieves Aldrey, 1999), Sweden (Hansson, 1991; Hedqvist, 2003), the United Kingdom (Boucek & Graham, 1978), and England (Thomson, 1958).

Hosts identified for the parasitoid include *Phorbia genitalis* (Schnabl, 1911) (Diptera, Anthomyiidae), *Clinodiplosis piceae* Kieffer, 1920, *Mayetiola destructor*, *M. avenae* (Marchal, 1895) (Diptera, Cecidomyiidae), and *Elachista klimeschi* Parenti, 1981 (Lepidoptera, Elachistidae) (Noyes, 2012). *A. maculipennis* was added to the insect fauna of the island for the first time in this study.

Meraporus graminicola was recorded in the Palearctic region, including Belgium, the Canary Islands, the Czech Republic, Denmark, the Faeroe Islands, Iran, Germany, Hungary, Iceland, Moldova, Morocco, the Netherlands, North Africa, Norway, Romania, Russia, Serbia, Slovakia, Spain, the Balearics, Sweden, Switzerland, the Transcaucasus, Ukraine, the UK, and the former Yugoslavia (Ghahari et al., 2015). This species has been reported as a parasite of *Mayetiola* sp. (Askew et al., 2001). *M. graminicola* was added to the insect fauna of Cyprus island for the first time through this study.

Eupelmus microzonus was found in the Nearctic (Canada) and Palaearctic regions (Gibson, 2011). Additionally, Noyes (2014) listed over 25 countries across the Palaearctic, including North Africa (Morocco) and the Middle East (Iran).

Noyes (2014) listed over 20 species of Cynipidae as well as five species of Eurytomidae (Hymenoptera), plus one or more species in Apionidae, Bruchidae, and Curculionidae (Coleoptera), Cecidomyiidae, Chloropidae, and Tephritidae (Diptera), and Lasiocampidae, Psychidae, and Pyralidae

(Lepidoptera). This species was reported in Cyprus (Anonymous, 2024). The number and relative abundance of pupal parasitoids obtained in the studies are shown in Table 1.

Table 1. *Pupal parasitoids species of Mayetiola destructor (Say) and their relative abundance*

Parasitoids	Number of species	Relative abundance
Arthrolytus maculipennis (Walk.)	34	59,6
Meraporus graminicola Walker	13	22,8
Eupelmus microzonus Folster	9	17,6

Among these species, *A. maculipennis* was identified as the most abundant and widespread, followed by *M. graminicola* and *E. microzonus*. Many species of Chalcidoidea (Hymenoptera) are known to attack the pupae of the Hessian fly. Morrill (1982) and Pike et al. (1983) reported that these parasitoids caused Hesse fly population reductions of 55%, 87%, and 98% in Georgia, Texas, and Washington cereal fields, respectively. Schuster and Lidell (1990) also recorded that parasitism rates in Texas wheat fields ranged from 0% to 87%. Larvae of the Hessian fly feeding on cereal roots cause the main damage. Since parasitization during the pupal stage mostly occurs in the spring population, it does not have a significant impact on preventing damage. However, it possesses biotic potential that can affect the decline of Hessian fly populations in the following season. Schuster and Lidell (1990) stated that parasitoids active in late spring do not protect the current crop but reduce the numbers of Hessian flies entering the summer season.

CONCLUSION

Arthrolytus maculipennis, *Meraporus graminicola* and *Eupelmus microzonus* species were identified as pupal parasitoids of *Mayetiola destructor* in Northern Cyprus. Among these specimens, *A. maculipennis* emerged as the most prevalent and abundant species. These parasitoids play a crucial role as effective biological adversaries in decreasing the Hessian fly population in subsequent growing seasons. Furthermore, it is evident that the cultivation of resistant varieties, post-harvest soil cultivation, combating with alternate host plants, and adjusting the timing of planting, along with reducing chemical usage, would be more effective in reducing the population of the Hessian fly and protecting the crop. The winters are short and rainy in Cyprus and this climate is quite suitable for Hessian fly development. Therefore, it is thought that it would be useful to evaluate these parasitoids in IPM in order to increase their effectiveness in future studies.

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AUTHOR CONTRIBUTIONS

The authors have contributed equally to this study.

CONFLICT of INTEREST

The authors declare there is no conflict of interest.

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Safety Measures and Risk Management in Agricultural Confined Spaces: A Study on Farm in Iğdır Province, Using Bow tie and Matrix Methods

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Abstract

In agriculture, confined space operations present significant hazards and increased risks to workers and emergency responders. When designing training initiatives to reduce confined space fatalities, it is imperative to assess human characteristics such as skill levels, gaps in understanding and attitudes toward risk in order to formulate effective programs. The aim of this study is to determine the safety practices and risk levels of farm owners operating in agricultural confined spaces in Iğdır province. To accomplish this, the first step was to semi-quantitatively assess the risks that can occur when working in confined spaces such as manure and silage storage facilities using a five-tier matrix, and to visualize the results using a bowtie diagram. In these confined spaces, the lack of atmospheric conditions was identified as the greatest source of danger, and therefore, these risks were prioritized (l: 5, s: 5, RS: 25). The risk of fire and explosion, which can be caused by the presence of contaminants in such areas, was assessed as quite high (RS: 20). Structured protocols or comprehensive frameworks are essential for identifying and mitigating the risks inherent in indoor work environments. Currently, there is a notable lack of an organized and reliable methodology specifically tailored to assess and manage the risks associated with working in confined spaces in agricultural activities. Recognizing this deficiency, it is proposed to establish procedural guidelines aimed at preventing and managing the risks associated with confined space work within the agricultural domain. The methodologies employed herein combine concepts and requirements outlined in various regulatory frameworks governing safe practices in confined spaces, with the goal of facilitating both risk assessment and management efforts. In addition, it is suggested that the personal proximity of ranchers to potential injuries in the field may serve as a critical indicator for improving safe work practices and risk awareness. This approach has the potential to enhance the safety knowledge of owners and their perception of risk-taking behaviors, thereby reducing the likelihood of injuries associated with agricultural enclosures.

Keywords: Agriculture, confined space, occupational risks, bow tie method

INTRODUCTION

Crop and animal production activities are among the sectors that pose significant risks due to the nature of the processes carried out. Statistics for 2022 show that occupational accidents in this sector have reached serious levels. In that year, a total of 3113 occupational accidents occurred in enterprises operating in crop and animal production (SGK, 2024). The data on the consequences of these accidents are worrying; 19 of these accidents unfortunately resulted in fatalities. Data on the number of employees affected by occupational accidents further illustrates the extent of the problem. The vast majority of workers injured in accidents required more than five days of treatment, including 886 people. This situation shows that occupational accidents are not only limited to the loss of working hours, but also cause serious health problems (Güğercin and Baytorun, 2018).

Activities in the agriculture and livestock sectors come with a variety of jobs, materials and equipment. This diversity increases the risk of occupational injuries and illnesses. However, workers in the sector feel unable to avoid risky behavior even when they are aware of the risks (Özel and Güğerçin,

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2020). Research emphasizes the need to improve safety in agricultural confined space work. A study by Issa et al. (2013) shows that grain entrapment was a significant problem in the US between 1964 and 2013. More than 1650 fatal and non-fatal accidents have been documented in these scenarios. Additionally, there were 77 fatal incidents recorded in animal waste handling and storage operations (Riedel and Field, 2011). Another study conducted by Beaver and Field (2007) revealed that there were 77 fatalities associated with manure storage operations between 1975 and 2004. These incidents involved individuals engaged in rescue operations who were cognizant of the risks posed by manure storage facilities. Within the agricultural sector, numerous confined spaces exist, including bulk feed silos, grain storage silos, grain dryers, manure storage pits, above-ground manure storage tanks, silage ditches or bunkers, oxygen-limited vertical silos, milk storage tanks, methane digesters, liquid manure spreaders, gravity flow grain wagons, grain trucks, chemical storage tanks, transport vehicles, fermentation tanks, and bulk milk tanks. These areas present potential hazards to agricultural workers. Research indicates that fatalities in feed storage structures also constitute a significant concern (Riedel and Field, 2011).

In Turkey, statistics on occupational accidents and occupational diseases started to be kept regularly in the early 2000s. Accident statistics are not recorded in detail without classifying the type of accident and the point of occurrence. Since accidents occurring in the agricultural sector are classified in general activity areas, there is no statistics classified under the name of confined space. Actually, in 2023, 12 people were injured, 1 dead and 2 seriously injured, as a result of an explosion caused by a dust explosion in the grain storage areas of the Turkish Grain Board (TMO) in Derince District of Kocaeli Province (TRT, 2023). In a similar case in December 2023, a worker who went to a wheat silo for cleaning in Mardin fell into the silo, drowned and lost his life (TG, 2023). In August 2023, in Şanlıurfa, a worker who went down a water well to fix a malfunction in a water pump was electrocuted and lost his life (DHA, 2023). These incidents are quite tragic as they usually result in death. It is not known why workers continue to enter agricultural confined spaces despite knowing the potential hazards in the agricultural sector. Aktuna (2019) stated that the problems experienced by people during work in agricultural activities, their past experiences cause differences in accident precaution levels and occupational perceptions. This situation affects the level of accident perception, especially when they are less educated and older due to the nature of the sector (Günaydın et al., 2018). Unsafe acts are generally accepted to be caused by human factors such as employee behavior, skill or lack of knowledge.

Confined spaces are very hazardous environments where toxic-explosive gases or dusts are present that may be insufficient oxygen level of farmers with the agricultural methods used recently (Kirkhorn and Schenker, 2002). A farmer who enters a confined space, such as a manure pit, silo, grain silo, or a poorly ventilated building, may be at risk of exposure to gas or dust, which can cause permanent lung damage or death (Kirkhorn and Garry, 2000). Manure pits and silos, as well as grain elevators, are dangerous areas for farmers. Toxic gases involve several hazards, such as the risk of suffocation and crushing (Cheng and Field, 2016). Hydrogen sulfide can be asphyxiating and deadly; It can lose its smell over time, creating a false sense of security (Zhao et al., 2008). Ammonia has a pungent odor and can irritate the eyes and respiratory system (Kirkhorn and Garry, 2000). Carbon dioxide, on the other hand, is a colorless, odorless and suffocating gas, it can consume enough oxygen and lead to suffocation (Kirkhorn and Garry, 2000). Exposure to these gases can cause serious health problems in farmers. Dusts are a common hazard in agriculture and can seriously affect farmers' health (Murphy and Manbeck, 2014). Organic or toxic dusts can cause irritation to the respiratory tract and lead to permanent diseases such as "Farmer's Lung". These diseases can increase susceptibility to respiratory infections and permanently affect lung function (Hoppin, 2007). Working in dusty environments can reduce the elasticity of the lungs and significantly reduce respiratory capacity. Therefore, it is important for farmers to use proper respiratory equipment and avoid dusty environments.

Attitudes towards safety programs to be implemented in agricultural activities are often negative, especially when implemented by employees with no farming experience (Akpınar and Özıldırım, 2016). Therefore, there is a need to develop security programs that can be implemented by industry employees. Creating a training program that addresses potential deficiencies in employee safety awareness and risk tolerance could serve to reduce the likelihood of injuries and fatalities associated with agricultural fencing. When formulating training strategies to minimize confined space fatalities in agriculture, it is essential to evaluate human characteristics such as employee skills, depth of understanding and risk acceptance within the industry. This assessment is critical to developing programs that effectively address the needs of the workforce and promote a culture of safety (Yeşilbaş, 2021).

The primary objective of this research is to determine the prevailing safety protocols and hazards associated with confined spaces in agricultural settings among farmers and employees. The primary objectives of this study include: defining the concept of agricultural confined spaces, assessing the inherent risks associated with working in such environments, evaluating the use of safety and rescue equipment by farm owners and employees when entering agricultural confined spaces, and defining the necessary actions to be implemented through a model confined space risk assessment within the regulatory framework.

MATERIALS and METHODS

Qualitative risk assessment methodologies primarily rely on the experiential insights and judgments of the risk assessment team. These approaches utilize descriptive terms such as "rarely," "unexpected," "possible," "likely," or "almost certain" to characterize the probability of potential undesirable events, while emphasizing terms like "fatal" or "serious" to denote the anticipated magnitude of their impact. Conversely, terms such as "minor" or "insignificant" are commonly employed to describe the extent of potential damage (Yılmaz and Şenol, 2017). Qualitative methodologies often incorporate qualitative scales to evaluate subjective criteria. Consequently, risk assessment emerges as a subjective undertaking, inherently susceptible to errors.

The predominant representative of these risk assessment methodologies is known as the risk matrix or risk rating matrix. These methodologies essentially serve as foundational techniques within the realm of semi-quantitative and quantitative risk assessment methods. Risk matrices are frequently employed by risk assessors to establish a coherent correlation between the likelihood of hazards or harm and their potential consequences (Yilmaz, 2010). Moreover, they serve as a standardized approach for determining the degree or level of individual risk assessments.

A three-step process is typically followed when constructing a risk matrix: first, vertical axes are designated to represent probabilities, followed by the assignment of horizontal axes to represent outcomes. The amalgamation of these axes culminates in the organization of risks, which constitutes the final step, as illustrated in Table 1. To obtain these data, it is imperative to gather information, which constitutes the foundational step for all risk assessment methodologies. Empirical evidence has underscored the efficacy of "checklists" as an optimal tool for identifying workplace hazards or risks. In order to garner a comprehensive understanding of all potential risks and hazards, thus enabling a more thorough risk assessment, all stakeholders in the work process (including management entities and end users/employees) should be engaged (Semerci, 2012).

The probability of an adverse event and its magnitude are delineated into five distinct levels when utilizing the risk matrix. These levels are categorized as follows: 1 - Very Unlikely, 2 - Unlikely, 3 - Possible, 4 - Likely, and 5 - Very Likely. In the context of the risk matrix, severity is assessed using five quantitative classifications: Negligible, Minor, Moderate, Significant, and Severe. If a risk is appraised as Very High or High, it is deemed unacceptable; however, if it falls within the Medium or Significant range, or if it pertains to the Low-risk category, it is considered acceptable (Özkilic, 2005).

Table 1. *Risk matrix method and evaluation table*

Likelihood \ Severity	Negligible 1	Minor 2	Moderate 3	Significant 4	Severe 5
Very Unlikely 1	Accep. Risk 1	Accep. Risk 2	Certain Risk 3	Certain Risk 4	Certain Risk 5
Unlikely2	Accep. Risk 2	Certain Risk 4	Certain Risk 6	Signif. Risk 8	Signif. Risk 10
Possible 3	Certain Risk 3	Certain Risk 6	Signif. Risk 9	High Risk 12	High Risk 15
Likely 4	Certain Risk 4	Signif. Risk 8	High Risk 12	High Risk 16	Very High-Risk 20
Very Likely 5	Certain Risk 5	Signif. Risk 10	High Risk 15	Very High-Risk 20	Very High-Risk 25

In this research, the bow tie method was used, which diagrammatically shows the process from the origins of the risks to the consequences after the risks in confined space have been dealt with by the matrix method. This methodology actually provides a synthesis between the concept of an error tree that analyzes the causes of the event and an event tree thought that studies its consequences. But the main emphasis of the bow tie is on the barriers between causes and risk and the links between risk and consequences. Bow tie diagrams can be derived from error and event trees; but rather, they are obtained directly from a brainstorming session.

When analyzing risk and security scenarios, it is very important to effectively consider threats and countermeasures. The bow tie method is a method that can be used to assess these threats and actions, prevent events from occurring, and avoid unintended consequences. This analysis has been successfully applied in various fields such as oil and gas industry, petrochemical industry, defense and security, shipping, mining, health care, aviation and emergency response (Afefy, 2015).

Bow tie analysis is used to visualize various possible causes and consequences of a risk (Figure 1). It is a method often resorted to when a complete error tree analysis is required, or when the focus is on identifying obstacles or checkpoints specific to each fault path. It is especially useful in scenarios where clear and discrete pathways that lead to failure exist (Jacinto and Silva, 2010). These barriers can be easily shown in works that are present in closed areas and involve a number of significant risks that require procedures. Bow tie analysis often stands out for being easier to understand compared to error and event trees, and can therefore serve as an effective communication tool where more complex analysis techniques are used.

Understanding the origins and consequences of a risk is important for identifying barriers and controls necessary to prevent, reduce or encourage that risk (IEC 31010, 2009).

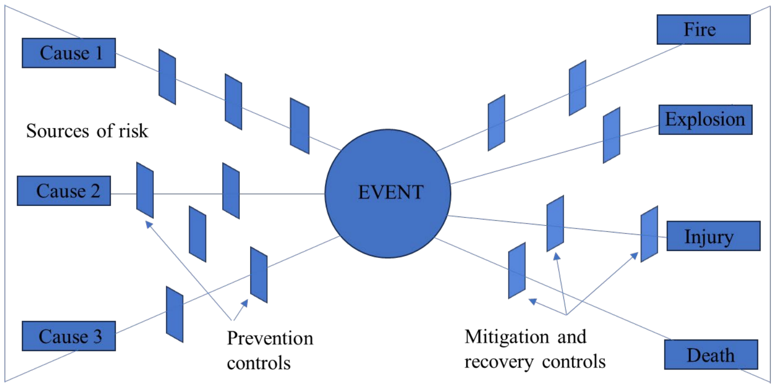

Figure 1. *Bow tie diagram for the unwanted consequences (IEC 31010, 2009)*

In general, a risk identified during the analysis process is shown as a central node in the bow tie diagram. The causes of the incident are identified, taking into account the origins of risks or threats to security, and are presented in a list. An indoor event may result in death, injury, or illness. The critical mechanism that caused the event that will cause these risks has been tried to be determined. For each cause, the flow of the event was determined by the lines showing successive events between the events on the left side of the bow tie diagram. Factors that may contribute to the growth of the problem are identified and added to the diagram. The obstacles necessary to avoid undesirable consequences from each cause are represented along the line in the form of vertical bars (Figure 1). In the presence of factors that could cause an increase, barriers were also used to stop the climb. With this approach, it can be seen that vertical obstacle bars reflect preventive measures that support positive outcomes (Saud et al., 2014).

On the right side of the bow tie diagram, as a rule, the various possible consequences of the risk are shown, the rays emitted from the risk event towards each possible outcome are sent to the result. Harm reduction measures in case of realization of the result are shown in the form of bars along the radial lines. Controls supporting management functions can be located at the bottom or top of the bow tie diagram and can be connected with the corresponding control points. In cases where the probability of a particular outcome or outcome is known and a prediction can be made for the effectiveness of a control, the bow tie diagram can be digitized to a certain degree (Khakzad, et al., 2012). However, the effectiveness of controls can be ambiguous, as often the paths and obstacles are not independent of each other. This makes the bow tie method procedural in most cases. Quantification is usually carried out more appropriately with techniques such as FTA (Failure Tree Analysis) and ETA (Event Tree Analysis). A bow tie diagram is a simple graph that shows the main risk pathways and barriers implemented to prevent, mitigate, or promote desired outcomes, and shows critical pathways (Garcia et al., 2019).

Bow tie analysis is an important advantage that it offers a clear visual representation that is easy to understand by focusing on the controls required for protection and mitigation and the effectiveness of these controls. In addition, the fact that it does not require expertise has made it easier to use despite other methods. But it can be considered a disadvantage that it has limitations in showing situations in which more than one factor occurs at the same time. When measurement is required, it can tend to oversimplify complex situations (IEC 31010, 2009).

RESULTS and DISCUSSION

This study was carried out in a family agricultural business operating in the province of Iğdır, and is interested in operating, farming and animal husbandry activities. In the farm where working workers are exposed to many hazards, jobs done indoors have the potential to lead to occupational accidents or occupational diseases, and are among the greatest hazards.

In instances where risk assessments conducted within the fertilizer storage facility, liquid fertilizer transportation vehicle, feed silo, and silage trenches, all commonly utilized within the farm premises, reveal the presence or potential presence of flammable or toxic gases or vapors, it becomes imperative to address the clearance of such gases or vapors from confined spaces. This clearance process typically involves the use of either air or inert gas to eliminate hazardous contaminants. However, it is crucial to note that when dealing with flammable contaminants, only inert gas should be employed for clearance, as the use of air may lead to the creation of flammable concentrations indoors (Kleinfeld and Feiner, 1966). Moreover, in cases where decontamination procedures are implemented, atmospheric testing becomes essential to verify the effectiveness of evacuation measures and ensure the safety of individuals prior to reentry (Sulardi and El-Ridho, 2019). Given the inherent risks associated with such environments, characterized by a heightened probability of work-related accidents or adverse events, the risk assessment yields a high probability (l:4) and severity (s:5) rating, resulting in an elevated risk value (RS:20), thereby warranting immediate intervention measures.

Employing inert gas, such as nitrogen displacement, may arguably represent the safest approach to mitigate the risk of flammable or explosive hazards (Wang et al., 2022). Moreover, alongside the establishment of comprehensive work permit procedures to delineate the requisite standards of protection for all individuals exposed to such risks, the utilization of full respirators can serve as a significant risk mitigation measure. Furthermore, precautions must be taken to safeguard individuals outside confined spaces from exposure to toxic, flammable, or irritant gases and vapors, particularly considering the potential for vented gases to affect workers or others present in the surrounding environment (Brown, 2011).

Adequate ventilation and the provision of breathable air are paramount considerations when operating in enclosed spaces. Inhalation of an oxygen-deficient atmosphere or air exhibiting abrupt fluctuations in concentration (l:5, s:5, RS:25) can precipitate unconsciousness within mere seconds. This perilous scenario arises from the atmosphere's dual failure to deliver oxygen and its potential to displace oxygen within the bloodstream (Veasey et al., 2005). In instances where the inhaled atmosphere contains residual oxygen, oxygen depletion from the bloodstream occurs at a slower pace. Nonetheless, affected individuals will experience profound fatigue and encounter difficulties in self-assistance owing to oxygen deprivation-induced circumstances. Prolonged exposure to such conditions may culminate in loss of consciousness. The onset of unconsciousness following exposure to an inert atmosphere is often rapid, and endeavors to effect rescue without appropriate respirators or respiratory protective equipment in such environments may tragically result in fatality (Kleınfeld and Feüner, 1966).

The cleaning or removal of residues that may deteriorate or cause gas formation in indoor environments should be the main purpose of the work. Cleaning up the debris is necessary so that the planned work can be carried out safely. The risk of residues is an important source of risk for the resulting outcome (RS: 20) and is one of the first tasks to be done. For the possibility of exposure to hazardous substances such as hazardous gases, fumes or vapors (l: 4), it is important to have electrical ventilation equipment, specially protected electrical equipment for use in hazardous atmospheres, respiratory-related protective equipment and atmospheric monitoring (Table 2). Repeated cleaning or removal may be required to ensure that all residues are removed, and in some cases, residues trapped in mud, lime or other deposits, behind bricks or loose liners, in liquid traps, or in joints may be dealt with.

In situations where indoor air poses a risk of flammability and explosiveness, the presence of inadequate lighting (Table 2) or faulty installations can significantly compound the challenges. Lighting fixtures must receive special protection when deployed in areas prone to the formation of flammable or potentially explosive atmospheres, particularly in instances where standard illumination, including emergency lighting, is impractical. Moreover, the exposure of lighting systems' unprotected hot surfaces to various gases may lead to thermal decomposition, generating additional toxic byproducts. Therefore, it is imperative that lighting fixtures are both waterproof and shielded with wire meshes to mitigate impacts. Furthermore, in environments where water is present, the use of appropriate sockets and connectors capable of withstanding moisture is essential, coupled with the implementation of leakage current relays to safeguard against electric shock hazards (Burlet et al., 2015).

In the agricultural sector, confined spaces often need to be isolated from the entry of substances that may pose a risk to those working in the field (Riedel and Field, 2011). The most effective method for this is to completely separate the confined space from each element of the plant by removing part of the pipe or duct or placing gaps. If blanks are used, window channels must be created that will allow the inside to be visible. One of the alternatives, when disconnection cannot be done in this way, can be provided with a locked, convenient, reliable valve, provided that there is no possibility of letting anything through while locked or there is no possibility of unlocking when people are inside the confined space.

Occasionally, confined spaces feature single brick walls, water seals, shut-off valves, or partitions sealed with sand or slime, serving to partially isolate one area of the facility from another (Botti et al., 2018). However, these barriers are typically installed for routine operations and may not furnish the requisite level of safety protection demanded by the elevated risks often associated with confined spaces. Hence, a more robust insulation method may be necessitated. Irrespective of the chosen insulation approach, rigorous testing is imperative to ascertain its reliability, involving assessments to verify the efficacy of the insulation against pertinent substances (Figure 2).

In the event of potential flammable or explosive atmospheres within indoor settings, the mitigation of static discharges and all ignition sources is paramount, given the significant risk involved (Table 2). All conductive components, such as steel ducts and airways, must be interlinked and adequately grounded (Figure 2). Should cleaning operations be undertaken, it is prudent to assess the hazards associated with the presence or utilization of materials with high resistance, such as synthetic plastics, within or in proximity to confined spaces. Certain equipment, notably most plastics, is susceptible to static accumulation due to their insulating nature. Additionally, there exists a heightened risk of electrostatic discharge from equipment utilized for steam or water jet applications. Moreover, static discharges may also be induced by garments containing cotton or wool fibers. Hence, it is advisable to explore safer alternatives for equipment selection and consider the utilization of antistatic footwear and attire.

When operating within confined spaces, it is imperative to have suitable and sufficient provisions in place for rescuing individuals in the event of an emergency. This entails the availability of requisite equipment to facilitate the establishment and rehearsal of rescue procedures (Figure 2). It is essential that these arrangements are established prior to any individual entering or commencing work within a confined space.

In some enclosed areas, there are electrical and mechanical equipment, and the power is provided from outside the area. The risk assessment shall be based on the objectives of the mission undertaken, and shall inspect lighting, communications, fire protection, pumping or cables in places where there is a risk of flooding. It must be ensured that the power is locked with a switch until these works are completed and that the switch is officially secured in accordance with the work permit (Brown, 2011). Lock and tag systems, where each operator has its own lock and key, can be useful here, giving confidence in the mechanism or system being disabled. It is essential to check that there is no stored energy left in the system that may cause the equipment to operate incorrectly.

Table 2. *Likelihood, severity and risk scores determined for a confined space*

Decision	Identified Risks	l	s	RS
Very High Risk	Not testing whether the indoor atmosphere contains gas, vapor and smoke	4	5	20
	Lack of knowledge of the properties of previously used chemicals	4	5	20
	Lack of a system to instantly monitor changes in the atmosphere	5	5	25
	Insufficient lighting	4	5	20
	Indoor air is flammable or explosive	5	5	25
	Insufficient cleaning of the atmosphere in the closed area	4	5	20
	Insufficient mechanical ventilation or inability to provide fresh air	5	5	25
	Insufficient cleaning of residues	4	5	20
High Risk	Presence of contaminants in liquid or solid form	3	4	12
	Lack of emergency alarms	4	4	16
	Presence of static electricity	3	5	15
	Not having enough drills for emergencies	4	3	12
Signif. Risk	No lookout person	2	5	10
	Manholes are closed	2	4	8
	No energy locks	3	5	10
	No grounding	2	3	6
	Lack of isolation from mechanical and electrical equipment	3	3	9
	Lack of fire extinguisher	2	4	8
Certain Risk	Lack of personal protective equipment and respiratory protective equipment	2	2	4
	Lack of employment of people with sufficient education and experience	2	3	6
	Failure to set educational standards	2	3	6
	Lack of determination of authority and responsibilities	1	3	3
	High temperature	2	2	4
Accep. Risk	Lack of means of communication	1	2	2
	Incompatibility of communication devices and equipment used	1	2	2
	Clutter on indoor floors prone to tripping and falling	2	1	2

Equipment intended for indoor use must be appropriately suited for its intended purpose. In scenarios where there exists a risk of flammable gas seepage into confined spaces, potentially leading to ignition by electrical sources, the utilization of specially protected electrical equipment becomes imperative. Examples include lamps approved for operation within explosive environments. It's crucial to recognize that even specialized low-voltage portable lights, while offering protection against electric shock, can still pose ignition hazards in flammable or potentially explosive settings. Therefore, careful selection of all equipment is paramount, accounting for prevailing conditions and associated risks. Grounding measures should also be implemented to mitigate the accumulation of static charges. Furthermore, in addition to isolation, mechanical equipment may require secure fixation to prevent unintended rotation, thereby averting potential hazards such as crushing or falling risks posed to individuals who may inadvertently step on or lean against them (Veasey et al., 2005).

To reasonably ensure the safety of working within confined spaces, it is imperative to acknowledge that reliance solely on personal protective equipment (PPE) and respiratory protective equipment (RPE) should be considered a last resort, except in cases of rescue operations (Figure 2). Within the context of risk assessment, there may arise circumstances where the necessity of employing PPE and RPE becomes apparent. In such instances, it is incumbent upon employers to furnish appropriate equipment and ensure its utilization by individuals tasked with entering and working within confined spaces. This provision of equipment is complementary to the implementation of engineering controls and adherence to safe operating protocols. The specific type of PPE provided will depend on the hazards identified, but may include, but is not limited to, safety ropes, harnesses and appropriate respirators. Careful selection of such equipment should factor in foreseeable hazards and the imperative for prompt evacuation should exigencies arise (Sulardi and El-Ridho, 2019).

The use of the RPE and PPE has the potential to induce heat stress in individuals. In severe cases, measures such as the provision of cooling air may be required to reduce the discomfort associated with wearing protective clothing. In addition, footwear and apparel may be required to have insulating properties to prevent softening of plastics, thereby preventing degradation of critical components such as visors, air hoses and crimped connections.

A secure pathway must be established both at the entry and exit points of confined spaces. Ideally, these pathways should facilitate swift, unimpeded, and readily accessible entry and exit. Additionally, the escape routes must be designed to facilitate quick egress for individuals entering confined spaces, ensuring suitability for emergency evacuation (Figure 2). The dimensions of openings leading into enclosed spaces should be sufficiently ample to accommodate safe passage. Furthermore, openings providing access to confined spaces, as well as pathways traversing partitions, compartments, or barriers within such areas, should be sufficiently wide and devoid of obstructions to enable the passage of individuals donning requisite protective attire and equipment, while also allowing for adequate access for rescue operations.

Adjacent to any openings permitting safe access, if present, clear and prominently displayed safety signage should be installed to deter unauthorized entry from alternative points of access. It is imperative to impose strict time limits on individuals working within confined spaces. Such limitations may be particularly warranted in scenarios involving the use of respiratory protective equipment or in environments characterized by extreme temperature and humidity conditions. This principle also applies to confined spaces of limited dimensions where mobility is severely constrained. In instances involving expansive enclosed spaces with multiple entry points, the implementation of a registration or tallying system may be necessary to monitor the ingress and egress of all personnel and track entry times effectively.

For a safe working system to be efficacious, it must be documented in writing. Such a system delineates the tasks to be undertaken and the corresponding precautionary measures to be observed. When formalized in writing, there should exist an official record confirming the proactive consideration of all foreseeable hazards and risks. The safe procedure encompasses the implementation of all pertinent measures in the appropriate sequence. However, the practical efficacy of a safe working system ultimately hinges on its implementation (Selman et al., 2019).

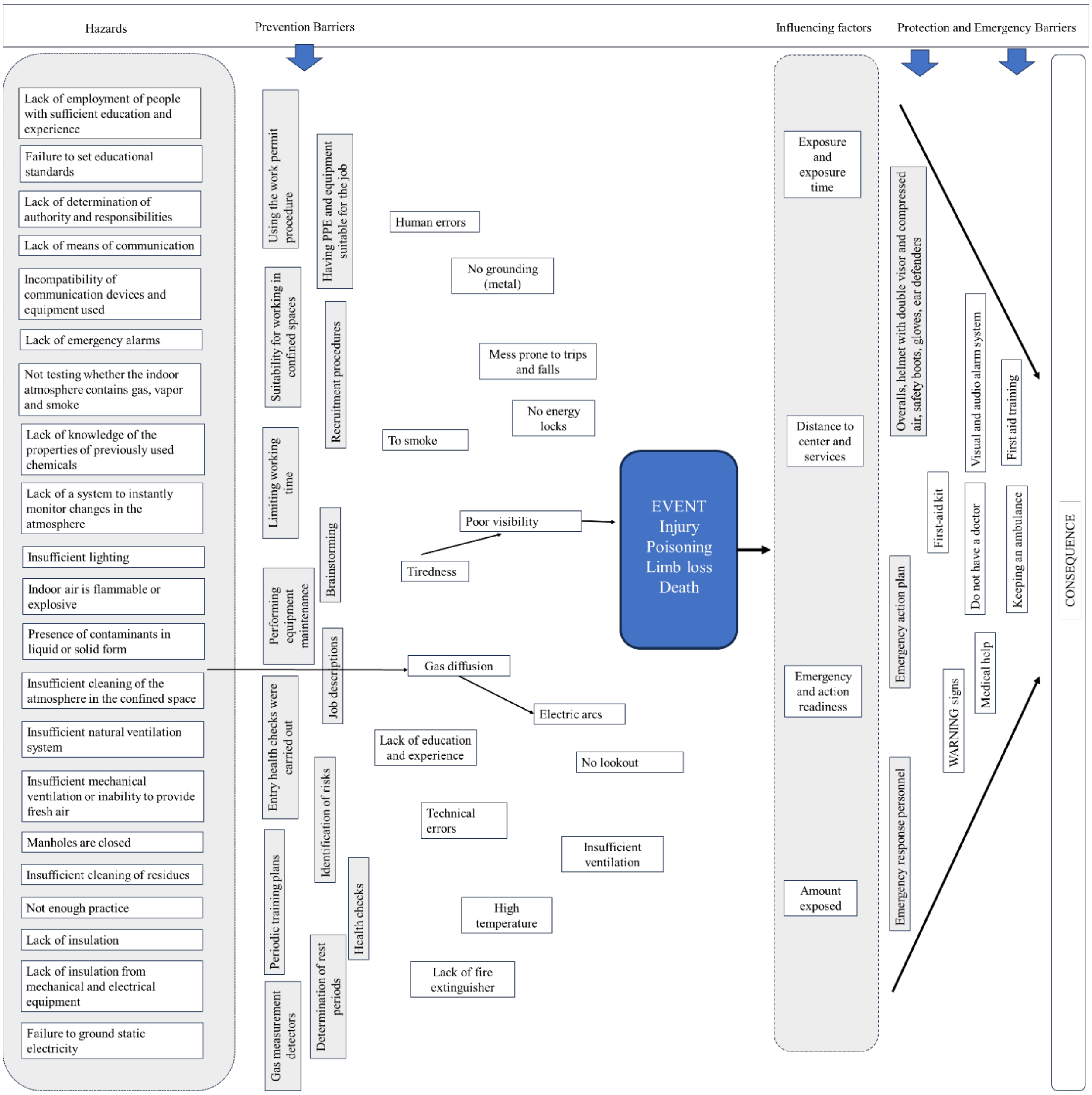

***Figure 2.** Schematic representation of hazard, barrier and event in the bow tie method*

The work permit system constitutes a formal written protocol typically mandated in situations where there exists a reasonably foreseeable risk of serious injury upon entry into a confined space or while conducting work within such an area (Figure 2). It is essential to recognize that the work permit procedure serves as an extension of, rather than a substitute for, the overarching safe system of work. Merely relying on the work permit system does not inherently render the work environment safe; rather, it functions to bolster the safety framework by facilitating the documentation of essential findings and obtaining necessary authorizations for entry. This documentation encompasses crucial details such as entry time limits, results of gas testing, and other pertinent information crucial in emergencies, while also preserving historical data on initial entry conditions for post-work assessment. A work permit system is deemed appropriate in several scenarios, including: (a) ensuring that individuals engaged in confined space work are cognizant of associated hazards and the specific nature and scope of their assigned tasks; (b) confirming the adequacy of safety measures through official verification before permitting entry or commencement of work; (c) coordinating or restricting access of other individuals and their activities in a controlled manner that may impact indoor work conditions; (d) instances where work necessitates authorization from multiple parties or imposes entry time constraints. Additionally, the implementation of a work permit system may be warranted when direct communication with external parties is unavailable, or when specialized respirators and/or the PPE are mandated. It is imperative that activities covered under the work permit are promptly revoked upon completion (Selman et al., 2019).

The extent of procedural requirements for obtaining a work permit varies according to the nature of the work and the associated risks. For instance, when (a) risks are deemed to be low and easily manageable, (b) the work system is characterized by simplicity, and (c) it is assured that concurrent business activities will not compromise safety within the workspace, unrestricted entry may be considered if a risk is effectively eliminated and the likelihood of its recurrence is deemed negligible, provided that the aforementioned conditions are met (Botti et al., 2018).

The individual tasked with conducting the risk assessment for confined space work must evaluate the suitability of personnel in relation to the specific tasks at hand. In instances where the risk assessment identifies significant physical constraints, the responsible individual may be required to ascertain whether the individuals possess the necessary physical attributes. This consideration is essential for safeguarding both the well-being of the individual worker and others who may be impacted by the nature of the work. Furthermore, the authorized personnel may need to take into account additional factors concerning individual suitability, such as claustrophobia or the ability to wear respiratory protective equipment. In such cases, seeking medical guidance may be warranted to assess the individual's fitness for the assigned work.

CONCLUSION

In essence, the methodology outlined here comprises two primary stages. The initial step involves a semi-quantitative assessment of risk, employing a five-level risk matrix. To mitigate the influence of subjective judgment, predefined scoring criteria for probability and severity are applied. Within this phase, the probability and severity scores are multiplied to generate a composite risk score. The subsequent step is predominantly qualitative in nature, employing the Bowtie diagram as a visual aid to delineate the causative factors and potential consequences of the evaluated risk. A notable advantage of this tool is its ability to facilitate a clear differentiation between preventive measures and mitigation strategies/barriers aimed at eliminating, mitigating, or alleviating the impact of a specific accident risk.

Understanding the mechanism behind accidents that may occur through the bowtie method requires a challenging experience and statistical knowledge. The bowtie diagram necessitates the analyst to identify the necessary barriers for each specific scenario. Employees within an organization can identify which barriers are missing or not being utilized properly, and which ones are failing. Thus, although there may not be a numerical way to evaluate the impact of such improvements, it provides a way to enhance safety conditions. In any case, the diagrams assist in determining risk controls and aid in their implementation before measurement.

This article explores the application of the bowtie methodology in conducting a semi-quantitative assessment of occupational accident risks. The proposed approach illustrates a systematic risk evaluation pertaining to a specific category of accidents commonly encountered in confined spaces within the agricultural sector. In the study, the risks caused by the atmosphere in confined space (RS: 20) were evaluated in the high-risk group, while the risks caused by chemical substances or their residues were also evaluated in this group. While the very high-risk score for explosion and poisoning of gases that are likely to be found in confined spaces is 25, it has been revealed that they must be ventilated before starting work. In addition, the issue of providing the necessary training and making measurements before starting to work in these areas is highlighted.

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Management of Johnsongrass (*Sorghum halepense* (L.) Pers.) in Alfalfa Cultivation Areas of Iğdır Province

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Abstract

One of the most important weed species that reduces productivity and quality in alfalfa (*Medicago sativa* L.) crops is *Sorghum halepense* (L.) Pers. (Johnsongrass). Therefore, it is of great importance to control this weed in alfalfa cultivation areas. In this context, this study was carried out in 2022-2023 to determine the frequency and density of *S. halepense*, which is a problem in alfalfa cultivation areas in Iğdır province, and the effects of some herbicides with different active substances on *S. halepense* and alfalfa yield. Within the scope of the study, surveys were carried out in 50 alfalfa cultivation areas in Iğdır province and its districts. In addition, herbicides with the active substances Quizalofop-p-ethy (Q), Haloxyfop (R) methyl ester (H) and Propaquizafop (P) and the mowing process with the Q+H mixture were compared with each other in order to determine their effects on *S. halepense* and alfalfa yield. As a result of the study, at the end of both years, theoccurrence frequency of *S. halepense* in alfalfa cultivation areas in Iğdır province was determined as 92.25% and its density was 48.15 plants/m^2. In the study, the effectiveness rates of herbicides on *S. halepense* varied between 95% and 100% in the last assessment. The effect of the herbicides used in the study on *S. halepense* dry weight varied between 78.90% and 91.56%. As a result of the study, herbicides with different active ingredients and their mixtures resulted in a statistical difference of 1% ($p<0.00$) on the, plant height, fresh weight and dry weight of *S. halepense* in alfalfa. At the end of the two year period, the highest plant height (80.98 cm), fresh weight (3483.41 kg/da) and dry weight (896.49 kg/da) were obtained in Q+H treatment. However, this herbicide mixture was in the same statistical group with the other herbicides used in terms of alfalfa yield and yield components. As a result, the herbicides used were effective on *S. halepense* and caused an increase in alfalfa yield.

Keywords: Alfalfa, *Sorghum halepense*, Herbicide, Weed, Iğdır, Survey

INTRODUCTION

Alfalfa (*Medicago sativa* L.), known as the queen of forage plants (Uslu and Balcı, 2020), is a perennial herbaceous plant with a deep and strong root system in the Fabaceae family (Davis, 1988). It is stated that its homeland is Asia, Iran, Turkmenistan and the surrounding areas (Bolton, 1962; McWilliam, 1968). Some of the features that make alfalfa superior to other plants are its high adaptability, longevity, high yield and nutritional values, and the ability to mow more than once during the vegetation period (; Karadaş and Aksoy, 2019). Alfalfa has become the most cultivated forage crop worldwide because it grows easily in both tropical and temperate climate zones (Berg et al., 2007; Zhang et al., 2008; Karadaş and Aksoy, 2019). Alfalfa has a higher feed value than forage crops and its protein yield per unit area is also higher. The dry and fresh weight of alfalfa is delicious and nutritious for all kinds of animals (Çaçan and Arslan, 2021). Alfalfa boasts protein, vitamins, minerals, and fiber (Richter et al., 2003), making the crop highly nutritious feed (Salzano et al., 2021). The herb, which is very rich in vitamins, also contains many substances that increase milk, meat and fertility (Collier et al., 1982). Alfalfa is also a legume forage plant and has an important place in maintaining and protecting the fertility of soils thanks to its deep roots (Çaçan et al., 2015). Alfalfa is of the most importance in the world and in Türkiye (Şakiroğlu et al., 2015; Keskin et al., 2020a; Eren and Keskin, 2021), since alfalfa, which is

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such an important food source for animals, has wide adaptability, It is the most grown forage plant in Türkiye. The country that produces the most alfalfa in the world is the USA (FAO, 2023). In 2022, the alfalfa area in Türkiye was 643,592.7 ha, producing 19,064,213 tonnes of alfalfa. In Iğdır province, the alfalfa area was 18,641 ha, with a production of 1,003,231 tonnes (TÜİK, 2023).

Alfalfa is also used in pellet feed and artificial pasture mixtures, as well as in the supply of hay, silage production (Karakurt and Fırıncıoğlu, 2002). As the availability of resources for crop production space and management continues to decrease, maximizing the yield and nutritional value of alfalfa is critical to meeting the agricultural needs of growers, farmers, ranchers, livestock producers and industry professionals (Beck et al., 20120. Although alfalfa is such an important forage crop in the world and in Turkiye, there are factors that affect alfalfa yield. Weeds are the most important of these factors. Weeds are a major problem in alfalfa production. They reduce forage quality and yield by competing with alfalfa for nutrients, space, sunlight and water (Konstantinovic and Meseldzija, 2005; Noroozi et al.,2022; Yang et al., 2022).

In their study, Tan and Serin (1998) found that when alfalfa was planted with a shelter crop, 581.5 - 629.1 kg/da of grass was taken in the first year and only 11.6 - 15.4% of this was weeds. Many weed species are problems in alfalfa cultivation areas (Özmen, 2019). Identifying the weeds seen in these areas and examining the changes of these weeds depending on the age of the alfalfa helps in weed control (Bükün, 2012). The overall value of alfalfa hay is enhanced by its primary role as forage and feed in livestock production, including dairy, meat, and fiber. Early-seeded weeds compete primarily for light, water, space, and nutrients, while late-season weeds in established alfalfa fields persistently compete for resources, affecting yields in subsequent growing seasons (Ashigh et al., 2010). Additionally, the presence of annual and perennial weeds at any time can reduce the nutritional value of the forage, reduce the lifespan of alfalfa caused by premature plant loss or decline, host diseases and insects, and create harmful harvest problems (Green et al., 2003). Controlling perennial weed populations in perennial crops such as alfalfa is particularly challenging because management practices must address seed production and vegetative reproductive structures that enable the plant to survive from season to season (Beck et al., 2020). Moreover, weeds mainly have low nutritional value, unpleasant odor and taste, and also contribute to the deterioration of alfalfa seed quality (Konstantinovic and Meseldzija, 2005). The mainly economically important perennial weed species that cause problems in alfalfa are: *Cirsium arvense, Sorghum halepense*, *Convolvulus arvensis* and species from the Cuscuta genus (Konstantinovic and Meseldzija, 2005).

Sorghum halepense L. (Pers.) (Johnsongrass) is a C4 perennial plant species from the Poaceae family and is among the world's most persistent weeds (Holm et al., 1997). Johnsongrass is a weed that can form a dense habitus, grow up to 50-200 cm tall and form many stems. Its reproductive ability is enormous, as it can produce up to 70 m of rhizome per plant in one growing season and can produce 28,000 seeds per plant (Monaghan, 1980) or more (up to 80,000 seeds per plant (Anderson, 1996). Along with the dense seed-forming potential of Johnsongrass, It also has an extremely strong vegetative reproduction system. As a matter of fact, a Johnsongrass plant can form a 200-300 m long rhizome in four weeks. Under suitable conditions, it can produce 1.8 tons of rhizome and 50 kg of seeds per decare in 16 weeks (McWhorter, 1981).

Therefore, it is very difficult to remove the Johnsongrass, which has all these features together, from where it entered. It can easily adapt to different ecological conditions (Davis, 1988). It is distributed over more than one-third of the total global area, causing significant losses in agriculture and natural biodiversity in Asia, Africa, America and Europe (Chirita et al., 2007; Peerzada, et al., 2017). *S. halepense* is ranked as the world's sixth worst weed, infesting 30 different crops in 53 countries, and is widely naturalized on millions of hectares worldwide (Peerzada, et al., 2017). *S. halepense* is well known for its detrimental effects on the growth and development of neighboring plants, owing to its strong competitive abilities and allelopathic potential (Huang et al., 2018 ; Peerzada et al., 2017). *S. halepense* is a serious perennial weed species worldwide, especially in humid warm-temperate and subtropical regions (McWhorter, 1989). It can cause significant yield losses in many products (Follak and Essl, 2013). Plants emerging from rhizomes are more competitive than seedlings due to their faster growth rate, even under stress conditions (Acciaresi and Guiamet, 2010). It is increasingly common in many European countries and harmful worldwide (Travlos et al., 2019), and is widely found in agricultural areas (Follak and Essl, 2013). *S. halepense* is considered a serious weed in the world causing significant yield losses as well as increases in production costs in a wide range of field crops such as corn, sorghum, soybeans, sunflowers, sugar cane, cotton, pastures and alfalfa (Travlos et al. al., 2018). *S. halepense* is one of the most important weed species with a wide range of climate adaptations with favorable growing conditions in managed and unmanaged areas in the world (Barney and DiTommaso, 2011; Peerzada, et al., 2017; Yazlık and Üremiş, 2022). *S. halepense* has a wide colonization in Turkiye (Uludağ et al., 1999; Arıkan et al., 2015). Considering this situation, *S. halepense* can be called a widespread species in Turkiye (Yazlık, 2014), due to the wide ecological tolerance of *S. halepense* and its strong competitive ability as an expanding species, necessary measures should be taken to control its distribution in every region. and even if it is in natural distribution, risk analysis should be done (Yazlık and Üremiş, 2022). Good soil preparation, timely and high quality planting, and all cultural practices that ensure higher crop establishment are the basic measures to protect lucerne and alfalfa from perennial weed species. In order to control these, treatment can be done in the one to three leaf phase of the alfalfa (Konstantinovic and Meseldzija, 2005). Adopting modified crop management practices, refining tillage strategies, and employing multiple chemical-based techniques stand out as optimal choices for effective control of johnsongrass (Travlos et al., 2019). Currently, within agricultural domains, the preference for chemical control methods to manage weeds is on the rise. This trend is driven by escalating costs and labour requirements, with chemical approaches favoured for their rapid efficacy, ease of use and economic nature. (Kitiş ve Gürbüz, 2021). Due to its rapid vegetative growth and increased herbicide tolerance, the scope of conventional management approaches is limited in the management of this weed (Peerzada, et al., 2017). The integration of chemical methods with cultural or mechanical approaches is important to limit future spread to uninfested areas (Peerzada, et al., 2017). Some of these effective techniques can be used in combination with herbicides (Travlos et al., 2019).

Since Iğdır province is hot and the ground water level is high, *S. halepense* is found not only in alfalfa cultivation areas but also in corn (Açıkgöz et al., 2023) and tomato (Akelma et al., 2022; Tülek et al., 2022; Usanmaz Bozhüyük et al., 2022) and in orchards (Parin and Gürbüz, 2022). It is abundant and causes significant yield and quality losses. That's why the local people call *S. halepense* "kankurutan". Metaphorically, a "blood dryer" symbolises something harmful that drains vitality, similar to the depletion of blood in veins, and represents situations or actions that drain energy, strength and resources, leading to significant challenges. This weed species poses a big problem in Iğdır province and it is extremely important to combat it. Due to all these features listed above, canker is a problem in almost all regions of our country, as well as throughout the world. *S. halepense* also poses a major problem in alfalfa production areas and causes a negative impact on alfalfa quality and yield. Therefore, it is necessary to combat Johnsongrass, which has a negative effect on alfalfa yield and quality. The aim of the study is to determine the occurrence of frequency and density of *S. halepense*, which poses a problem in the alfalfa cultivation areas of Iğdır province. It was also carried out to determine the effects of herbicides with different active ingredients on *S. halepense* and alfalfa yield.

MATERIALS and METHODS

The research was carried out in a 2-year-old alfalfa cultivation area in Mürşitali village of Karakoyunlu district of Iğdır province (40°01'14"N 44°08'01"E) during the growing season of 2022 and 2023. Surface irrigation was used during the growing season of alfalfa. In the first year, the drum was mowed with a mower a total of 4 times. In addition, surveys were carried out in the alfalfa planting areas in Iğdır province and its affiliated districts to determine the frequency and density of *S. halepense* in the alfalfa planting areas. In the first year, the alfalfa field was mowed four times with a mowing machine. In addition, extensive surveys were carried out within the alfalfa production areas of Iğdır province and its districts. The aim of these surveys was to determine the frequency and density of *S. halepense* in alfalfa fields. The climate data for the months in which the study was conducted and the long-term average (1941–2022) are given in Table 1, and the soil properties of the trial field are given in Table 2.

Table 1. *The weather conditions of the region*

Months	Temperature (°C)			Precipitation (mm)			Humidity (%)		
	2022	**2023**	**LTP (1941-2022)**	**2022**	**2023**	**LTP (1941-2022)**	**2022**	**2023**	**LTP (1941-2022)**
March	5.1	11,7	6,2	17,7	27,2	22,1	54,8	55,40	52,2
April	15.7	13,7	13	24,7	51,2	33,8	44,1	60,10	49,9
May	17.1	18,1	17,7	50,5	43,2	46,5	53,8	53,80	51,5
June	24.5	23	22,1	22,3	48,3	32	47,5	52,60	47,3
July	27.7	26,5	25,9	1,4	10,5	13,7	37,5	42,20	45,3
August	27.9	28,3	25,3	2,3	0,8	9,7	42,3	39,80	47,1
September	23.1	22	20,4	5,1	7,6	11,5	41.9	50,10	46,2
October	15.4	15,1	13,1	12	29,5	26,3	49.6	64,70	48,53

LTP= Long-term period, Meteorological Service (MS, 2023).

Table 2. *Soil characteristics of the trial field*

Soil characteristics	Units	Trial area
Profile Depth	cm	0-30
Constitution Class	-	Clay-Loam
Phosphorus (P_2O_5)	kg da^{-1}	0,82
Lime ($CACO_3$)	%	11,01
Potassium (K_2O)	kg da^{-1}	9,05
pH	-	7,7
Total Salt	mmhos/cm	1,8
Organic Matter	%	1,82

Quizalofop-p-ethy, Haloxyfop (R) methyl ester and Propaquizafop herbicides and mixtures of Quizalofop-p-ethy + Haloxyfop (R) methyl ester herbicides were used in the research. General properties of the herbicides used in the experiment are given in Table 3.

Table 3. *Herbicides used in the study and their general properties*

Kod	Active ingredients	Formulation	Mode of Action	Dose	Application time
Q	Quizalofop-p-ethyl	EC	A1	75 ml/da 100 ml/da	Post Emergence
H	Haloxyfop (R) methyl ester	EC	A1	45-60 ml/da	Post Emergence
P	Propaquizafop	EC	A	50-100 ml/da	Post Emergence

In the study, a total of 100 alfalfa fields in 50 different alfalfa fields were surveyed in both years to determine the frequency and density of *S. halepense* in alfalfa production areas in Iğdır province and its districts.

Experiment setup and herbicide application

In the Mürşitali village of Karakoyunlu district of Iğdır province, where the research was conducted, there is 2-year-old alfalfa ready planted and the alfalfa is irrigated with surface irrigation. The drum mower was used for mowing a total of 4 times in the first year. The experiment was carried out in a randomized block design with 6 characters (Quizalofop-p-ethy, Haloxyfop (R) methyl ester, Propaquizafop, Quizalofop-p-ethy + Haloxyfop (R) methyl ester herbicide mixtures, mowing and weedy check) with 4 replications, totaling 24 samples. Parcelization was done after alfalfa emergence before herbicide application. The plots will be 20 m^2 (5×4 m) wide, with 1 m strips left between the plots and 1.5 m strips between the blocks. For parcelization, slats were fixed to the ground and rope was used in strips. The trial area was 710.5 m^2 in total. The herbicides with 3 different active substances and the mixture of herbicides with 2 active substances used in the research were set up with different mowing times and weedy control plots. For herbicide applications, herbicide was applied when the alfalfa height reached 10 cm. In the study, the herbicide application was carried out on 22 March 2020, two days after the parcelling process, when the Johnsongrass was approximately 25 - 40 cm in height. Herbicides in the trial; It was applied with a 25 liter tank capacity, gasoline engine, back sprayer with fan beam heads. Afterwards, when the alfalfa reached the full bloom period, the mowing was done. For the mowing control process, mowing was done when the alfalfa reached the 10% flowering period. Control plots were mowed when the alfalfa reached the full bloom period and were evaluated until the second mowing was performed. The experiment was conducted for 2 mowing periods.

Determination of the effects of herbicides

In the study, in order to determine the effect of the applications on *S. halepense*, the weeds in the plots were counted before harvest, a 1 m^2 frame was used, and the *S. halepenses* in the frame were counted by randomly throwing them into each plot (TAGEM, 2020). *S. halepense* counts in herbicide, mowing and control plots were evaluated 4 times throughout the application (Table 4). In addition, some symptoms of phytotoxicity on alfalfa of the herbicides used in the study (number of plants in a certain period, length, weight, diameter, etc. of plants or plant parts) were evaluated (TAGEM, 2020).

In the evaluations made in the study, the percentage effect rates of herbicides on *S. halepense* were determined according to the following formula (Abbott, 1925).

$$\text{Herbicide effect (\%)} = \frac{(\text{Number of Weeds in Control} - \text{Number of Weeds in Treatments}) \times 100}{\text{Number of Weeds in Control}}$$

Table 4. *Assessments and time in study*

Assessments	Assessment time
1. Assessment	10 days after application
2. Assessment	30 days after application
3. Assessment	50 days after application
4. Assessment	Just before harvest

Effect of herbicides on *Sorghum halepense* dry weight

Following the conclusive assessment in the study, *S. halepense* specimens identified within each plot were meticulously trimmed at ground level using scissors. Subsequently, these specimens were gathered, segregated, and carefully deposited into distinct paper bags for further analysis. The samples were then taken to the Herbology Laboratory of the Faculty of Agriculture at Iğdır University. The weeds were then individually placed in paper bags and placed in an oven at 70°C for 24 hours to facilitate desiccation. Following this process, each dried sample was carefully weighed to determine its individual dry weight. The resulting numerical data were carefully noted and recorded for analysis.

Alfalfa yield and yield components

Following the assessment of plant height, the alfalfa within each plot underwent uniform mowing using a sickle, leaving a 0.5-meter space from the plot's inception and excluding one row from each edge to mitigate edge effects. The freshly harvested alfalfa from each plot was then quantified by weight to determine the fresh yield per decare in kilograms. To determine the dry matter content of the alfalfa, samples were taken from a 1 square metre area of freshly harvested alfalfa in each plot. These samples were dried in ovens set at a constant temperature of 70°C until a constant weight was reached. The study aimed to analyse the effect of the herbicides used on various parameters, including alfalfa plant height (measured in centimetres), alfalfa fresh weight (measured in kilograms per decare) and alfalfa dry weight (measured in kilograms per decare).

Surveys

In both years of the study, surveys were carried out in the alfalfa production areas of Iğdır province and its districts to determine the frequency and density of *S. halepense*, which is a problem in alfalfa production areas. According to TÜİK, the surveys carried out by districts were determined based on the alfalfa production areas in Iğdır province. The alfalfa area and the number of surveys in Iğdır province and districts are shown in Table 5.

Table 5. *Alfalfa planting areas and survey numbers in Iğdır province and districts*

	Year 2022		Year 2023	
Districts	Cultivation area (da)	Number of surveys	Cultivation area (da)	Number of surveys
Centre	72.000	13	65.000	17
Aralık	160.000	26	67.000	18
Karakoyunlu	45.120	9	45.410	12
Tuzluca	8.300	2	9.000	3
Total	277.431	50	186.410	50

Prior to the surveys, specific alfalfa fields were identified. Surveyors then traversed these areas in linear paths, stopping intermittently at random points approximately every 10 kilometres to access the nearest field (Uygur, 1985). Using the methodology outlined by Sırma et al. (2001), frames were strategically positioned according to field dimensions, as shown in Table 6. This methodology facilitated the survey of a total of 50 alfalfa fields for each year.

Table 6. *Number of frames taken in surveys according to field size*

Field size (da)	Frames (number)
0-5	4
5-10	6
10-20	8
20-50	12
50	16

A 1 m² frame was used for the counts, starting from 5-10 m inside, away from the edge effect, to represent the field, and the *S. halepense* that entered the frame were counted randomly. Occurrence Frequency (R.S) was calculated according to (Odum, 1983; Uygur, 1985). Frequency of Occurrence; It is the value that shows the percentage of a weed species encountered within the surveyed regions. The calculation of these values was made with the formula below.

$$R.S.(\%) = 100X\frac{N}{M}$$

R.S: Occurrence Frequency (%)

N = Number of fields where a species is found

M = Total number of fields surveyed

In determining *S. halepense* densities, an evaluation was made based on the arithmetic mean. Weed density (plant/m^2) was calculated by dividing the total number of plants per m^2 in the surveys by the number of surveys (Odum, 1971).

$$\text{Density (number/m}^2\text{)} = \frac{\text{B}}{\text{M}}$$

B; Total sample count

M; Total number of frames that were thrown

Statistical analysis

As a result of four different counts, *S. halepense* densities per square meter, dry weights and alfalfa yield and yield components were evaluated. Relevant data were subjected to one-way analysis of variance. Means were compared using Duncan's multiple comparison test ($p < 0.05$) (SPSS 20). Additionally, a series of statistical analyzes were conducted to correlate the findings of the study. After the transformation/normalisation of the data, we carried out a series of analyses: Correlation analysis using JASP, Heat map clustering using SRplot, Principal component analysis (PCA) using PAST software, Network graph analysis using PAST software.

RESULTS and DISCUSSION

Frequencies and densities of *Sorghum halepense* in alfalfa cultivation areas

The frequency and density of encountering *S. halepense* throughout Iğdır province varied according to districts, and the highest frequency and density were determined in the central district (Table 6). In both study years, the peak *S. halepense* frequencies (first year = 100% and second year = 96%) and density (first year = 56 numbers/m^2 and second year 50 numbers/m^2) were determined in the central district. In the study, Iğdır province-wide, the frequency of *S.halepense* was determined as 94% in the first year and 90.5% in the second year, and its density was determined as 49.75 numbers/m^2 in the first year and 46.5 numbers/m^2 in the second year.

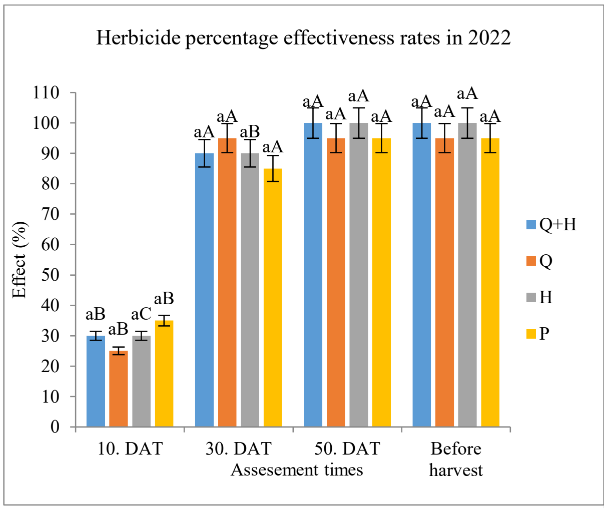
Table 6. *Frequencies and densities of S. halepense in alfalfa cultivation areas in Iğdır province and its districts*

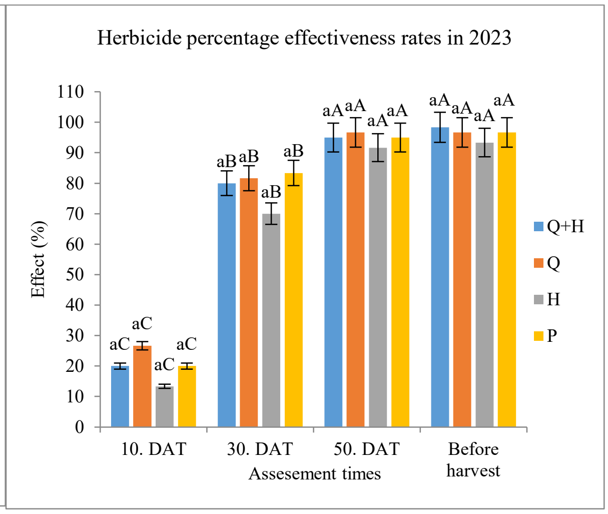
District	2022		2023		Mean	
	Frequency (%)	Density	Frequency	Density	Frequency	Density
Centre	100	56	96	50	98	53
Aralık	86	48	88	42	87	45
Karakoyunlu	94	50	90	48	92	49
Tuzluca	96	45	88	46	92	45,5
Mean	94	49,75	90,5	46,5	92,25	48,15

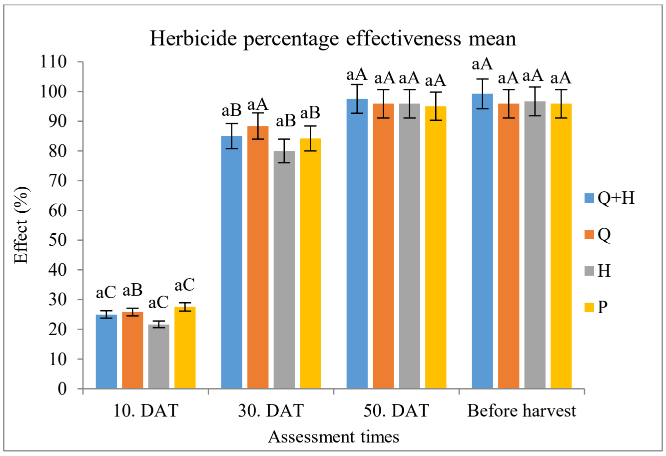
The average frequency of both years on a provincial basis was determined as 92.25% and the density was 48.15 numbers/m^2 (Table 6). Özmen (2019), determined the frequency of *S. halepense* in alfalfa cultivation areas as 9.75. According to Konstantinović et al. (2004), *S. halepense* was one of the most important weed species affecting alfalfa yield. Karkanis et al. (2022) found that *S. halepense* was abundant in the trial area. The frequency of of weeds may vary from region to region (Güncan, 2019). One of the most important reasons for the high frequency of *S. halepense* in Iğdır province is due to the high air temperature and ground water level. In Iğdır province, the frequency of S. *halepense* has been determined not only in alfalfa but also in corn, 94% (Açıkgöz et al., 2023) and tomato (82% in the first year, 86% in the second year) (Akelma et al., 2022). Kostov and Pacanoski (2006) determined the density of *S. halepense* in the trial area as 132.8 numbers/m^2. Özmen (2019) determined the density of *S. halepense* in alfalfa cultivation areas as 0.11 numbers/m^2. Karkanis et al. (2022) found that *S. halepense* was abundant in the trial area. According to Konstantinović et al. (2004), *S. halepense* is one of the most common weed species found in alfalfa cultivation areas and it affects the yield of alfalfa. In Iğdır province, *S. halepense* density is 24.24 numbers/m^2 in corn (Açıkgöz et al., 2023), 24.24 numbers/m^2 in tomato (first year: 24.24 numbers/m^2 and 19.2% numbers/m^2 in the second year (Akelma et al., 2022) and 19.2% numbers/m^2 in the second year (Akelma et al., 2022) and other products. For tomatoes, they determined it to be 10.5 numbers/m^2 in the first year and 12.25 numbers/m^2 in the second year (Tülek et al., 2022).

Effect of herbicides on weeds

The effects of the herbicides used in the study on *S. halepense* were similar in both years. In all four evaluations, no statistical difference was observed in the effects of the herbicides on *S. halepense* (Figure 1).







Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop (R) methyl ester, DAT: Day after treatment

Figure 1. *Percentage effects of herbicides on S. halepense according to evaluation times*

The effects of herbicides on S. halepsense were low in the first evaluation, but high effect rates were determined in the second evaluation. over 95% at the end of both years. *S. halepense* effect rates were determined (Figure 1). Kostov and Pacanoski (2006) found that the effects of the herbicides used in the study on *S. halepense* ranged between 93.4% and 97.7%. Çağlar et al. (2023), the effects of herbicides on *S. halepense* on the 7th day were 30.00% to 62.5%, on the 21st day; It was determined that it yielded between 83.75% and 80.00% and between 56.25% and 95.00% during the harvest period. Karkanis et al. (2022) stated that herbicides were 90% effective on *S. halepense* compared with the weed-infested treatment. The effects of herbicides on the dry weight of *S. halepense* are given in Table 7.

Table 7. *Variance analysis and effects of treatments on S. halepense dry weight.*

	Year 2022		Year 2023		Average	
Treatments	**Dry Weight (g m^{-2})**	**Effect (%)**	**Dry Weight (g m^{-2})**	**Effect (%)**	**Dry Weight (g m^{-2})**	**Effect (%)**
Q+H	15,00±3,53c	91,56	16,25±6,88c	89,84	15,62±5,03c	90,75
Q	26,75±5,96c	84,95	21,25±8,00c	86,72	24,00±6,57c	85,79
H	37,50±6,61c	78,90	25,00±7,35c	84,38	31,25±4,84c	81,50
P	21,25±4,26c	88,05	17,50±3,22c	89,06	19,37±3,28c	88,53
Mowing	77,50±11,08b	56,40	62,75±6,12b	60,78	70,12±6,77b	58,48
Weddy	177,75±9,04a	0,00	160,00±10,80a	0,00	168,87±4,87a	0,00
Mean	59,29±12,11		50,45±11,06		54,87±11,43	
F	73,622		57,800		121,993	
p- value	,000		,000		,000	

Means with the same letter do not differ significantly at the 0.05 significance leve
Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

In the study, the lowest *S. halepense* dry weights were recorded in the plots where herbicides were applied consistently over two years, with all herbicides falling into the same statistical group. . The effect rates of the herbicides used in the study on *S. halepense* dry weight at the end of two years varied between 81.50% and 90.75%. In the study, the lowest *S. halepense* dry weights were obtained in the plots where herbicides were used in both years, and all herbicides were in the same statistical group. The effect rates of the herbicides used in the study on *S. halepense* dry weight at the end of two years varied between 81.50% and 90.75%. The highest dry weight of *S. halepense* was obtained in the weedy control plots (first year = 177.75 g/m^2 and second year = 160 number/m^2), which were in a single statistical group (Table 7). Karkanis et al. (2022) determined the lowest dry weight of *S. halepense* as 7.7 g/m^2. It was determined that the herbicides used in the study caused a 99.8% decrease in the dry weight of *S. halepense*.

Effect of herbicides on alfalfa yield and yield components

The herbicides utilized in the study displayed significant effects on alfalfa growth parameters across both years. They notably increased plant height (first year: F=321.165, p<0.000; second year: F=92.907, p<0.000), fresh weight (first year: F=267.599, p<0.000; second year: F=98.141, p<0.000), and hay weight (first year: F=559.992, p<0.000; second year: F=135.533, p<0.000) with statistical significance (p<0.01) at the 1% level, as shown in Table 8.

Table 8. *Variance analysis and effects of treatments on alfalfa biomass and height.*

Treatment	Year 2022			Yeae 2023			Average		
	Plant height	Fresh Weight (g m^{-2})	Dry Weight (g m^{-2})	Plant height	Frewsh Weight (g m^{-2})	Dry Weight (g m^{-2})	Plant height	Fresh Weight (g m^{-2})	Dry Weight (g m^{-2})
Q+H	82,03±,30 a	3.509,33±10,84a	911,73±5,12a	79,93±,78a	3457,50±21,74a	881,25±11,96a	80,98±,49a	3483,41±7,43 a	896,49±6,20 a
Q	81,08±,37 ab	3.438,27±20,77ab	883,23±4,56b	79,80±,99a	3447,50±28,68a	886,25±11,43a	80,43±,59a	3442,88±10,25ab	884,74±6,86 ab
H	80,83±,07 c	3.354,02±5,28 bc	864,65±1,82c	80,75±,96a	3455,00±20,61a	876,75±9,86 a	80,43±,52a	3404,50±10,64ab	870,70±5,14 b
P	80,68±,06 bc	3.301,90±8,69 c	852,02±2,77c	80,35±,98a	3374,50±12,12a	882,00±11,88a	80,01±,50a	3338,20±10,37b	867,00±5,22 b
Mowing	78,85±,11 d	3.210,25±60,84d	849,25±7,96d	74,07±,67b	2625,00±149,30b	728,00±11,28b	74,46±,34b	2668,12±102,78c	738,62±6,89 c
Weedy	77,45±,81 e	3.105,68±49,68e	782,82±9,65e	58,45±,99c	1887,50±42,69c	502,50±20,56c	60,95±,86c	1996,59±10,96d	517,65±8,57 d
Mean	80,15±1,34	3.319,91±105,71	857,28±27,03	75,56±1,69	3041,16±126,34	792,79±29,88	76,21±1,51	3055,62±115,45	795,87±28,25
F	321,165	267,599	559,992	92,907	98,141	135,533	185,951	195,878	503,956
p- value	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Means with the same letter do not differ significantly at the 0.05 significance leve
Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

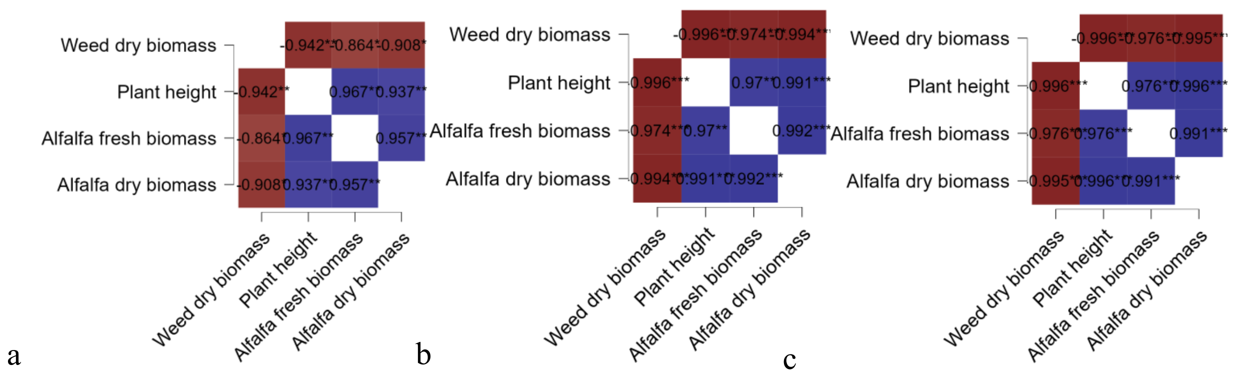
In both years of the study, the highest alfalfa plant height was obtained in Q+H (first year: 82.03 cm and second year: 79.93 cm) parcels. In both years of the study, the lowest plant height was obtained in the weedy control plots (Table 8). Çoruh and Tan (2016) determined the average alfalfa plant height between 41.3 cm and 47.9 cm. Harmanlıoğlu (2019) determined the average alfalfa plant height between 55.75 cm and 84.83 cm. The average height of alfalfa plants ranged from 66.7 to 80.2 cm according to Keskin et al. (2020b).

Among the applications, the highest fresh alfalfa weights were recorded in the Q+H plots (first year: 3,509.33 kg/da and second year: 3,457.50 kg/da). In both years of the study, the lowest alfalfa fresh weight was obtained in the weedy control plots (Table 8). Harmanlıoğlu (2019) determined alfalfa fresh weights between 5.125 kg/da and 7.389 kg/da. Cosgrove and Barrett (1987) stated that herbicides were not effective on alfalfa yield. Arregui et al. (2001) reported that some of the herbicides they used increased alfalfa yield, some did not, and some damaged alfalfa. Temme et al. (1979) stated that alfalfa seeding alone using herbicides is beneficial for weed control in alfalfa and that the feed produced in this way will increase the performance of farm animals. The highest values of dry weights were obtained in Q+H parcels in both years (first year: 911.73 kg/da and second year: 881.25 kg/da). The herbicides used at the end of both years of the study were in the same statistical group. The lowest alfalfa dry weight was obtained in the weedy control plots, which were in a single statistical group in both years (Table 8). Cosgrove and Barrett (1987) reported that total feed efficiency did not change with herbicide applications. Arregui et al. (2001) reported that some of the herbicides they used increased alfalfa yield, some did not, and some damaged alfalfa. In their study in different locations, Kostov and Pacanoski (2006) determined that the lowest alfalfa yield was in weedy control plots (1,143 kg/ha and 1,914 kg/ha), while the highest alfalfa yield was 2,891 kg/ha and 2,720 kg/ha. Çoruh and Tan, (2016). They determined alfalfa dry weights between 776 kg/da and 946 kg/da. In his study, Harmanlıoğlu (2019) determined alfalfa hay weights between 1,878.86 kg/da and 1,349.30 kg/da. Keskin et al. (2020b) found fresh yield between 3966.0 and 6180.4 kg da-1, and dry yield between 979.7 and 1586.7 kg da-1. Temme et al. (1979) stated that alfalfa seeding alone using herbicides is beneficial for weed control in alfalfa and that the feed produced in this way will increase the performance of farm animals. Differences in alfalfa yield values are affected by factors such as alfalfa variety, growing region, and climatic conditions. In our studies with the studies mentioned above, the similarities and differences between alfalfa yield and yield elements depend on the alfalfa variety, growing conditions and climate. due to variation from region to region.

Multivariate analysis of the parameters and the applications

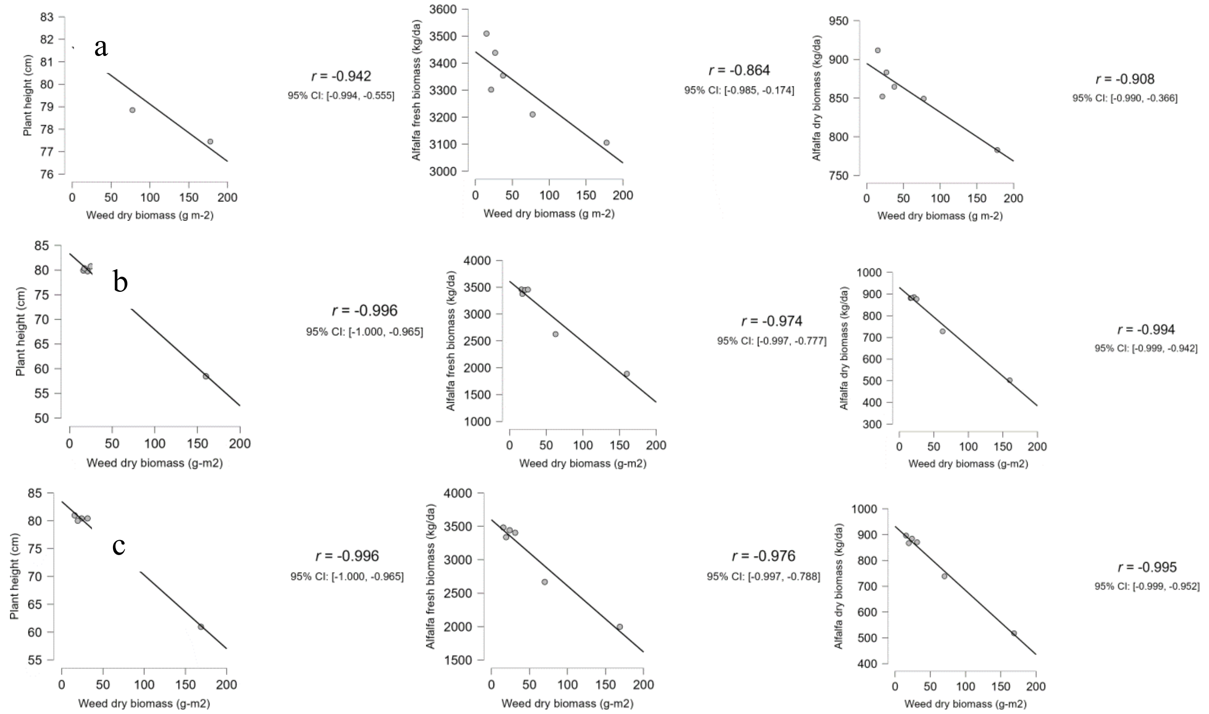
In addition to one-way analysis of variance, the mean values obtained were subjected to multiple statistical analyses to visualize the magnitude, correlations, and estimated parameters associated with independent processes. Since weed dry weights are critical issues considered in agricultural/non-agricultural fields, we discussed their relationships with other parameters. In this context, advanced analyzes such as correlation coefficient, heat map clustering, network graph analysis and principal component analysis were performed on the average values of the variables in the study.

In the current study, as discussed in the multivariate statistical analysis section, weed dry weight is negatively correlated with coefficients ranging from -0.864 to -0.942 in the first year: -0.864 to -0.942, in the second year: -974 to -996, and the average of both years is between -976 and -996. Based on the average of both years in the study, weed dry weight, plant height (r= -0.996, p<0.000), fresh weight (r=-976, p<0.000), dry weight (r=-995, P=0.000).) parameters showed a negative correlation and was statistically significant (Figure 2, Figure 3).



a: Year 2022, b: Year 2023, c: Average

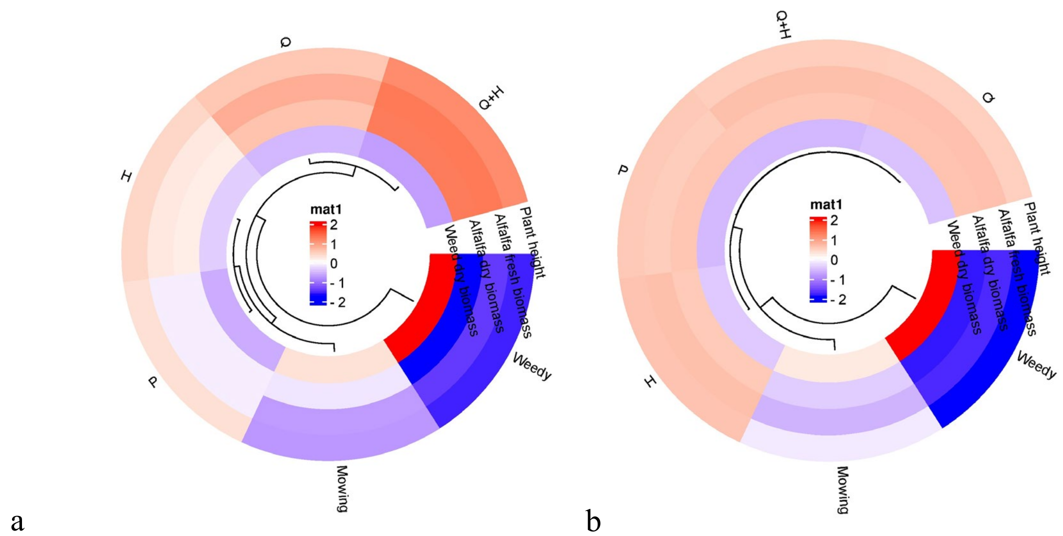
Figure 2. *Correlation analysis of estimated parameters*

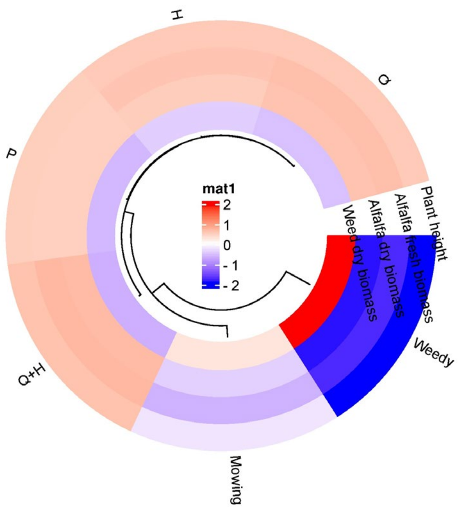


a: Year 2022, b: Year 2023, c: Average

***Figure 3.** Correlations between weed dry weight and other parameters*

Heat map clustering is clearly distinguished by separating dependent and independent variables into two main clusters with a color range (+2 to -2; red to blue) indicating the resulting values (Figure 4). Among the main clusters, a single cluster contained a weed control plot. The results obtained from heat map clustering showed that it was effective in controlling weeds, although the herbicides used in the study were different.



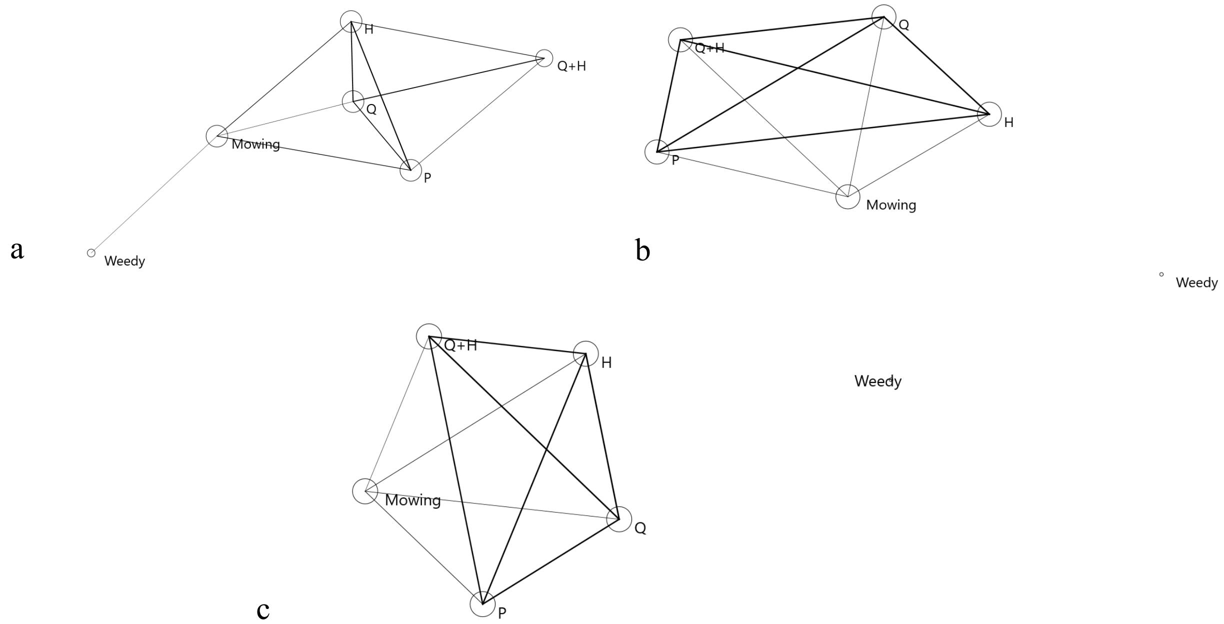


c

a: Year 2022, b: Year 2023, c: Average, Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

Figure 4. *Heat map of parameters corresponding to applications*

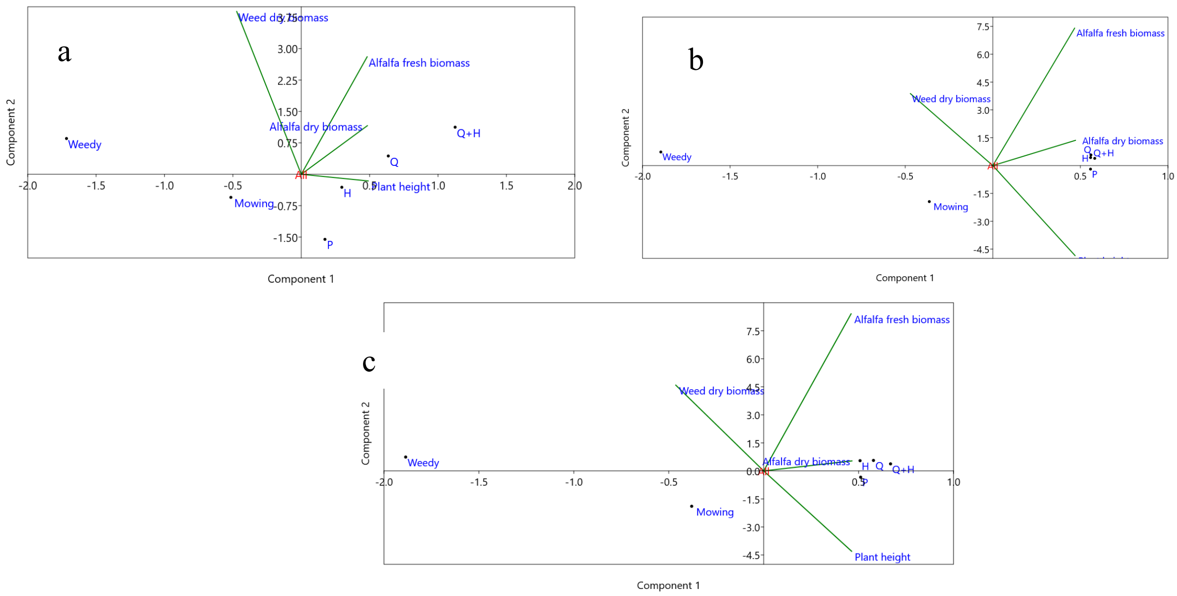
To consolidate the effects of the trials/treatments on alfalfa, a network graph analysis was also conducted to determine the relationship between treatments based on their effects/performance on agronomic traits and weed dry weights (Figure 5). The nodes along the lines represent the extent of the relationships, with thinner or lighter lines indicating weaker connections and thicker lines indicating stronger relationships. Consistent with heat map clustering, a clear separation emerged. In this analysis, the weedy control group was partially associated with mowing in the first year, but was not associated with any practice in the second year and when the average of both years was taken. Other practices are interrelated to a certain degree.



a: Year 2022, b: Year 2023, c: Average, Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

Figure 5. *Network graph analysis of applications*

To describe the rate of variation, the dry and fresh weights of alfalfa and the dry weight of weeds were distributed over a biplot pair (Figure 6). Accordingly, in the first year, the first two components (PC1: 94.70% and PC2: 3.60%) accounted for 98.30% of the variability of the original data, and in the second year, (PC1: 98.97% and PC2: 0.91%).) explained 99.88% of the variability of the original data and on average (PC1: 99.13% and PC2: 0.76%) explained 99.89% of the variability of the original data. Such a high variance explained clearly shows that principal component analysis can be used successfully to evaluate the impact of estimated parameters together with applications. At the end of both years, the first component (PC1), mowing (with -0.75 points), weed control (with -3.75 points) groups were negatively related, while Q+H (with 1.33 points), Q (It is positively related to (with a score of 1.15), H (with a score of 1.01) and P (with a score of 1.01). In addition, in both years when the study was conducted, "weed dry weight" was negative in the first year (with -0.48 points), in the second year (with -0.50 points) and based on the average of both years (with -0.50 points). While other parameters were found to be positively related.



a: Year 2022, b: Year 2023, c: Average, Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

Figure 6. Principal component analysis of parameters and applications

Advanced analyzes such as correlation, heat map clustering, hierarchical clustering, network plot analysis and principal component analysis performed on the average values of the variables in the study support the analysis of variance. In general, the effects and the relationships between the applications and the parameters are clearly stated.

CONCLUSION

The purpose of this study was to have a look at the frequency and density of *S. halepense* in alfalfa production areas in Iğdır province and the control possibilities of herbicides with different active ingredients against this weed. In the study, at the end of both years, the frequency of *S. halepense* in alfalfa cultivation areas in Iğdır province was determined as 92.25% and its density was 48.15 plants/m^2. The effects of the herbicides used in the study on *S. halepense* were similar in both years. The effects of herbicides on S. halepsense were low in the first assessment, but high effect rates were determined in the second assessment. At the end of both years, herbicide efficacy was found to be greater than 95% on *S. halepense*. In the study, the lowest *S. halepense* dry weights were obtained in the plots where herbicides were used in both years, and all herbicides were in the same statistical group. The effect rates of the herbicides used in the study on *S. halepense* dry weight at the end of two years varied between 81.50% and 90.75%. As a result, the herbicides used were effective on *S. halepense* and caused an increase in alfalfa yield. Management of *S. halepense* requires not only the use of herbicides, but also the adoption of modified crop management practices, including improved tillage. Certain effective methods can be used in conjunction with herbicides. Further research is essential to develop comprehensive, long-term strategies that integrate both chemical and non-chemical approaches for sustainable control of this troublesome weed species..

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Contributions to the Chrysomelidae (Coleoptera) Family from Different Habitats in the South and East of Turkey

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Abstract

This study was conducted on different plants in different habitats of Artvin, Bingöl, Diyarbakır, Elazığ, Erzurum, Kahramanmaraş, Muş, and Van provinces in southern and eastern Turkey between 2015 and 2023. Samples were collected by hand, mouth aspirator, and sweep nets during different periods. Seven subfamilies, 20 genera and 36 species were identified in this study. Among these species, 36 species, including 4 species in Artvin, 10 species in Bingöl, 2 species in Elâzığ, 2 species in Kahramanmaraş, 9 species in Muş and 8 species in Van, are new records for the fauna of their provinces. Among these species, *Cryptocephalus lederi* Weise, 1889 is the 3rd, *Chrysolina grata grata* (Faldermann, 1837) is the 2nd, *Derocrepis serbica* Kutschera, 1860 is the 4th, *Longitarsus cerinthes* (Schrank, 1798) and *Exosoma thoracicum* (Redtenbacher, 1843) is the 5th record for the fauna of Turkey. In addition, *Cassida palaestina* Reiche, 1858 are new records of Eastern Anatolia. In the present study, the location of the species, the plants on which they were collected, their distribution in Turkey and new records for some species were evaluated.

Keywords: Coleoptera, Chrysomelidae, Fauna, Turkey

INTRODUCTION

The family Chrysomelidae is one of the main families in the order Coleoptera, which is important in terms of the number of species it harbors, and is rich in species diversity (Kısmalı, 1973; Lopatin, 1977). Chrysomelidae, one of the largest families of beetles, harbors more than 35.000 species described to 19 subfamilies and more than 2000 genera worldwide. The total number of species was considered to be greater than 50,000. While the Palaearctic region is represented by approximately 3,500 species (Gruev, 1992; Konstantinov *et al*., 2009; Aslan and Ayvaz, 2009; Aslan *et al*., 2012; Ghahari and Jedryczkowski, 2012; Ekiz *et al*., 2013; Konstantinov *et al*., 2013), according to the most recent studies, it is reported to be represented by approximately 9,293 species in the region (Bezděk and Sekerka (in press)). In Turkey, about 968 Chrysomelidae species in 11 subfamilies and 113 genera have been identified (Bezděk and Sekerka (in press)).

Chrysomelidae and leaf beetles are phytophagous insects adapted to feed on a wide variety of plant groups. Both adults and larvae feed on cultivated plants as well as some useful wild plants or shrubs (Jolivet *et al*., 1988). The close relationship between the group and plants is important both ecologically and economically, because of their impact on agriculture. Although many species are known to be serious pests of cultivated plants, many others are accepted as useful biological control agents for weeds (Booth *et al*., 1990; Jolivet and Verma, 2002).

Some important studies on Chrysomelidae species that are harmful to some economically important crops and trees Glover (1871), Riley (1883), Dörtbudak *et al*., (1973), Jolivet, (1988), Aslan (1997, 2001), Bayram *et al*., (2004), Doğanlar *et al*., (2004), Coşkuncu and Gençer (2006), Tosun *et al*., (2008), Kennedy (2009), Özger *et al*., (2011), Aslan and Başar (2016), Özgen *et al*., (2018), Dağ (2019), Saygılı (2019), Soycan *et al*., (2019), Alaserhat *et al*., (2020).

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In this study, it was aimed to reveal new records of Chrysomelidae species obtained in Artvin, Bingöl, Diyarbakır, Elâzığ, Erzurum, Kahramanmaraş, Muş and Van provinces to the fauna of the provinces locally and the country in general.

MATERIAL and METHOD

This research was conducted in 93 different locations in the Artvin, Bingöl, Diyarbakır, Elazığ, Erzurum, Kahramanmaraş, Muş and Van provinces between 2015-2023. During the study period, samples were collected using a sweep net, mouth aspirator and hand at various vegetation stages. The location information of the collected samples was noted on labelling papers and the samples were preserved and brought to the laboratory. During preparation, large insects were pinned and small insects were glued to gluing cartons in the walking position and kept in insect storage boxes in the Entomology Museum (EMIT) of the Department of Plant Protection, Faculty of Agriculture, Iğdır University. Insects were identified using the identification keys given by Warchałowski (2003, 2010), Özdikmen *et al*. (2016), Özdikmen and Silkin (2016), and Özdikmen *et al*. (2022).

RESULTS and DISCUSSION

In thise study, 36 species/subspecies belonging to seven subfamilies and 20 genera were identified in 93 localities in the Artvin, Bingöl, Diyarbakır, Elazığ, Erzurum, Kahramanmaraş, Muş and Van provinces. Information on the material examined and the distribution of these species are presented below.

Subfamily **Criocerinae** Latreille, 1804

Oulema melanopus (Linnaeus, 1758)

Material examined: TR-Bingöl: Central, Sarıçiçek, 38°52´29″N 40°35´18″E, 1024 m, 12.06.2021, C. Gözüaçık, 1 specimen; TR-Elâzığ: Kovancılar, Çakırtaş, 38°45´33″N 39°37´16″E, 1024 m, 11.06.2021, C. Gözüaçık, 2 specimens; TR-Erzurum: Horasan**,** Aşağıaktaşlı, 39°52´41″N 42°23´1″E, 2139 m, 04.08.2023, M. Güven, 1 specimen; TR-Muş: Central, Aydıngün neighbourhood, 38°56´37″N 41°30´19″E, 2042 m, 11.06.2021, C. Gözüaçık, 1 specimen; Bulanık, Arakonak, 39°6´33″N 47°9´56″E, 1460 m, 10.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Adana, Afyonkarahisar, Aksaray, Ankara, Antalya, Ardahan, Aydın, Çanakkale, Çankırı, Çorum, Diyarbakır, Eskişehir, Erzincan, Erzurum, Gaziantep, Hatay, Iğdır, İzmir, Kahramanmaraş, Karaman, Kastamonu, Kayseri, Konya, Karabük, Kars, Kütahya, Manisa, Muğla, Osmaniye, Samsun, Siirt, Tokat; **Europe:** Edirne, Kırklareli, Tekirdağ (Medvedev, 1970; Gül-Zümreoğlu, 1972; Tomov and Gruev, 1975; Gruev and Tomov, 1984; Campobasso *et al*., 1999; Aslan, 2000; Turanlı *et al*., 2002; Gök and Çilbiroğlu, 2003; Gök and Gürbüz, 2004; Gruev, 2005; Özdikmen and Turgut 2008; Aslan *et al*., 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Özbek, 2014; Medvedev, 2015; Bal *et al*., 2018a; Özdikmen *et al*., 2020; Bal and Şahin, 2021).

Remarks: It is new record for Bingöl, Elâzığ and Muş provinces. It was collected using a sweep net in a wheat field.

Subfamily **Clytrinae** Kirby, 1837

Clytra valeriana valeriana (Ménétriés, 1832)

Material examined: TR-Van: Başkale, Aşalan, 38°3′45″N 44°6′1″E, 2129 m, 21.06.2015, M. Açıkgöz, 1 specimen.

Distribution in Turkey: Asia: Aksaray, Ankara, Antalya, Aydın, Çankırı, Eskişehir, Erzincan, Erzurum, Gümüşhane, İzmir, Kayseri, Kırıkkale, Konya, Kars, Manisa, Mersin, Nevşehir, Niğde, Osmaniye, Sivas, Uşak, Yozgat; **Europe:** Çanakkale, Edirne, İstanbul, Kırklareli, Tekirdağ (Tomov and Gruev, 1975; Kasap, 1987b; Aydın and Kısmalı, 1990; Aslan and Özbek, 1998; Warchałowski, 2003; Özdikmen *et al*., 2010; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Mercan, 2014; Bal *et al*., 2018a; Bal, 2021).

Remarks: This is a new record for Van province. Specimens were collected manually form *Rumex crispus* L.

Labidostomis brevipennis Faldermann, 1837

Material examined: TR-Bingöl: Karlıova, Sudağı, 39°6′5″N 40°39′37″E, 1657 m, 12.06.2021, C. Gözüaçık, 1 specimen; TR-Van: Saray, Yamanyurt, 38°31′46″N 44°15′30″E, 2184 m, 04.06.2021, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Bingöl, Çankırı, Hakkâri, Elâzığ, Erzincan, Konya, Malatya, Şırnak (Warchałowski, 1985, 2003; Regalin, 2002; Ekiz *et al*., 2013; Özdikmen and Mercan, 2014; Özdikmen *et al*., 2016; Aslan *et al*., 2020).

Remarks: This is a new record for Van province. The samples were collected using a sweep net on *Rheum ribes* L. and *Onobrychis* sp.

Labidostomis longimana (Linnaeus, 1761)

Material examined: TR-Bingöl: Central, Aşağıpazar, 39°36′9″N 43°34′4″E, 1881 m, 08.06.2021, C. Gözüaçık, 1 specimen; Yeniköy, 39°12′0″N 40°56′35″E, 1791 m, 12.06.2021, C. Gözüaçık, 1 specimen; Saray neighbourhood, 38°53′24″N 40°31′50″E, 1098 m, 12.06.2021, C. Gözüaçık, 1 specimen; TR-Erzurum: Horasan, Aşağıaktaşlı, 39°51′58″N 42°23′13″E, 2141 m, 19.07.2022, M. Güven, 1 specimen; Aşağıaktaşlı, 39°54′41″N 42°23′2″E, 2128 m, 13.07.2023, M. Güven, 2 specimens; Azap, 40°2′2″N 42°5′10″E, 1583 m, 15.06.2015, M. Açıkgöz, 1 specimen; Şenkaya, Değirmenlidere, 40°45′0″N 42°32′24″E, 1915 m, 24.07.2022, M. Güven, 5 specimens; TR-Muş: Korkut, Kıryaka, 39°52′18″N 41°57′7″E, 1669 m, 10.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Ağrı, Ankara, Ardahan, Balıkesir, Bayburt, Bilecik, Bolu, Düzce, Eskişehir, Erzurum, Gümüşhane, Isparta, Kahramanmaraş, Kastamonu, Kayseri, Kırıkkale, Konya, Kars, Nevşehir, Niğde, Osmaniye, Samsun, Siirt, Sivas, Yozgat, Zonguldak; **Europe:** Edirne, Kırklareli, Tekirdağ (Tomov and Gruev, 1975; Gruev and Tomov, 1979, 1984; Kasap, 1987a; Aydın and Kısmalı, 1990; Aslan and Özbek 1998; Gök, 2003; Özgen and Tok, 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Mercan, 2014; Özdikmen *et al*., 2016; Bal, 2021; Özdikmen and Şahin, 2021).

Remarks: This is a new record for the Bingöl and Muş provinces. Specimens were collected using a sweep net on *Melilotus officinalis* (L.) Desr.

Smaragdina limbata (Steven, 1806)

Material examined: TR-Muş: Bulanık, Arakonak, 39°6′33″N 47°9′56″E, 1460 m, 10.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Adana, Afyonkarahisar, Amasya, Ankara, Antalya, Aydın, Balıkesir, Bilecik, Bursa, Bolu, Burdur, Çanakkale, Çankırı, Çorum, Denizli, Diyarbakır, Düzce, Erzincan, Eskişehir, Erzurum, Gaziantep, Hakkari, Hatay, Isparta, İstanbul, İzmir, Kahramanmaraş, Kastamonu, Kayseri, Konya, Karabük, Kütahya, Manisa, Mersin, Muğla, Niğde, Osmaniye, Sakarya, Samsun, Sinop, Şanlıurfa, Uşak, Yozgat, Zonguldak; **Europe:** İstanbul, Kırklareli, Tekirdağ (Sahlberg, 1913; Medvedev, 1970; Tomov and Gruev, 1975; Gruev and Tomov, 1979, 1984; Kasap, 1987b; Aydın and Kısmalı, 1990; Aslan and Özbek, 1998; Gök, 2003; Warchałowski, 2003; Gök and Gürbüz, 2004; Gruev, 2004, 2005; Gök and Çilbiroğlu 2005; Aslan *et al*., 2009; Şen and Gök, 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Mercan, 2014; Coral Şahin, 2020; Bal, 2021; Özdikmen *et al*., 2021a; Özdikmen and Şahin, 2021).

Remarks: This is a new record for the Muş province. However, the host plant has not yet been determined.

Smaragdina xanthaspis (Germar, 1824)

Material examined: TR-Artvin: Şavşat, Yavuzköy, 41°14′4″N 42°24′29″E, 1604 m, 24.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Afyonkarahisar, Amasya, Ankara, Antalya, Artvin, Balıkesir, Bartın, Bursa, Bilecik, Bolu, Çankırı, Çorum, Düzce, Erzurum, Isparta, Kahramanmaraş, Kastamonu, Kayseri, Konya, Karabük, Kütahya, Niğde, Ordu, Sakarya, Samsun, Sinop, Sivas, Trabzon, Yozgat, Zonguldak; **Europe:** Edirne (Medvedev, 1970; Tomov and Gruev, 1975; Gruev and Tomov, 1979, 1984; Kasap, 1987b; Aydın and Kısmalı, 1990; Aslan and Özbek, 1998; Gök, 2003; Warchałowski, 2003; Gruev, 2004, 2005; Aslan *et al*., 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Mercan, 2014; Bal, 2021; Özdikmen and Şahin, 2021; Ünal, 2021).

Remarks: The host plant has not been determined.

Subfamily **Cryptocephalinae** Gyllenhal, 1813

Cryptocephalus connexus Olivier, 1807

Material examined: TR-Bingöl: Kaleönü neighborhood., 38°53′9″N 40°36′26″E, 1118 m, 12.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Amasya, Ankara, Antalya, Artvin, Balıkesir, Bolu, Bursa, Çanakkale, Çankırı, Çorum, Erzincan, Erzurum, Giresun, Isparta, İzmir, Kahramanmaraş, Kastamonu, Kayseri, Konya, Karabük, Kars, Kütahya, Manisa, Mersin, Niğde, Sinop, Sivas, Tokat, Yozgat, Zonguldak; **Europe:** Edirne, Kırklareli (Ekiz *et al*., 2013; Özdikmen and Cihan, 2014; Şen and Gök, 2014; Bal *et al*., 2016; Özdikmen *et al*., 2020; Özdikmen and Şahin, 2021).

Remarks: Samples were collected using a sweep net from *Lotus corniculatus* L. and *Medicago* sp.

Cryptocephalus duplicatus Suffrian, 1847

Material examined: TR-Artvin: Şavşat, Yavuzköy, 41°14´4″N 42°24´29″E, 1604 m, 24.07.2022, M. Güven, 2 specimens; TR-Erzurum: Şenkaya, Değirmenli, 40°45´0″N 42°32´24″E, 1915 m, 24.07.2022, M. Güven, 1 specimen; Horasan, Saç Dağı, 39°51´58″N 42°23´13″E, 2141 m, 19.07.2022, M. Güven, 3 specimens; Aşağıaktaşlı, 39°52´42″N 42°23´0″E, 2130 m, 01.07.2023, M. Güven, 5 specimens.

Distribution in Turkey: Asia: Adana, Afyonkarahisar, Amasya, Ankara, Antalya, Artvin, Bartın, Bilecik, Bitlis, Bolu, Bursa, Çankırı, Çorum, Denizli, Erzincan, Eskişehir, Erzurum, Giresun, Gümüşhane, Hakkâri, Isparta, İstanbul, İzmir, Kahramanmaraş, Kastamonu, Karabük, Kars, Kayseri, Kocaeli, Konya, Kütahya, Manisa, Mersin, Nevşehir, Ordu, Sakarya, Samsun, Sinop, Siirt, Sivas, Tokat, Tunceli, Trabzon, Van, Yozgat, Zonguldak; **Europe:** Kırklareli, Tekirdağ (Aslan and Özbek 1997; Sassi and Kısmalı, 2000; Turanlı *et al*., 2002; Warchałowski, 2003; Atay and Çam, 2006; Şen and Gök, 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Cihan, 2014; Bal *et al*., 2016; Gök and Bostan, 2020; Özdikmen *et al*., 2020; Özdikmen and Şahin, 2021; Bal *et al*., 2022).

Remarks: Samples were collected by hand from *Tragopogon* sp., *Achillea millefolium* L., *Scorzonera tomentosa* L. and *Crepis setosa* Hall. Fil.

Cryptocephalus exiguus variceps Weise 1884

Material examined: TR-Artvin: Şavşat, Yavuzköy, 41°14´4″N 42°24´29″E, 1604 m, 24.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Adana, Erzurum, İstanbul, İzmir, Sakarya, Tokat; **Europe:** Çanakkale, Edirne, İstanbul, Kırklareli, Tekirdağ (Weise, 1884; Medvedev, 1970; Gruev and Tomov, 1984; Tomov, 1984; Aslan and Özbek, 1997; Sassi and Kısmalı, 2000; Warchałowski, 2003; Gruev, 2004, 2005; Atay and Çam, 2006; Ekiz *et al*., 2013; Özdikmen and Cihan, 2014).

Remarks: This is a new record for Artvin province. However, the host plant has not yet been determined.

Cryptocephalus lederi Weise, 1889

Material examined: TR-Artvin: Şavşav**,** Karaköy**,** 41°13´35″N 42°28´13″E, 2199 m, 24.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Ankara and Malatya (Sassi and Kısmalı, 2000; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Cihan, 2014).

Remarks: This is new for Artvin province and the 3rd record for Turkey. Specimens were collected manually from *Picris hieracioides* L.

Cryptocephalus octacosmus Bedel, 1891

Material examined: TR-Erzurum: Horasan, Aşağıaktaşlı, 39°52´41″N 42°26´1″E, 2139 m, 04.08.2023, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Adana, Aksaray, Ankara, Antalya, Bayburt, Bilecik, Bolu, Bursa, Çanakkale, Çankırı, Denizli, Diyarbakır, Eskişehir, Erzurum, Hakkâri, Isparta, İzmir, Kayseri, Kocaeli, Konya, Karabük, Kütahya, Manisa, Mardin, Mersin, Muş, Nevşehir, Niğde, Sakarya, Samsun, Sinop, Sivas, Tokat, Tunceli, Zonguldak; **Europe:** Kırklareli, Tekirdağ (Medvedev, 1975; Tomov and Gruev, 1975; Gruev and Tomov, 1984; Tomov, 1984; Aslan and Özbek, 1997; Sassi and Kısmalı, 2000; Gök, 2002; Turanlı *et al*., 2002; Warchałowski, 2003; Gök and Gürbüz, 2004; Gruev, 2005; Atay and Çam, 2006; Aslan *et al*., 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Ünal, 2021).

Remarks: The host plant has not been determined.

Cryptocephalus sericeus (Linnaeus, 1758)

Material examined: TR-Artvin: Şavşat, Yavuzköy, 41°14´4″N 42°24´29″E, 1604 m, 24.07.2022, M. Güven, 2 specimens; TR-Erzurum: Şenkaya, Değirmenlidere, 40°45´0″N 42°32´24″E, 1915 m, 24.07.2022, M. Güven, 2 specimens; TR-Muş: Varto, Merkez, 39°07´04″N 41°17´40″E, 1977 m, 25.07.2018, C. Gözüaçık, 2 specimens.

Distribution in Turkey: Asia: Ankara, Ardahan, Artvin, Balıkesir, Bursa, Çankırı, Çorum, Erzincan, Erzurum, Gümüşhane, Isparta, İzmir, Kastamonu, Konya, Kars, Nevşehir, Samsun, Sivas; **Europe:** Kırklareli (Ekiz *et al*., 2013; Özdikmen and Cihan, 2014; Bal *et al*., 2022).

Remarks: This is a new record for the Muş province. Specimens were collected by hand on *Centaurea solstitialis* L., *Achillea millefolium* L. subsp. *millefolium* L., and *Inula oculus-christi* L.

Pachybrachis tesselatus tauricus (Olivier, 1791)

Material examined: TR-Bingöl: Central, Sarıçiçek, 38°53´09″N 40°36´26″E, 1148 m, 12.06.2021, M. Güven, 1 specimen; Aşağıakpınar, 39°36´09″N 43°34´21″E, 1881 m, 08.06.2021, M. Güven, 1 specimen; TR-Erzurum: Horasan, Aşağıaktaşlı, 39°52´42″N 42°23´0″E, 2130 m, 01.07.2023, M. Güven, 10 specimens; TR-Muş: Merkez, Şenoba, 38°53´43″N 41°30´34″E, 1291 m, 11.06.2021, C. Gözüaçık, 1 specimen; Bulanık, Tepecik, 38°56´2″N 41°59´24″E, 1705 m, 10.06.2021, C. Gözüaçık, 1 specimen; Varto, Central, 39°10´44″N 41°26´3″E, 1509 m, 11.06.2021, C. Gözüaçık, 5 specimens.

Distribution in Turkey: Asia: Adana, Adıyaman, Afyonkarahisar, Ağrı, Aksaray, Amasya, Ankara, Antalya, Bartın, Bayburt, Bilecik, Bolu, Bursa, Çankırı, Çanakkale, Çorum, Elâzığ, Erzincan, Erzurum, Eskişehir, Gaziantep, Gümüşhane, Giresun, Hatay, Isparta, İzmir, Kahramanmaraş, Karaman, Kastamonu, Kayseri, Konya, Kars, Kütahya, Malatya, Mardin, Mersin, Muğla, Muş, Nevşehir, Niğde, Ordu, Samsun, Sivas, Tokat, Uşak, Van, Yozgat (Medvedev, 1970; Tomov and Gruev, 1975; Gruev and Tomov, 1984; Tomov, 1984; Aslan and Özbek, 1997; Sassi and Kısmalı, 2000; Gök, 2002; Gök and Çilbiroğlu 2005; Şen and Gök, 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Cihan, 2014; Şen and Gök, 2014; Bal *et al*., 2016; Aslan *et al*., 2020; Özdikmen and Şahin, 2021).

Remarks: This is a new record for the Bingöl and Muş provinces. Specimens were collected from different habitats on different plants such as *Lappula barbata* (Bieb.) Gürke, *Papaver rhoeas*, *Onobrychis* sp.

Subfamily **Chrysomelinae** Latreille, 1802

Chrysolina grata grata (Faldermann, 1837)

Material examined: TR-Kahramanmaraş: Central, Yeşilgöz, 37°54´56″N 36°37´49″E, 1389 m, 13.08.2023, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Şanlıurfa (Bienkowski, 2001).

Remarks: This is new for the Kahramanmaraş province and the 2nd record for Turkey. Specimens were collected from *Astragalus* spp.

Chrysolina herbacea alacris Bechyné, 1950

Material examined: TR-Bingöl: Heserek, 38°53´16″N 40°17´43″E, 1940 m, 10.07.2021, C. Gözüaçık, 2 specimens.

Distribution in Turkey: Asia: Antalya, Diyarbakır, Isparta, Kahramanmaraş, Karaman, Mersin, Osmaniye (Ekiz *et al*., 2013; Özdikmen, 2014; Özdikmen *et al*., 2021c).

Remarks: This is a new record for Bingöl province. Specimens were collected by hand from *Mentha longifolia* (L.) Hudson subsp. *longifolia* (L.) Hudson.

Entomoscelis adonidis (Pallas, 1771)

Material examined: TR-Van: Başkale, Aşalan, 38°03´45″N 44°05´40″E, 2129 m, 21.06.2015, M. Açıkgöz, 3 specimens.

Distribution in Turkey: Asia: Afyonkarahisar, Aksaray, Amasya, Ankara, Antalya, Ardahan, Burdur, Çankırı, Çorum, Denizli, Diyarbakır, Düzce, Elâzığ, Eskişehir, Erzurum, Gaziantep, Hatay, Isparta, İzmir, Kahramanmaraş, Karaman, Kastamonu, Kayseri, Kırıkkale, Karabük, Konya, Kırşehir, Nevşehir, Niğde, Sivas, Tokat, Yozgat, Zonguldak; **Europe:** Çanakkale, Edirne, İstanbul, Kırklareli, Tekirdağ (Ekiz *et al*., 2013; Özdikmen, 2014; Medvedev, 2015; Bal *et al*., 2018a; Aslan *et al*., 2020; Özdikmen *et al*., 2020, 2021c; Özdikmen and Şahin, 2021).

Remarks: This is a new record for Van province. Specimens were collected from plants such as *Calamagrostis epigejos* (L.) Roth and *Delphinium laxiusculum* (Boiss.) Rouy, *Sisymbrium loeselii* L., *S. altissimum* L., *Lepidium draba* L., *Bunias orientalis* L., *Hordeum vulgare* L.

Gastrophysa polygoni (Linnaeus, 1758)

Material examined: TR-Bingöl: Çeltiksuyu, 38°50´13″N 40°32´25″E, 1071 m, 12.06.2021, C. Gözüaçık, 8 specimens; Gümüşlü, 38°44´48″N 40°30´40″E, 1010 m, 11.06.2021, C. Gözüaçık, 1 specimen; Heserek, 38°53´16″N 40°17´43″E, 1904 m, 10.07.2021, C. Gözüaçık, 1 specimen; TR-Muş: Central, Şenoba, 38°53´43″N 41°30´34″E, 1291 m, 11.06.2021, C. Gözüaçık, 1 specimen; Aydıngün neighborhood, 38°56´37″N 41°30´19″E, 2042 m, 11.06.2021, C. Gözüaçık, 1 specimen; TR-Van: Erciş, Kırkpınar neighborhood, 39°7´37″N 43°8´43″E, 1962 m, 10.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Afyonkarahisar, Adana, Aksaray, Amasya, Ankara, Ardahan, Artvin, Bartın, Bolu, Çankırı, Denizli, Diyarbakır, Düzce, Erzincan, Eskişehir, Erzurum, Isparta, İstanbul, İzmir, Kahramanmaraş, Karabük, Karaman, Kastamonu, Kayseri, Konya, Kars, Kütahya, Mardin, Mersin, Nevşehir, Niğde, Ordu, Samsun, Sinop, Trabzon, Tokat, Yozgat; **Europe:** Edirne, İstanbul (Ekiz *et al*., 2013; Sert and Kabalak, 2013; Özdikmen, 2014; Şen and Gök, 2014; Gök and Bostan, 2020; Özdikmen *et al*., 2020, 2021c; Özdikmen and Şahin, 2021; Ünal, 2021).

Remarks: This is a new record for the Bingöl, Muş, and Van provinces. Specimens were collected from *Rumex tuberosus* L. subsp. *horozontalis* (Koch) Rech., *Picris hieracioides* L., *Phlomis tuberosa* L., *Polygonum aviculare* L., *P. bellardii* and *Salvia verticillata* L. subsp. *verticillata* L.

Gonioctena fornicata (Brüggemann, 1873)

Material examined: TR-Bingöl: Central, Saray neighbourhood, 38°53′24″N 40°31′50″E, 1098 m, 12.06.2021, C. Gözüaçık, 1 specimen; Kaleönü neighbourhood, 38°53′9″N 40°36′26″E, 1118 m, 12.06.2021, C. Gözüaçık, 6 specimens; Sarıçiçek, 38°52′44″N 40°36′25″E, 1097 m, 12.06.2021, C. Gözüaçık, 6 specimens; Sarıçiçek, 38°53′9″N 40°36′26″E, 1097 m, 12.06.2021, C. Gözüaçık, 1 specimen; Garip, 38°44′51″N 40°30′23″E, 1030 m, 11.06.2021, C. Gözüaçık, 3 specimens; Çeltiksuyu, 38°50′13″N 40°32′25″E, 1071 m, 12.06.2021, C. Gözüaçık, 2 specimens; Heserek, 38°53′16″N 40°17′43″E, 1904 m, 10.06.2021, C. Gözüaçık, 1 specimen; Yeniköy, 38°52′18″N 40°36′30″E, 1112 m, 12.06.2021, C. Gözüaçık, 1 specimen; Karlıova, Sudağı, 39°6′5″N 40°50′37″E, 1657 m, 12.06.2021, C. Gözüaçık, 5 specimens; Çilliköy, 39°9′30″N 40°53′23″E, 1794 m, 12.06.2021, C. Gözüaçık, 1 specimen; Genç, Gümüşlü, 38°44′48″N 40°30′40″E, 1010 m, 11.06.2021, C. Gözüaçık, 6 specimens; TR-Diyarbakır: Çermik, Aynalı, 38°7′46″N 39°27′37″E, 856 m, 15.04.2021, C. Gözüaçık, 5 specimens; TR-Muş: Central, Aydıngün neighbourhood, 38°56′37″N 41°30′19″E, 2042 m, 11.06.2021, C. Gözüaçık, 7 specimens; Şenoba, 38°53′43″N 41°30′34″E, 1291 m, 11.06.2021, C. Gözüaçık, 2 specimens; Bulanık, Tepecik, 38°56′2″N 41°59′24″E, 1705 m, 10.06.2021, C. Gözüaçık, 1 specimen; Bulanık, Arakonak, 39°6′33″N 47°9′56″E, 1460 m, 10.06.2021, C. Gözüaçık, 1 specimen; Varto, Central, 39°10′44″N 41°26′3″E, 1509 m, 11.06.2021, C. Gözüaçık, 1 specimen; Korkut, Kıryaka, 39°52′18″N 41°57′7″E, 1669 m, 10.06.2021, C. Gözüaçık, 2 specimens.

Distribution in Turkey: Asia: Adana, Afyonkarahisar, Aksaray, Ankara, Antalya, Artvin, Bolu, Bilecik, Bursa, Çankırı, Çorum, Denizli, Diyarbakır, Düzce, Erzincan, Eskişehir, Erzurum, Gaziantep, Hatay, Isparta, İzmir, Kahramanmaraş, Karaman, Kastamonu, Kayseri, Konya, Karabük, Kütahya, Mardin, Mersin, Muş, Nevşehir, Niğde, Osmaniye, Sinop, Tokat, Tunceli, Yozgat, Zonguldak; **Europe:** Çanakkale, Edirne, İstanbul, Kırklareli, Tekirdağ (Sahlberg, 1913; Medvedev, 1970; Gruev and Tomov, 1979; Aslan and Özbek, 1999; Aslan *et al*., 2003; Gök and Çilbiroğlu, 2003; Warchałowski, 2003, 2010; Gök and Gürbüz, 2004; Gruev, 2004, 2005; Atay and Çam, 2006; Aslan *et al*., 2009; Şen and Gök, 2009; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Cihan, 2014; Özdikmen *et al*.,2021b; Ünal, 2021).

Remarks: This is a new record for Bingöl province. Specimens were collected using a sweep net from *Medicago* sp.

Subfamily **Galerucinae** Latreille, 1802

Calomicrus lividus (Joannis, 1866)

Material examined: TR-Bingöl: Central, Saray neighbourhood, 38°53′24″N 40°31′50″E, 1098 m, 12.06.2021, C. Gözüaçık, 3 specimens; Yeniköy, 39°12′0″N 40°56′35″E, 1791 m, 12.06.2021, C. Gözüaçık, 2 specimens; TR-Muş: Varto, Central, 39°10′44″N 41°26′3″E, 1509 m, 11.06.2021, M. Güven, 1 birey.

Distribution in Turkey: Asia: Adana, Ağrı, Antalya, Diyarbakır, Erzincan, Eskişehir, Erzurum, Hatay, Isparta, İzmir, Konya, Kars, Mersin, Osmaniye (Fairmaire, 1884; Weise, 1898, 1900; Sahlberg, 1913; Tomov, 1984; Aslan, 1998; Aslan *et al*., 2000, 2009; Warchałowski, 2003; Gök and Duran, 2004; Bezdek, 2007; Özdikmen and Arslan, 2009; Şen and Gök, 2009; Ekiz *et al*., 2013; Özdikmen and Topçu, 2014).

Remarks: This is a new record for the Bingöl and Muş provinces. Specimens were collected from *Falcaria vulgaris* Bernh.

Exosoma thoracicum (Redtenbacher, 1843)

Material examined: TR-Bingöl: Karlıova, Sudağı, 39°6´5″N 40°50´37″E, 1657 m, 12.06.2021, C. Gözüaçık, 1 specimen; TR-Muş: Bulanık, Arakonak, 39°6´33″N 47°9´56″E, 1460 m, 10.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Adana, Diyarbakır, Malatya, Mardin, Şanlıurfa (Ekiz *et al*., 2013; Özdikmen and Topçu, 2014; Özgen *et al*., 2018).

Remarks: Specimens were collected from *Rorippa austriaca* (Crantz) Besser, *Onobrychis* sp., *Papaver rhoeas* L. and *Hordeum vulgare* L. Özgen *et al*., (2018) reported that this species caused significant damage in onion (*Allium cepa*) cultivation areas in Malatya province.

Galeruca armeniaca Weise, 1886

Material examined: TR-Erzurum: Horasan, Tavşancık, 40°6´20″N 42°22´39″E, 1504 m, 15.06.2015, M. Açıkgöz, 1 specimen.

Distribution in Turkey: Asia: Afyonkarahisar, Çankırı, Erzincan, Erzurum, Iğdır, Isparta, Kars (Ekiz *et al*., 2013; Özdikmen and Topçu, 2014; Bal *et al*., 2018a).

Remarks: Samples were collected with hands and sweep nets from *Cephalaria sparsipilosa* Matthews, *Papaver rhoeas* L., and *Glycyrrhiza glabra* L.

Galeruca pomonae pomonae (Scopoli, 1763)

Material examined: TR-Erzurum: Horasan, Aşağıaktaşlı, 39°51´58″N 42°23´13″E, 2141 m, 19.07.2022, M. Güven, 2 specimens; Aşağıaktaşlı, 39°54´41″N 42°23´2″E, 2128 m, 13.07.2023, M. Güven, 1 specimen; Aşağıaktaşlı, 39°52´41″N 42°23´1″E, 2139 m, 04.08.2023, M. Güven, 1 specimen; Şenkaya, Değirmenlidere, 40°45´0″N 42°32´24″E, 1915 m, 24.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Afyonkarahisar, Aksaray, Ankara, Antalya, Artvin, Bolu, Çanakkale, Çankırı, Çorum, Erzurum, Giresun, Isparta, İzmir, Kahramanmaraş, Kastamonu, Kayseri, Konya, Nevşehir, Niğde, Osmaniye, Rize, Zonguldak (Ekiz *et al*., 2013; Özdikmen and Topçu, 2014).

Remarks: Specimens were collected with hand from *Cephalaria sparsipilosa* Matthews.

Galeruca spectabilis orientalis (Osculati, 1844)

Material examined: TR-Kahramanmaraş: Ilıca, 37°50´17″N 36°52´15″E, 904 m, 17.08.2020, C. Gözüaçık, 2 specimens; TR-Van: Tuşba, Çakırbey, 38°55´13″N 43°36´14″E, 1724 m, 30.06.2021, C. Gözüaçık, 2 specimens.

Distribution in Turkey: Asia: Aksaray, Ankara, Antalya, Ardahan, Artvin, Bayburt, Çankırı, Erzurum, Kastamonu, Kayseri, Kırıkkale, Konya, Kars, Mersin, Nevşehir, Niğde, Sinop, Trabzon (Tomov and Gruev, 1975; Gruev and Tomov, 1979; Tomov, 1984; Aslan, 1998; Aslan *et al*., 2000; Warchałowski, 2003; Özdikmen, 2011; Özdikmen and Topçu, 2014; Bal *et al*., 2018a).

Remarks: This is a new record for the Kahramanmaraş and Van provinces. Specimens were collected by hand from *Papaver rhoeas* L.

Galeruca tanaceti tanaceti (Linnaeus, 1758)

Material examined: TR-Artvin: Şavşat, Karaköy, 41°13´35″N 42°28´13″E, 2199 m, 24.07.2022, M. Güven, 9 specimens; TR-Erzurum: Horasan, Aşağıaktaşlı, 39°52´42″N 42°23´0″E, 2130 m, 01.07.2023, M. Güven, 2 specimens.

Distribution in Turkey: Asia: Ankara, Çankırı, Çorum, Eskişehir, Erzurum, Isparta, Kastamonu, Kars, Ordu, Sinop (Ekiz *et al*., 2013; Özdikmen and Topçu, 2014; Bal *et al*., 2018a).

Remarks: This is a new record for the Artvin province. Specimens were collected by hand from *Cephalaria sparsipilosa* Matthews.

Subfamily **Alticinae** Newman, 1834

Altica ampelophaga Guérin, 1858

Material examined: TR-Van: Çaldıran, Soğuksu, 39°17´17″N 44°2´22″E, 2244 m, 04.06.2021, M. Güven, 1 specimen; TR-Muş: Central, Aydıngün neighbourhood, 38°56´37″N 41°30´19″E, 1263 m, 11.06.2021, C. Gözüaçık, 6 specimens.

Distribution in Turkey: Asia: Ankara, Iğdır, Isparta, İzmir, Konya (Sahlberg, 1913; Kerville, 1939; Aslan and Warchałowski, 2001; Gruev and Döberl, 2005; Aslan, 2007; Aslan and Ayvaz, 2009; Ekiz *et al*., 2013).

Remarks: This is a new record for Van and Muş provinces. Specimens were collected using a sweep net from *Medicago* sp..

Altica oleracea oleracea (Linnaeus, 1758)

Material examined: TR-Bingöl: Karlıova, Sudağı, 39°6´5″N 40°50´37″E, 1657 m, 12.06.2021, C. Gözüaçık, 3 specimens; TR-Erzurum: Horasan, Saç Dağı, 39°51´58″N 42°23´13″E, 2141 m, 19.07.2022, M. Güven, 1 specimen; Aşağıaktaşlı, 39°54´41″N 42°23´2″E, 2128 m, 13.07.2023, M. Güven, 1 specimen; Aşağıaktaşlı, 39°52´41″N 42°23´1″E, 2139 m, 04.08.2023, M. Güven, 59 specimens.

Distribution in Turkey: Asia: Ankara, Antalya, Artvin, Bayburt, Bolu, Burdur, Düzce, Erzurum, Erzincan, Eskişehir, Isparta, Kayseri, Konya, Kars, Kütahya, Nevşehir, Rize, Samsun, Sivas, Zonguldak; **Europe:** Edirne (Ekiz *et al*., 2013; Özdikmen, 2014; Bayram and Aslan, 2015; Turantepe, 2017; Gök and Turantepe, 2019; Aslan *et al*., 2020; Gök and Bostan, 2020; Özdikmen *et al*., 2020; Ünal, 2021; Özdikmen and Şahin, 2022).

Remarks: The specimens were collected using a mouth aspirator and sweep net on *Cephalaria sparsipilosa* Matthews, *Arctium minus* (Hill) Bernh. subsp. *minus* (Hill) Bernh., *Falcaria vulgaris* Bernh. and *Crambe orientalis* L.

Chaetocnema arenacea (Allard, 1860)

Material examined: TR-Elâzığ: Kovancılar, Çakırtaş, 38°45´33″N 39°37´16″E, 1024 m, 11.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Adana, Aksaray, Ankara, Çankırı, Denizli, Eskişehir, Erzurum, Gümüşhane, Hakkâri, Kayseri, Konya, Kütahya, Mersin, Nevşehir, Niğde, Sivas, Yozgat; **Europe:** Edirne (Sahlberg, 1913; Král, 1967; Gruev and Kasap, 1985; Gruev and Döberl, 1997; Aslan *et al*., 1999; Gruev, 2001, 2004; Warchałowski, 2003; Konstantinov *et al*., 2011; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen, 2014; Şen and Gök, 2014; Aslan *et al*., 2015; Özdikmen *et al*., 2020; Ünal, 2021; Özdikmen and Şahin, 2022).

Remarks: This is a new record for Elâzığ province. However, the host plant has not yet been determined.

Chaetocnema aridula (Gyllenhal, 1827)

Material examined: TR-Bingöl: Central, Yeniköy, 38°52´18″N 40°36´30″E, 1112 m, 12.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Ankara, Erzurum, İstanbul, Kayseri, Kütahya, Manisa, Sivas, Yozgat; **Europe:** Edirne, Kırklareli (Král, 1967; Gruev and Kasap, 1985; Gruev and Döberl, 1997; Aslan *et al*., 1999; Warchałowski, 2003; Gruev, 2004; Konstantinov *et al*., 2011; Ekiz *et al*., 2013; Özdikmen, 2014; Coral Şahin, 2020; Ünal, 2021).

Remarks: This is a new record for Bingöl province. Samples were collected from *Triticum* spp., *Medicago* spp., and *Rorippa austriaca* (Crantz) Besser.

Derocrepis serbica Kutschera, 1860

Material examined: TR-Artvin: Şavşat, Yavuzköy, 41°14´4″N 42°24´29″E, 1604 m, 24.07.2022, M. Güven, 2 specimens.

Distribution in Turkey: Asia: Bursa, İstanbul, Tokat (Ekiz *et al*., 2013; Özdikmen, 2014).

Remarks: New for Artvin province, 4th for Turkey record. Specimens were collected using a sweep net from *Triticum aestivum* L.

Longitarsus cerinthes (Schrank, 1798)

Material examined: TR-Muş: Bulanık, Central, 39°7´47″N 42°18´24″E, 1486 m, 10.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Aydın, Iğdır, Kayseri, Mersin (Gruev, 2003; Aslan, 2004; Gruev and Döberl, 2005; Döberl, 2010; Ekiz *et al*., 2013; Özdikmen, 2014; Bayram and Aslan, 2015; Coral Şahin, 2020; Özdikmen and Şahin, 2022).

Remarks: This is a new record for the Muş province and the 5th record for Turkey. However, the host plant has not yet been determined.

Longitarsus luridus luridus (Scopoli, 1763)

Material examined: TR-Artvin: Şavşat, Karaköy, 41°13´35″N 42°28´13″E, 2199 m, 24.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Ankara, Antalya, Artvin, Aydın, Bayburt, Burdur, Bursa, Çankırı, Eskişehir, Erzurum, Isparta, İstanbul, Kayseri, Kırşehir, Kütahya, Sivas, Tunceli, Yozgat; **Europe:** İstanbul (Ekiz *et al*., 2013; Özdikmen, 2014; Aslan *et al*., 2015; Bayram and Aslan, 2015; Bal *et al*., 2018c; Gök and Turantepe, 2019; Aslan *et al*., 2020; Coral Şahin, 2020; Ünal, 2021; Özdikmen and Şahin, 2022).

Remarks: Samples were collected form *Salvia verticillata* L. subsp. *verticillata* L. and *Hordeum vulgare* L.

Longitarsus niger (Koch, 1803)

Material examined: TR-Erzurum: Şenkaya, Değirmenlidere, 40°45′0″N 42°32′24″E, 1915 m, 24.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Eskişehir, Erzurum, Kayseri, İstanbul (Ekiz *et al*., 2013; Özdikmen, 2014; Özdikmen and Şahin, 2022).

Remarks: The specimens were collected using with sweep net from *Sisymbrium loeselii* L.

Phyllotreta diademata Foudras, 1860

Material examined: TR-Van: Çaldıran, Soğuksu, 39°10′44″N 41°26′3″E, 1509 m, 11.06.2021, C. Gözüaçık, 1 specimen; Alikelle, 39°2′39″N 44°1′2″E, 2051 m, 04.06.2021, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Adana, Aksaray, Ankara, Antalya, Bartın, Erzincan, Erzurum, Eskişehir, Isparta, Kayseri, Kocaeli, Konya; **Europe:** Edirne (Ekiz *et al*., 2013; Özdikmen, 2014; Özdikmen *et al*., 2017; Özdikmen and Şahin, 2022).

Remarks: This is a new record for Van province. The specimens were collected using sweep net from *Lepidium draba* L. and *Melilotus officinalis* (L.) Desr.

Phyllotreta nigripes nigripes (Fabricius, 1775)

Material examined: TR-Van: Çaldıran, Soğuksu, 39°10′44″N 41°26′3″E, 1509 m, 11.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Adana, Ankara, Antalya, Bayburt, Bilecik, Çankırı, Erzincan, Eskişehir, Erzurum, Hatay, Iğdır, Isparta, Kayseri, Konya, Kars, Kütahya, Manisa, Mersin, Sivas, Yozgat; **Europe:** Edirne (Ekiz *et al*., 2013; Özdikmen, 2014; Aslan *et al*., 2015; Bayram and Aslan, 2015; Özdikmen *et al*., 2017,2020; Bal, 2018; Tolga and Yoldaş, 2020; Ünal, 2021; Özdikmen and Şahin, 2022).

Remarks: This is a new record for Van province. However, the host plant has not yet been determined.

Subfamily **Cassidinae** Gyllenhal, 1813

Cassida palaestina Reiche, 1858

Material examined: TR-Erzurum: Horasan, Aşağıaktaşlı, 39°51′58″N 42°23′13″E, 2141 m, 19.07.2022, M. Güven, 1 specimen.

Distribution in Turkey: Asia: Adana, Bursa, Diyarbakır, Hatay, İzmir, Kilis, Mersin (Gül-Zümreoğlu, 1972; Kısmalı and Sassi, 1994; Warchałowski, 2003, 2010; Borowiec, 2007; Borowiec and Sekerka, 2010; Özdikmen, 2011; Ekiz *et al*., 2013; Özdikmen and Kaya, 2014; Borowiec, 2021; Borowiec and Świętojańska, 2021; Özdikmen and Şahin, 2021).

Remarks: This is a new record for the Eastern Anatolia Region. However, the host plant has not yet been determined.

Hypocassida subferruginea (Schrank, 1776)

Material examined: TR-Bingöl: Karlıova, Sudağı, 39°6′5″N 40°50′37″E, 1657 m, 12.06.2021, C. Gözüaçık, 1 specimen.

Distribution in Turkey: Asia: Adana, Ağrı, Aksaray, Amasya, Ankara, Antalya, Aydın, Balıkesir, Bitlis, Bolu, Burdur, Bursa, Çanakkale, Çankırı, Çorum, Denizli, Düzce, Elâzığ, Erzincan, Erzurum, Eskişehir, Hatay, Isparta, İstanbul, İzmir, Kahramanmaraş, Karabük, Karaman, Kastamonu, Kayseri, Kocaeli, Konya, Kütahya, Manisa, Mersin, Muş, Niğde, Osmaniye, Rize, Sakarya, Samsun, Siirt, Sinop, Sivas, Şanlıurfa, Yozgat, Zonguldak; **Europe:** Edirne, İstanbul, Tekirdağ (Sahlberg, 1913; Günther, 1954; Kısmalı and Sassi, 1994; Aslan and Özbek, 1999; Gök and Çilbiroğlu, 2003; Gök and Gürbüz, 2004; Borowiec, 2007; Aslan *et al*., 2009; Borowiec and Sekerka, 2010; Özdikmen, 2011; Ersin Doğan, 2012; Özdikmen *et al*., 2012, 2020; Ekiz *et al*., 2013; Özdikmen and Kaya, 2014; Bal *et al*., 2018b; Aslan *et al*., 2020; Özdikmen and Şahin, 2021).

Remarks: This is a new record for Bingöl province. Specimens were collected from *Convolvulus arvensis* L.

CONCLUSION

Field studies were conducted in 93 locations in the Artvin, Bingöl, Diyarbakır, Elazığ, Erzurum, Kahramanmaraş, Muş and Van provinces. The Coleoptera order, Chrysomelidae family, seven subfamilies, 20 genera and 36 species were identified. *Cassida palaestina* Reiche, 1858 were identified in the Eastern Anatolia Region for the first time in this study.

In addition, plants such as *Rumex tuberosus* L. subsp. *horozontalis* (Koch) Rech., *R. crispus* L., *Onobrychis* sp., *Melilotus officinalis* (L.) Desr., *Lotus corniculatus* L., *Medicago* sp., *Tragopogon* sp., *Achillea millefolium* L., *Achillea millefolium* L. subsp. *millefolium* L., *Scorzonera tomentosa* L., *Crepis setosa* Hall. Fil., *Centaurea solstitialis* L., *Inula oculus-christi* L., *Lappula barbata* (Bieb.) Gürke, *Papaver rhoeas* L., *Astragalus* spp., *Calamagrostis epigejos* (L.) Roth, *Delphinium laxiusculum* (Boiss.) Rouy, *Sisymbrium loeselii* L., *S. altissimum* L., *Lepidium draba* L., *Bunias orientalis* L., *Hordeum vulgare* L., *Picris hieracioides* L., *Phlomis tuberosa* L., *Polygonum bellardii* All., *Salvia verticillata* L. subsp. *verticillata* L., *Falcaria vulgaris* Bernh., *Rorippa austriaca* (Crantz) Besser, *Cephalaria sparsipilosa* Matthews, *Glycyrrhiza glabra* L., *Arctium minus* (Hill) Bernh. subsp. *minus* (Hill) Bernh., *Crambe orientalis* L. and *Triticum aestivum* L. which are preferred by Chrysomelidae species were determined for the first time.

In conclusion, many studies on the family Chrysomelidae have been conducted by local and foreign researchers. These are faunistic, systematic and biological control studies based on plant-insect relationships. With the researches carried out in this way, new species are identified and added to the fauna of the country daily. In this study, 28 species were identified as new records for Chrysomelidae fauna in different provinces.

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AUTHOR CONTRIBUTIONS

The authors have contributed equally to this study.

CONFLICT of INTEREST

The authors declare there is no conflict of interest.

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Pandemi Öncesi ve Pandemi Sonrasi Bazi Endüstri Bitkileri Üretiminin Türkiye'deki Durumu

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Bu makale için etik kurul beyanına ihtiyaç yoktur. Çalışmada FAO, TÜİK, WORLDBANK gibi kurumlardan internet yoluyla elde edilen ikincil veriler kullanılmıştır.

Özet

Türkiye tarımında önemli bir rol oynayan endüstri bitkileri, bitkisel üretim kapsamında birçok sanayi sektörüne doğrudan veya dolaylı olarak ham madde sağlayarak ulusal gelir ve ihracata önemli katkı sunmaktadır. Bu çalışma pandemi öncesi ve pandemi sonrası Türkiye'deki bazı endüstri bitkilerine ait hasat edilen alan, verim ve üretim miktarındaki değişimlerin analiz edilmesi amacıyla yapılmıştır. Çalışmada 2012-2022 yılları arasındaki FAO ve TÜİK kayıtlarından elde edilen bazı endüstri bitkilerinin; hasat edilen alan, üretim miktarı ve verim değerlerine ait ikincil veriler kullanılmıştır. Ayrıca internet kaynakları, yerli ve yabancı kaynaklardan derlenen genel bilgiler, konuyla ilgili istatistik verilerden de faydalanılmıştır. Çalışmada endeks hesabı yönteminden faydalanılmıştır. Çalışma bulgularına göre; tarım sektöründe birçok alanda olduğu gibi endüstri bitkilerinin verim, üretim ve hasat edilen alan değerlerinin değişmesinde sebeplerden birinin de pandemi olduğu kanısına varılmıştır. Pandemi sürecinde gıda güvenliği ve kendi kendine yeterlilik konularının ön plana çıkması bazı çiftçilerin endüstri bitkilerinden gıda ürünlerine yönelmesine neden olmuştur. Yine bazı üreticilerin, yüksek belirsizlik nedeniyle endüstri bitkileri yerine daha hızlı gelir getiren veya temel gıda maddeleri üretimine yönelmeleri, endüstri bitkileri için ayrılan ekim alanlarında azalmaya neden olmuştur. Sonuç olarak; COVID-19 pandemisi, Türkiye'de endüstri bitkileri üretimini birçok açıdan etkilemiş, işgücü ve tedarik zinciri sorunları, pazar belirsizlikleri ve değişen ekim alanları, üretim ve verimlilik üzerinde belirleyici olmuştur. Bu süreçte, tarım sektörünün dayanıklılığını artırmak ve gelecekte benzer krizlere hazırlıklı olmak için tarım teknolojilerinin benimsenmesi, eğitim ve destek politikalarının güçlendirilmesi son derece önemlidir.

Anahtar Kelimeler: Alfalfa, COVID 19, endüstri bitkileri, verim, üretim, hasat edilen alan, eğitim ve destek politikaları.

The State of Certain Industrial Plant Productions in Turkey Before and After the Pandemic

Abstract

Industrial crops, which play an important role in Turkish agriculture, make the highest contribution to national income and exports by providing raw materials directly or indirectly to many industrial sectors within the scope of plant production. This study was conducted to analyze the changes in harvested area, yield and production amount of some industrial plants in Turkey before and after the pandemic. The fact that a similar study on the effects of the COVID-19 pandemic on the use of herbal products has not yet been conducted emphasizes the importance of the data to be obtained. In the study, some industrial plants obtained from FAO and TURKSTAT records between 2012-2022; Secondary data on harvested area, production amount and yield values were used. In addition, internet sources, general information compiled from domestic and foreign sources, and statistical data on the subject were also used. The index calculation method was used in the study. According to the study findings; The COVID-19 pandemic has affected many areas in the agricultural sector, as well as the yield, production and harvested area values of industrial plants. Food safety and self-sufficiency issues came to the fore during the pandemic period, causing some farmers to turn to food products from industrial plants. Again, due to high uncertainty, some producers have turned to the production of more rapid income-generating or basic foodstuffs instead of industrial plants, causing a decrease in the cultivation areas allocated for industrial plants. In conclusion; The COVID-19 pandemic has affected industrial crop production in Turkey in many ways, and workforce and supply chain problems, market uncertainties and changing cultivation areas have been decisive on production and productivity. In this process, it is extremely important to adopt agricultural technologies and strengthen education and support policies in order to increase the resilience of the agricultural sector and be prepared for similar crises in the future.

Keywords: COVID 19, industrial crops, yield, production, harvested area, training and support policies.

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GİRİŞ

Türkiye tarımında önemli bir rol oynayan endüstri bitkileri, bitkisel üretim kapsamında birçok sanayi sektörüne doğrudan veya dolaylı olarak ham madde sağlayarak ulusal gelir ve ihracata en yüksek katkıyı sunmaktadır. Endüstri bitkileri, diğer birçok kültür bitkisine kıyasla daha yüksek verime sahip olmasına rağmen, çoğunun çapa bitkisi olması nedeniyle tarımında yoğun işgücü ve girdi kullanımı gerekmektedir. (Tunçtürk ve ark., 2004; Tunçtürk ve ark., 2005). Bu nedenle, genellikle üretim maliyetleri yüksek olmaktadır. Ancak, endüstri bitkileri yoğun işgücü gerektirdiğinden hem üretim aşamasında hem de işlendiği sanayi kollarında büyük bir istihdam potansiyeli yaratmaktadır. Ayrıca, endüstri bitkilerinin yetiştiriciliği ileri tarım teknikleri gerektirdiği için, çiftçilerin tarımsal bilgi ve teknoloji kullanım düzeylerini artırmaktadır (Eryiğit, 2011). Türkiye, çeşitli iklim ve toprak koşulları sayesinde geniş bir yelpazede endüstri bitkileri üretimi yapabilmektedir. Türkiye, endüstri bitkileri genetik kaynakları açısından önemli bir potansiyele ve çeşitliliğe sahiptir (Harlan, 1951; Tan, 1992; Tan, 1993 a,b; Tan ve Tan, 1996; Tan, 1998; Tan, 2004; Tan, 2010 a,b; Karagöz ve ark., 2010; Tan ve ark., 2013 a,b,c,d,e; Tan ve ark., 2015 a,b,c; Tan ve ark., 2016; Tan ve ark., 2016b). Endüstri bitkilerinin (Pancar, haşhaş, susam, tütün, crambe, keten, kenevir, aspir, ayçiçeği, yağ şalgamı vb.) bir kısmı halen köy çeşitleri olarak tarımı yapılmakta ve bir kısmının tarımı ise giderek gerilemektedir (Tan ve ark., 2016b). Türkiye, endüstri bitkileri üretiminde önemli bir potansiyele sahiptir ve bu potansiyelin değerlendirilmesi için gerekli adımlar atılmaktadır. Ancak, sürdürülebilirlik ve verimlilik konularında daha fazla çaba sarf edilmesi gerekmektedir. Tarım politikalarının doğru bir şekilde uygulanması ve çiftçilerin desteklenmesi, endüstri bitkileri üretiminin geleceği için büyük önem taşımaktadır. Tarım ve Orman Bakanlığı verilerine göre Türkiye'nin 2002 yılında tohum ithalatı 55.3 milyon dolar iken 2022 yılında 170 milyon dolara ulaşmıştır. (Tablo 1). Türkiye tohum ihracatı 2002 yılında 17.3 milyon dolar iken 2022 yılında yaklaşık 13 kat artarak 233 milyon dolara yükselmiştir (Tablo 2). 2022 yılı tohum ihracatının %47'sini ayçiçeği tohumu oluştururken, bunu %26 ile hibrit mısır, %12 ile sebze bitkileri ve kalan %15'ini ise diğer çeşitler oluşturmaktadır. Tarla bitkilerinde başlıca ihracat kalemleri ayçiçeği, mısır ve buğday olup ihracatın yapıldığı başlıca ülkeler ise Irak, Rusya Fedarasyonu, Ukrayna, İtalya ve Azerbaycan'dır.

Tablo 1. *Türkiye'nin ithal ettiği bazı endüstri bitkilerine ait 2022 yılı tohum miktarı (ton) ve değerleri (1.000 USD)*
Table 1. *Seed quantity (tonnes) and value (1,000 USD) of some industrial crops imported by Turkey in 2022*

Ürünler	Miktar (ton)	Oran (%)	Değer (1000$)	Oran (%)
Pamuk	68	0.3	68	0.2
Ayçiçeği	518	2.5	10659	28.9
Soya	0	0.0	0	0.0
Yerfıstığı	0	0.0	0	0.0
Patates	17233	82.1	11687	31.7
Şeker pancarı	524	2.5	11806	32.0
Kanola	2636	12.6	2702	7.3
TOPLAM	20979	100	36922	100.0
GENEL TOPLAM	37729	55.6	169614	21.8

Kaynak: Tohumculuk Sektör Raporu, 2022

Tablo 2. *Türkiye'nin ihraç ettiği bazı endüstri bitkilerine ait 2022 yılı tohum miktarı (ton) ve değerleri (1.000 USD)*
Table 2. *Seed quantity (tonnes) and value (1,000 USD) of some industrial crops exported by Turkey in 2022*

Ürünler	**Miktar (ton)**	**Oran (%)**	**Değer (1000$)**	**Oran (%)**
Pamuk	4836	13.8	11257	9.2
Ayçiçeği	26205	74.7	109133	88.9
Soya	542	1.5	910	0.7
Yerfıstığı	0	0.0	0	0.0
Patates	3454	9.8	1154	0.9
Şeker pancarı	36	0.1	278	0.2
Kanola	6	0.0	25	0.0
TOPLAM	35079	100	122757	100.0
GENEL TOPLAM	86412	40.6	232663	52.8

Kaynak: Tohumculuk Sektör Raporu, 2022

Tablo 3. *Bazı endüstri bitkilerinin 2022-2023 yılı denge tablosu*
Table 3. *Balance table of some industrial crops for 2022-2023*

	Patates	**Ayçiçeği**	**Kolza**	**Pamuk**	**Soya**	**Şeker pancarı**
Üretim (Ton)	5200 000	2550000	150 000	1 650 000	155 000	-
Ekilen alan (Hektar)	139172	980974	41146	573161	38009	-
Üretim kayıpları (Ton)	88400	20400	1950	33000	1240	-
Arz= Kullanım (Ton)	5245881	8359620	375253	1650094	3041844	19253962
Kullanılabilir üretim (Ton)	5111600	2529 600	148 050	1 617 000	153760	19253962
İthalat (Ton)	134281	5830020	227203	33094	2888 084	0
Yurt içi kullanım (Ton)	4934385	4935036	308 853	1 526 577	2970616	19253948
İnsan tüketimi (Ton)	4438423	4821621	301 853	1 431 138	18 632	-
Tohumluk kullanım (Ton)	347930	14715	823	22 926	3 801	-
Kayıplar (Ton)	148032	98701	6177	72512	37133	395897
İhracat (Ton)	311496	3402238	66400	61548	71228	14
Stok değişimi (Ton)	-	22346	0	61969	0	0
Kişi başına tüketim (Kg)	52	56.5	3.5	16.8	0.2	-
Yeterlilik derecesi (%)	103.6	51.3	47.9	105.9	5.2	100.0

Kaynak: TÜİK, 2023

Tablo 4. *Bazı endüstri bitkilerinin 2023 yılına ait ekilen alan üretim ve verim değerleri*
Table 4. *Cultivated area production and yield values of some industrial crops for 2023*

Ürünler	**Alan (da)**	**Üretim (ton)**	**Verim (kg/dekar)**
Soya	326 840	137 500	421
Yerfıstığı	460 098	185 137	402
Ayçiçeği	9 526 052	2 198 000	231
Susam	220 205	16 190	74
Aspir	321 298	39 000	121
Kolza	322 910	120 000	372
Pamuk	-	1 260 000	264
Keten	245	32	131
Kenevir	3 923	327	83
Haşhaş	-	7 922	36
Toplam	11 181 571	3 964 108	

Kaynak: TÜİK, 2023

Bu çalışma pandemi öncesi ve pandemi sonrası Türkiye'deki bazı endüstri bitkilerine ait hasat edilen alan, verim ve üretim miktarındaki değişimlerin analiz edilmesi amacıyla yapılmıştır. COVID-19 pandemisinin bitkisel ürün kullanımına etkileriyle ilgili benzer bir çalışmanın henüz yapılmamış olması, elde edilecek verilerin önemini vurgulamaktadır. Bu veriler, pandeminin üretimle ilgili ürün seçim tercihine nasıl etki ettiği konusunda genel bir anlayış sağlayacak ve gelecekte yapılacak çalışmalara yol gösterecektir.

MATERYAL VE METOT

Bu çalışmada; 2012-2022 yılları arasındaki FAO ve TÜİK kayıtlarından elde edilen bazı endüstri bitkilerinin; hasat edilen alan, üretim miktarı ve verim değerlerine ait ikincil veriler kullanılmıştır. Ayrıca internet kaynakları, yerli ve yabancı kaynaklardan derlenen genel bilgiler, konuyla ilgili istatistik verilerden ve endeks hesabı yönteminden faydalanılmıştır. Endeks hesabı; genellikle bir dizi verinin oranını belirli bir referans noktasına göre değerlendirmek için kullanılan bir finansal veya istatistiksel hesaplama yöntemini ifade eder. Endeksler, belirli bir dönemdeki fiyatlar, performanslar veya diğer verilerin bir ölçüsünü sağlar. Örneğin, bir endeks, birkaç şirketin hisse senedi fiyatlarını veya belirli bir ekonominin genel performansını temsil edebilir. Endeks hesabı, genellikle bir baz döneme göre diğer dönemlerdeki değişiklikleri izlemek için kullanılır. Endeks hesabında, genellikle bir baz dönemdeki değer 100 olarak alınır ve diğer dönemlerdeki değerler bu referans değere göre oranlanır. Bu sayede, zaman içindeki değişiklikler görsel olarak daha kolay anlaşılabilir hale gelir. Endeks hesabı, finansal piyasalardaki endekslerin yanı sıra ekonomik göstergelerin izlenmesinde de sıkça kullanılır. Örneğin, tüketici fiyat endeksi (TÜFE) veya gayri safi yurt içi hasıla (GSYİH) gibi ekonomik göstergelerin izlenmesinde endeks hesabı önemli bir rol oynar. Bu hesaplama yöntemi, ekonomik veya finansal eğilimleri analiz etmek ve karar vermeyi kolaylaştırmak için yaygın olarak kullanılmaktadır. Araştırmada 2019 yılına ait değer; covid 19 pandemisinin 2020 yılında başladığı varsayılarak 100 olarak kabul edilmiş ve pandemi öncesi ve pandemi sonrası durum oransal olarak belirlenmeye çalışılmıştır. Verim endeksi hesaplaması yapılırken Tablo 1'den, üretim miktarı endeksi hesaplaması yapılırken Tablo 2'den ve hasat edilen alan endeksi hesabı yapılırken ise Tablo 3'ten yararlanılmıştır.

Tablo 5. *Türkiye'de bazı endüstri bitkilerinin hektara tohum verimleri (kg/ha)**
Table 5. *Seed yields per hectare (kg/ha)* of some industrial crops in Turkey*

Yıllar	Yer fıstığı	Kenevir	Patates	Kolza	Aspir	Pamuk	Susam	Soya fasulyesi	Şeker pancarı	Ayçiçeği
2012	33.01	6.66	280.38	36.66	12.50	47.49	5.60	36.39	716.66	22.64
2013	35.68	10.00	315.32	32.78	15.37	49.90	6.23	41.60	566.79	24.98
2014	37.08	10.00	324.47	34.23	14.11	50.33	6.73	43.71	582.44	25.07
2015	39.05	5.00	309.48	34.41	16.35	47.23	6.59	43.99	598.04	24.53
2016	38.86	3.33	328.25	35.28	14.73	50.48	6.76	43.21	608.55	23.25
2017	39.41	5.00	336.01	36.37	18.26	48.85	6.56	44.20	624.08	25.20
2018	39.24	5.00	334.79	33.02	14.17	49.55	6.71	42.62	599.80	26.54
2019	40.10	4.16	353.76	34.27	13.79	46.04	6.79	42.49	583.21	27.93
2020	39.42	9.00	351.43	34.73	14.10	49.37	7.30	44.18	684.58	28.37
2021	40.43	6.17	368.19	37.23	11.20	52.05	6.99	41.47	631.62	26.82
2022	40.77	8.19	373.90	36.51	11.43	47.97	7.16	40.78	692.10	26.02

*: FAO, 2024 (https://www.fao.org/faostat/en/#data/QCL, 20.03.2024)

Tablo 6. *Türkiye'de bazı endüstri bitkilerinin tohum üretim değerleri (t)**
Table 6. *Seed production values of some industrial crops in Turkey (t)**

Yıllar	Kolza	Aspir	Susam	Pamuk	Yer fıstığı	Kenevir	Soya fasulyesi	Şeker pancarı	Ayçiçeği	Patates
2012	110.000	19.500	16.221	1.373.440	122.780	4	115.000	14.919.940	1.370.000	4.821.937
2013	102.000	45.000	15.457	1.287.000	128.265	1	180.000	16.488.590	1.523.000	3.955.294
2014	110.000	62.000	17.716	1.391.200	123.600	1	150.000	16.743.045	1.637.900	4.166.000
2015	120.000	70.000	18.530	1.213.600	147.537	1	161.000	16.462.000	1.680.700	4.760.000
2016	125.000	58.000	19.521	1.260.000	164.186	1	165.000	19.592.731	1.670.716	4.750.000
2017	60.000	50.000	18.410	1.470.000	165.330	1	140.000	21.149.020	1.964.385	4.800.000
2018	125.000	35.000	17.437	1.542.000	173.835	3	140.000	17.436.100	1.949.229	4.550.000
2019	180.000	21.883	16.893	1.320.000	169.328	20	150.000	18.085.528	2.100.000	4.979.824
2020	121.542	21.325	18.648	1.064.189	215.927	9	155.225	23.025.738	2.067.004	5.200.000
2021	140.000	16.200	17.657	1.350.000	234.167	20	182.000	18.250.000	2.415.000	5.100.000
2022	150.000	30.000	17.399		186.340	159	155.000	19.000.000	2.550.000	5.200.000

*: FAO, 2024 (https://www.fao.org/faostat/en/#data/QCL, 20.03.2024)

Tablo 7. *Türkiye'de bazı endüstri bitkilerinin tohum hasat alanları (ha)**
Table 7. *Seed harvesting areas of some industrial crops in Turkey (ha)**

Yıllar	Yer fıstığı	Kenevir	Patates	Kolza	Aspir	Pamuk	Susam	Soya fasulyesi	Şeker pancarı	Ayçiçeği
2012	37.195	6	171.976	30.000	15.590	488.496	28.949	31.599	208.186	605.000
2013	35.943	1	125.434	31.109	29.260	450.890	24.785	43.260	290.910	609.622
2014	33.327	1	128.392	32.133	43.935	466.839	26.315	34.317	287.461	653.323
2015	37.773	2	153.802	34.869	42.793	434.000	28.088	36.592	275.262	685.174
2016	42.244	3	144.706	35.430	39.352	416.002	28.872	38.178	321.953	718.317
2017	41.950	2	142.851	16.495	27.376	501.478	28.031	31.670	338.883	779.439
2018	44.290	6	135.904	37.846	24.693	518.634	25.981	32.848	290.698	734.190
2019	42.218	48	140.766	52.510	15.860	477.807	24.855	35.295	310.100	751.693
2020	54.775	10	147.965	34.989	15.114	359.220	25.514	35.135	336.348	728.368
2021	57.919	32	138.513	37.602	14.452	432.279	25.249	43.885	288.940	900.135
2022	45.701	194	139.072	41.081	26.234	573.223	24.285	38.009	274.524	979.691

*: FAO, 2024 (https://www.fao.org/faostat/en/#data/QCL, 20.03.2024)

BULGULAR VE TARTIŞMA

Bazı Endüstri Bitkilerine Ait Özellikler

Verim

Türkiye'de endüstri bitkilerinin verimi, üretim alanları ve iklim koşullarına bağlı olarak değişiklik göstermektedir. Türkiye'de pamuk verimi ortalama olarak 450-550 kg/da arasında değişmektedir. Ancak, son yıllarda su kaynaklarının azalması ve üretim maliyetlerinin artması nedeniyle verimde dalgalanmalar yaşanmaktadır. Türkiye, dünya şeker pancarı üretiminde üst sıralarda yer almaktadır. Verimlilik, modern tarım teknikleri ile artırılmakta, ortalama 6-8 ton/da arasında değişmektedir. Türkiye, ayçiçeği yağı üretiminde önemli bir yere sahiptir. Yerli üretim, iç tüketimi büyük oranda karşılamakta olup ortalama 200-250 kg/da arasında değişmektedir. Türkiye'de patatesin verim ortalaması 30-35 ton/da arasında değişmektedir. Tablo 10'a göre ortalama verim değeri yerfıstığı için

38.45, kenevir için 6.59, patates için 334.18, kolza için 35.04, aspir için 14.18, pamuk için 49.02, susam için 6.67, soya fasulyesi için 42.24, şeker pancarı için 626.17 ve ayçiçeği için ise 25.58 100 g/ha olarak belirlenmiştir. Yerfıstığı verim değeri 2020 yılında bir önceki yıla göre yaklaşık %2 azalmış daha sonraki yıllarda ise 2019 yılına göre sırasıyla %0.80 ve %1.66 oranında artmıştır. Kenevir veriminde 2020 yılında yaklaşık olarak %116 artış olurken diğer yıllarda ise 2019 yılına göre sırasıyla %48.14 ve %96.69 oranında artışlar gerçekleşmiştir. Patatesteki verimde 2020 yılında az da olsa düşüş yaşanmış olup pandemiden hemen sonraki 2021 ve 2022 yıllarında ise %4 ve %5 oranında artışlar görülmüştür. Aspir, ayçiçeği ve soya fasulyesi bitkilerinin verim değerleri pandemi yılında (2020) artmış fakat ilerleyen yıllarda (2021 ve 2022) verim değerlerinde düşüş yaşanmıştır (Tablo 10).

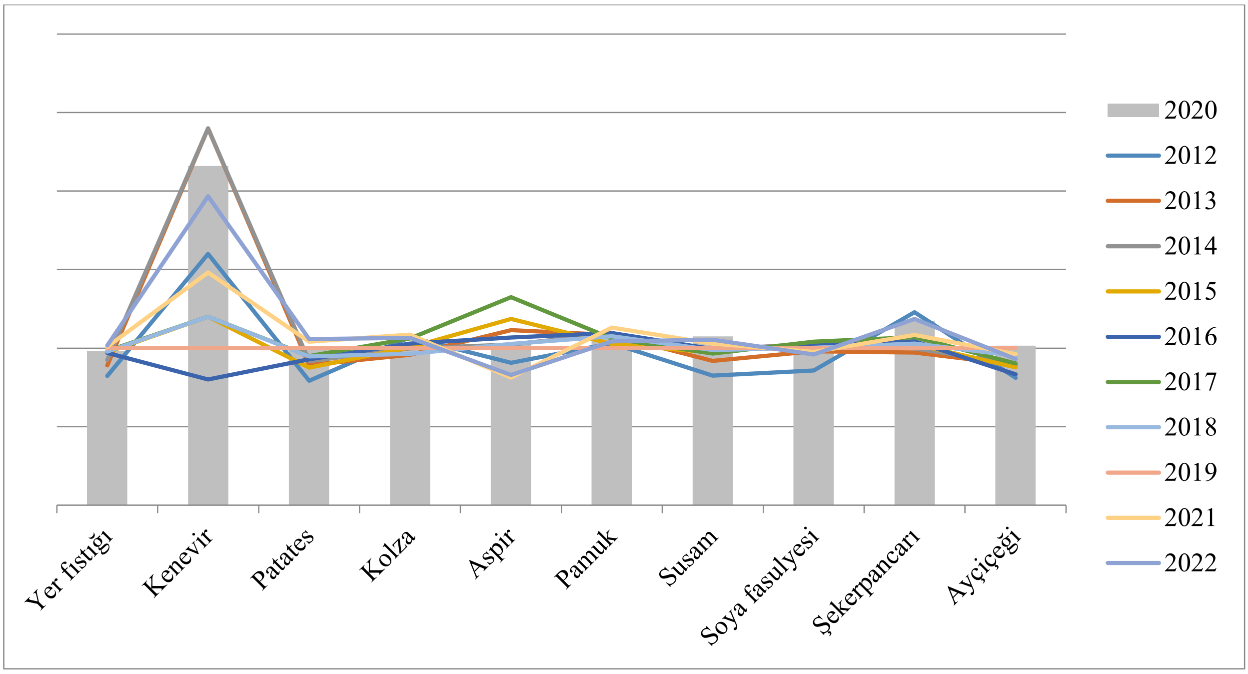
Tablo 8. *Bazı endüstri bitkilerinin 2012-2022 yılları verimine ait özellikler (100 g/ha)*
Table 8. *Yield characteristics of some industrial crops for 2012-2022 (100 g/ha)*

Ürünler	Ortalama	Standart sapma	Minimum	Maksimum
Yer fıstığı	38.45	2.32	33.01	40.77
Kenevir	6.59	2.36	3.33	10.00
Patates	334.18	27.21	280.38	373.90
Kolza	35.04	1.49	32.78	37.23
Aspir	14.18	2.06	11.20	18.26
Pamuk	49.02	1.72	46.04	52.05
Susam	6.67	0.46	5.60	7.30
Soya fasulyesi	42.24	2.26	36.39	44.20
Şeker pancarı	626.17	50.06	566.79	716.66
Ayçiçeği	25.58	1.78	22.64	28.37

Tablo 9. *Bazı endüstri bitkilerinin verimine ait endeks değerleri*
Table 9. *Index values of yield of some industrial crops*

Yıllar	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Yer fıstığı	82.30	88.97	92.47	97.38	96.90	98.26	97.86	100.00	**98.29**	100.80	101.66
Kenevir	160.00	239.98	239.98	119.99	79.99	119.99	119.99	100.00	**215.98**	148.14	196.69
Patates	79.26	89.13	91.72	87.48	92.79	94.98	94.64	100.00	**99.34**	104.08	105.69
Kolza	106.97	95.65	99.87	100.40	102.92	106.11	96.35	100.00	**101.34**	108.61	106.52
Aspir	90.65	111.46	102.28	118.55	106.82	132.37	102.73	100.00	**102.25**	81.24	82.88
Pamuk	103.15	108.38	109.33	102.59	109.64	106.11	107.62	100.00	**107.23**	113.04	104.19
Susam	82.43	91.75	99.04	97.06	99.47	96.63	98.73	100.00	**107.53**	102.88	105.41
Soya fasulyesi	85.63	97.91	102.85	103.53	101.69	104.02	100.29	100.00	**103.96**	97.58	95.96
Şeker pancarı	122.88	97.18	99.87	102.54	104.35	107.01	102.84	100.00	**117.38**	108.30	118.67
Ayçiçeği	81.06	89.43	89.74	87.80	83.26	90.21	95.03	100.00	**101.58**	96.03	93.17

Kenevir bitkisi pandemiyle birlikte ve pandeminin etkin olduğu yıllar 2021 ve 2022 yıllarında verim değeri açısından en çok artışın olduğu bitkidir. Pandemi yılında (2020) Aspir, ayçiçeği ve soya fasulyesi bitkilerinin verim değerleri artmış fakat ilerleyen yıllarda (2021 ve 2022) Aspir, ayçiçeği ve soya fasulyesi bitkilerinin verim değerlerinde düşüş yaşanmıştır (Şekil 1). Tablo 10'da görüldüğü üzere yerfıstığı, kenevir, patates, kolza, pamuk, susam, şeker pancarı ve ayçiçeği gibi bitkilerinin verim değerlerinde pandemiden önceki yıllara ve pandemiden sonraki yıllara ait ortalamalar kıyaslandığında artış olduğu, aspir ve soya fasulyesinde ise düşüş olduğu belirlenmiştir. Özellikle şeker pancarı ve patatesteki artış dikkat çekmektedir (Şekil 2).

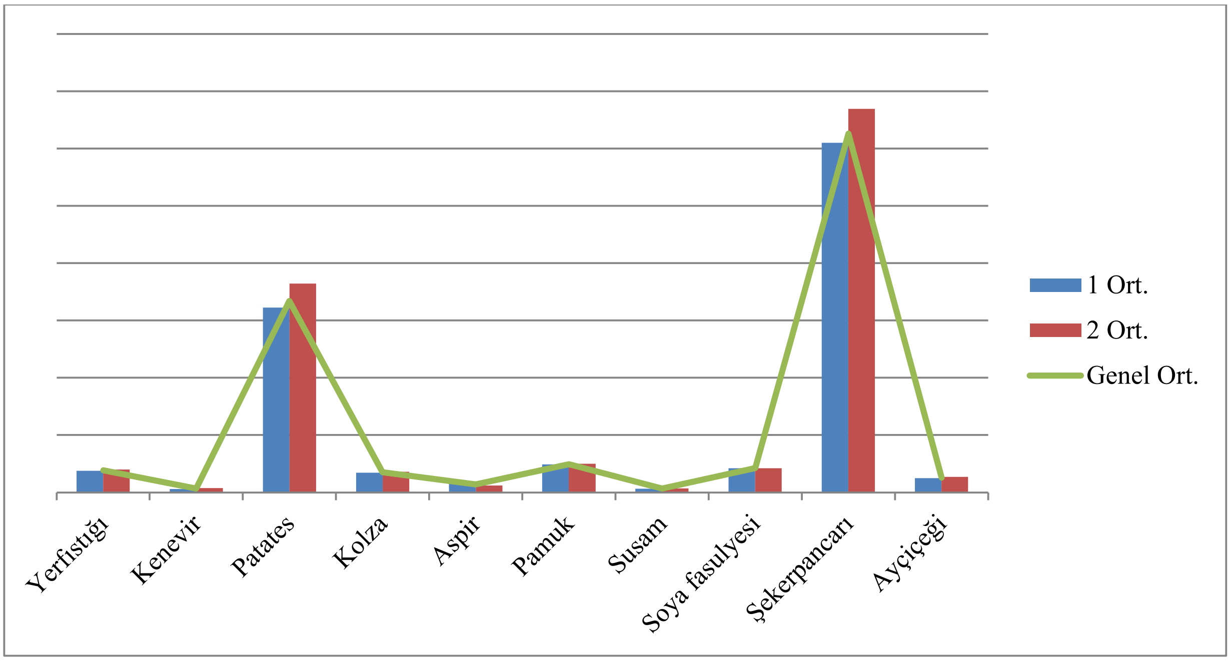


***Şekil 1**. Bazı endüstri bitkilerinin verim değerine ait endeks değerleri*
***Figure 1.** Index values of yield value of some industrial crops*

***Tablo 10.** Bazı endüstri bitkilerinin covid 19 pandemi öncesi ve sonrası verim değeri (100g/ha)*
***Table 10.** Yield value of some industrial crops before and after covid 19 pandemic (100g/ha)*

Yıllar		**Yerfıstığı**	**Kenevir**	**Patates**	**Kolza**	**Aspir**	**Pamuk**	**Susam**	**Soya fasulyesi**	**Şeker pancarı**	**Ayçiçeği**
1	Ort.	37.80	6.14	322.81	34.63	14.91	48.73	6.50	42.28	609.95	25.02
	Std. s.	2.40	2.55	21.85	1.40	1.76	1.63	0.40	2.53	46.54	1.68
	Std. h.	0.85	0.90	7.72	0.49	0.62	0.57	0.14	0.89	16.45	0.59
2	Ort.	40.20	7.78	364.51	36.16	12.25	49.79	7.15	42.14	669.43	27.07
	Std. s.	0.70	1.45	11.68	1.28	1.61	2.07	0.15	1.79	32.96	1.19
	Std. h.	0.40	0.84	6.74	0.74	0.93	1.19	0.09	1.03	19.03	0.68
Genel	Ort.	38.45	6.59	334.18	35.04	14.18	49.02	6.67	42.24	626.17	25.58
	Std. s.	2.32	2.36	27.21	1.49	2.06	1.72	0.46	2.26	50.06	1.78
	Std. h.	0.70	0.71	8.20	0.45	0.62	0.51	0.13	0.68	15.09	0.53

1: covid 19 pandemisinden önce; 2: covid 19 pandemisinden sonra; Ort: Ortalama; Std. s.: standart sapma; Std. h.: Standart hata



***Şekil 2.** Bazı endüstri bitkilerinin covid 19 pandemi öncesi ve sonrası verim değeri*
***Figure 2.** Yield value of some industrial crops before and after covid 19 pandemic*

Üretim

Türkiye, geniş tarımsal alanları ve çeşitli iklim koşulları sayesinde birçok endüstri bitkisi üretiminde önemli bir konuma sahiptir. Türkiye'de endüstri bitkileri üretimi, iklim değişiklikleri, su kaynaklarının azalması, tarımsal maliyetlerin artması ve tarımsal destek politikalarındaki değişiklikler gibi faktörlerden etkilenmektedir. Ayrıca, uluslararası piyasalardaki dalgalanmalar ve tarım politikaları da üretim üzerinde belirleyici rol oynamaktadır. Sonuç olarak, Türkiye endüstri bitkileri üretiminde önemli bir potansiyele sahiptir. Ancak, sürdürülebilir üretim ve verimliliğin artırılması için modern tarım tekniklerinin uygulanması, su yönetimi stratejilerinin geliştirilmesi ve destekleyici tarım politikalarının sürdürülmesi gerekmektedir. Pamuk, Türkiye'de özellikle Ege, Güneydoğu Anadolu ve Çukurova bölgelerinde yaygın olarak yetiştirilir. Türkiye, dünya pamuk üretiminde önemli bir yere sahiptir ve yüksek kaliteli pamuk üretimiyle tanınır. Ancak son yıllarda su kaynaklarının azalması ve maliyetlerin artması nedeniyle üretim miktarında dalgalanmalar yaşanmaktadır. Şeker pancarı, Türkiye'de Konya, İç Anadolu ve Karadeniz bölgelerinde yoğun olarak yetiştirilir. Şeker pancarı üretimi, ülkenin şeker ihtiyacının büyük bir kısmını karşılar. Türkiye, şeker pancarı üretiminde dünya sıralamasında üst sıralarda yer almaktadır. Ayçiçeği, Türkiye'nin Trakya ve İç Anadolu bölgelerinde yaygın olarak yetiştirilir ve özellikle yemeklik yağ üretiminde kullanılır. Türkiye, ayçiçeği yağı üretiminde önemli bir ülke olup, yerli üretim iç tüketimi büyük oranda karşılamaktadır. Yerfıstığı, Türkiye'de hem iç tüketim hem de ihracat açısından önemli bir üründür. Türkiye'de yerfıstığı üretimi, özellikle Akdeniz Bölgesi'nde yoğunlaşmış durumdadır. Adana, Osmaniye, Mersin ve Hatay, yerfıstığı üretiminin en yoğun yapıldığı iller arasında yer almaktadır. Türkiye, yerfıstığı üretiminde dünya sıralamasında üst sıralarda yer almaktadır. Türkiye'de yerfıstığı ekim alanları ve üretim miktarları yıllar içinde dalgalanma göstermektedir. Bu dalgalanmalarda iklim koşulları, tarımsal destek politikaları ve piyasadaki fiyat dalgalanmaları etkili olmaktadır. Türkiye'de yıllık patates üretimi yaklaşık olarak 4-5 milyon ton civarındadır. Üretim alanı ise yıllık olarak yaklaşık 130.000-140.000 hektar arasında değişmektedir. Türkiye'de yıllık pamuk üretimi yaklaşık olarak 800.000-900.000 ton civarındadır. Türkiye'de yıllık yerfıstığı üretimi yaklaşık olarak 150.000-200.000 ton civarındadır. Tablo 11' e göre Türkiye patates üretimi yaklaşık olarak 4.7 milyon ton, pamuk üretimi 1.3 milyon ton ve yerfıstığı üretimi ise 166.481 ton olarak hesaplanmıştır (TEPGE, 2023).

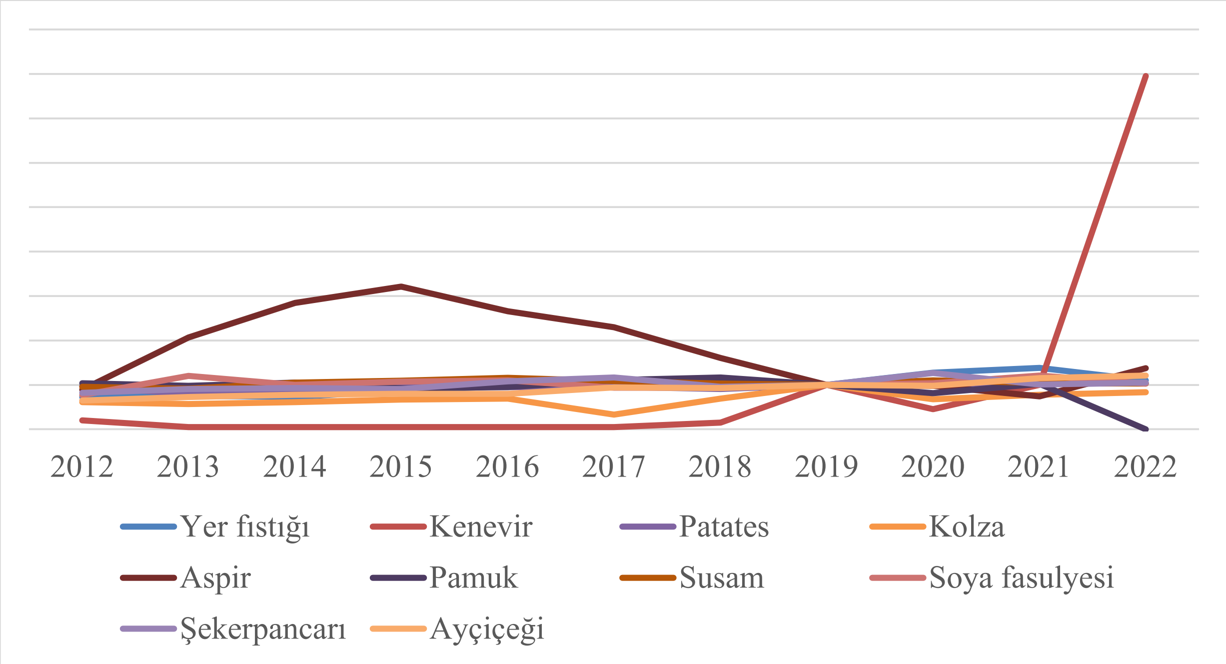
Tablo 11. *Bazı endüstri bitkilerinin 2012-2022 yıllarına ait üretim miktarına ait tanımlayıcı istatistikler (t)*
Table 11. *Descriptive statistics of the production amount of some industrial crops for the years 2012-2022 (t)*

Ürünler	Ortalama	Standart sapma	Minimum	Maksimum
Yer fıstığı	166.48136	36.134963	122.780	234.167
Kenevir	20.000	46.6819	1.0	159.0
Patates	4753005.00	400076.030	3955294	5200000
Kolza	122.14018	30.043291	60.000	180.000
Aspir	38.99164	19.001280	16.200	70.000
Pamuk	1327142.90	133976.901	1064189	1542000
Susam	17.62627	1.156701	15.457	19.521
Soya fasulyesi	153.92955	18.914138	115.000	182.000
Şeker pancarı	18286608.36	2321893.225	14919940	23025738
Ayçiçeği	1902539.45	368035.647	1370000	2550000

Yıllar itibariyle bazı endüstri bitkilerinin üretim miktarına ait endeks hesaplaması sonucunda ortaya çıkan veriler tablo 12 de verilmiştir. Yerfıstığı üretim miktarı pandemi yılı olan 2020 yılında %27.5, patates %4, susam %10.4, soya fasulyesi %3,5 ve şeker pancarı ise %27 oranında artmıştır. Kenevir üretim miktarı pandemi yılı olan 2020 yılında %55, kolza %32,5, aspir %2.2, pamuk %19 ve ayçiçeği ise %2 oranında azalmıştır. Endüstri bitkilerinin 2022 yılı üretim değerlerinde en yüksek artışlar kenevir, aspir ve ayçiçeğinde yaşanmıştır (Şekil 3).

Tablo 12. *Bazı endüstri bitkilerinin üretim miktarı endeks hesaplaması*
Table 12. *Production quantity index calculation of some industrial crops*

Yıllar	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Yer fıstığı	72.5	75.7	73.0	87.1	97.0	97.6	102.7	100.00	127.5	138.3	110.0
Kenevir	20	5	5	5	5	5	15	100.00	45	100	795
Patates	97	79	84	96	95	96	91	100.00	104	102	104
Kolza	61.1	56.7	61.1	66.7	69.4	33.3	69.4	100.00	67.5	77.8	83.3
Aspir	89.1	206.4	284.4	321.1	266.1	229.4	160.6	100.00	97.8	74.3	137.6
Pamuk	104	98	105	92	95	111	117	100.00	81	102	-
Susam	96.0	91.5	104.9	109.7	115.6	109.0	103.2	100.00	110.4	104.5	103.0
Soya fasulyesi	76.7	120.0	100.0	107.3	110.0	93.3	93.3	100.00	103.5	121.3	103.3
Şeker pancarı	82	91	93	91	108	117	96	100.00	127	101	105
Ayçiçeği	65	73	78	80	80	94	93	100.00	98	115	121



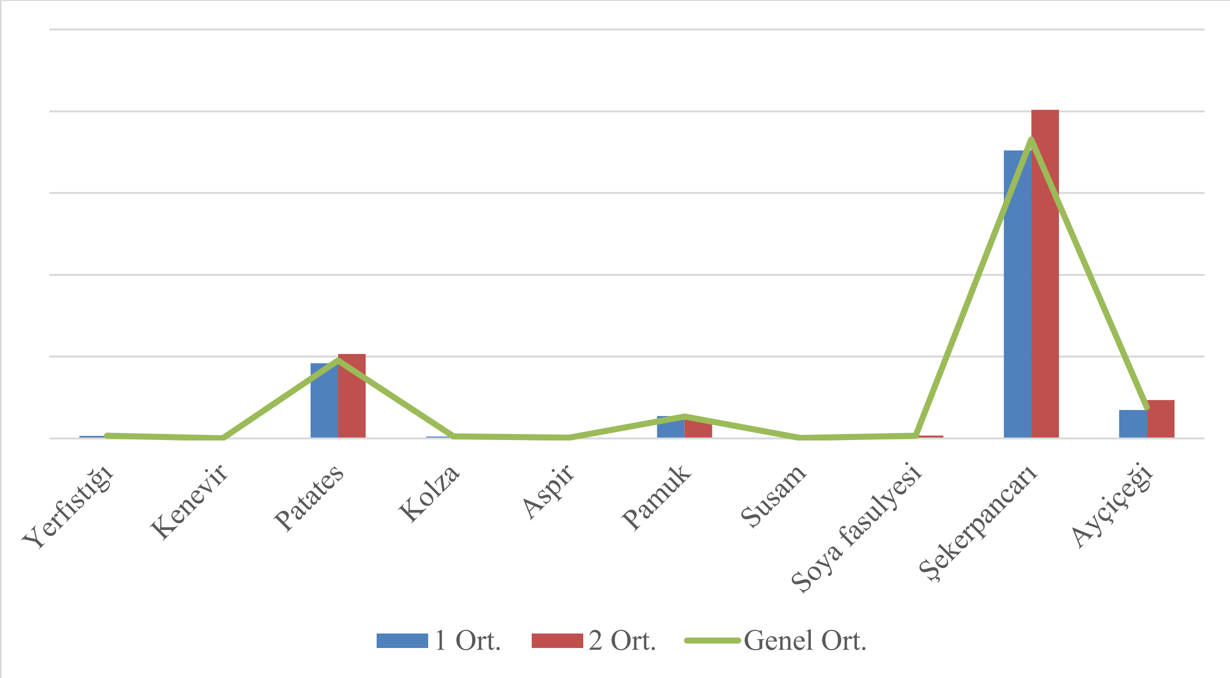
Şekil 3. *Bazı endüstri bitkilerinin üretim miktarına ait endeks oranları*
Figure 3. *Index ratios of production amount of some industrial plants*

Tablo 13 ve Şekil 4'te bazı endüstri bitkilerinin üretim değerlerinin pandemi öncesi ve sonrası değişimlerine ait tanımlayıcı istatistikler verilmiştir. Pandemi öncesine göre pandemiden sonra yerfıstığı, kenevir, patates, kolza, susam, soya fasulyesi, şeker pancarı ve ayçiçeği üretiminde artış olurken aspir ve pamuk üretiminde ise azalma olmuştur.

Tablo 13. *Bazı endüstri bitkilerinin covid 19 pandemi öncesi ve sonrası üretim miktarı (t)*
Table 13. *Production amount of some industrial plants before and after covid 19 pandemic (t)*

Yıllar		**Yerfıstığı**	**Kenevir**	**Patates**	**Kolza**	**Aspir**	**Pamuk**	**Susam**	**Soya fasulyesi**	**Şeker pancarı**	**Ayçiçeği**
1	Ort.	149357.63	4.00	4597881.88	116500.00	45172.88	1357155.00	17523.13	150125.00	17609619.25	1736991.25
	Std. s.	21682.759	6.568	356187.799	33114.520	18487.087	109983.948	1320.061	19533.396	1973964.462	246803.321
	Std. h.	7666.013	2.322	125931.404	11707.751	6536.172	38885.198	466.712	6906.098	697901.828	87258.151
2	Ort.	212144.67	62.67	5166666.67	137180.67	22508.33	1207094.50	17901.33	164075.00	20091912.67	2344001.33
	Std. s.	24136.798	83.608	57735.027	14436.964	6975.687	202098.896	659.374	15523.913	2568291.906	249202.512
	Std. h.	13935.387	48.271	33333.333	8335.185	4027.415	142905.500	380.690	8962.735	1482804.023	143877.137
Genel	Ort.	166481.36	20.00	4753005.00	122140.18	38991.64	1327142.90	17626.27	153929.55	18286608.36	1902539.45
	Std. s.	36134.963	46.682	400076.030	30043.291	19001.280	133976.901	1156.701	18914.138	2321893.225	368035.64
	Std. h.	10895.101	14.075	120627.462	9058.393	5729.102	42367.216	348.758	5702.827	700077.148	110966.923

1: covid 19 pandemisinden önce; 2: covid 19 pandemisinden sonra; Ort: Ortalama; Std. s.: standart sapma; Std. h.: Standart hata



Şekil 4. *Bazı endüstri bitkilerinin covid 19 pandemi öncesi ve sonrası üretim miktarı*
Figure 4. *Production amount of some industrial plants before and after covid 19 pandemic*

Hasat edilen alan

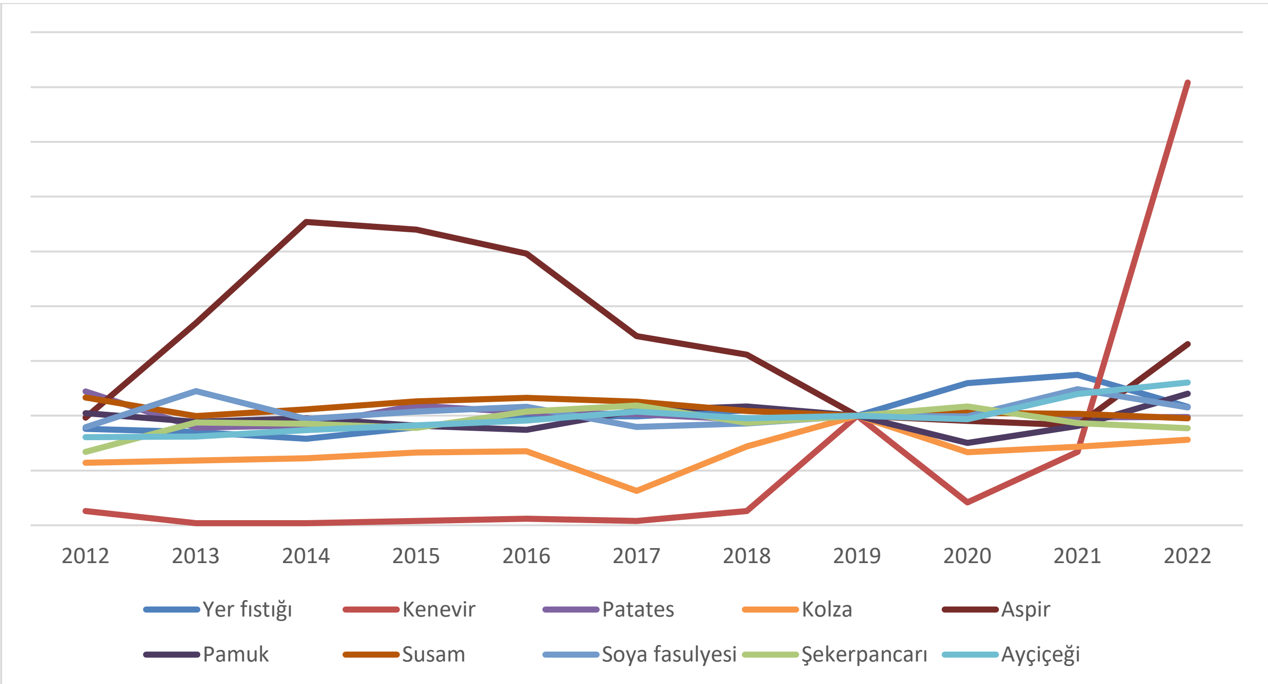
Pandemi öncesinde Türkiye'de endüstri bitkileri için hasat edilen alanlar genel olarak istikrarlıydı. Ancak pandemi ile birlikte yaşanan aksaklıklar ve belirsizlikler, bu alanlarda bazı değişimlere neden olmuştur. Pandemi sürecinde işgücü sıkıntıları ve pazar belirsizlikleri, pamuk hasat edilen alanlarında bazı daralmalar yaratmıştır. Şeker pancarında, tedarik zinciri aksaklıkları ve işgücü sorunları, hasat edilen alanların verimliliğini etkilemiştir. Pandemi sürecinde yaşanan tarım girdileri ve lojistik sorunlar, ayçiçeği hasat alanlarını da etkilemiştir.

Tablo 14. *Bazı endüstri bitkilerinin 2012-2022 yıllarına ait üretim alanına ait tanımlayıcı istatistikler (ha)*
Table 14. *Descriptive statistics of production area of some industrial crops for the years 2012-2022 (ha)*

Ürünler	Ortalama	Standart sapma	Minimum	Maksimum
Yer fıstığı	43030.45	7595.063	33327	57919
Kenevir	27.73	57.182	1	194
Patates	142671.00	12631.506	125434	171976
Kolza	34914.91	8656.592	16495	52510
Aspir	26787.18	11191.344	14452	43935
Pamuk	465351.64	56972.396	359220	573223
Susam	26447.64	1727.825	24285	28949
Soya fasulyesi	36435.27	4172.020	31599	43885
Şeker pancarı	293024.09	36084.933	208186	338883
Ayçiçeği	740450.18	114527.880	605000	979691

Tablo 15. *Bazı endüstri bitkilerinin üretim alanına ait endeks değerleri*
Table 15. *Index values of production area of some industrial crops*

Yıllar	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Yer fıstığı	88.1	85.1	78.9	89.5	100.1	99.4	104.9	100.00	129.7	137.2	108.3
Kenevir	13	2	2	4	6	4	13	100.00	21	67	404
Patates	122.2	89.1	91.2	109.3	102.8	101.5	96.5	100.00	105.1	98.4	98.8
Kolza	57.1	59.2	61.2	66.4	67.5	31.4	72.1	100.00	66.6	71.6	78.2
Aspir	98.3	184.5	277.0	269.8	248.1	172.6	155.7	100.00	95.3	91.1	165.4
Pamuk	102.2	94.4	97.7	90.8	87.1	105.0	108.5	100.00	75.2	90.5	120.0
Susam	116.5	99.7	105.9	113.0	116.2	112.8	104.5	100.00	102.7	101.6	97.7
Soya fasulyesi	89.5	122.6	97.2	103.7	108.2	89.7	93.1	100.00	99.5	124.3	107.7
Şeker pancarı	67.1	93.8	92.7	88.8	103.8	109.3	93.7	100.00	108.5	93.2	88.5
Ayçiçeği	80.5	81.1	86.9	91.2	95.6	103.7	97.7	100.00	96.9	119.7	130.3



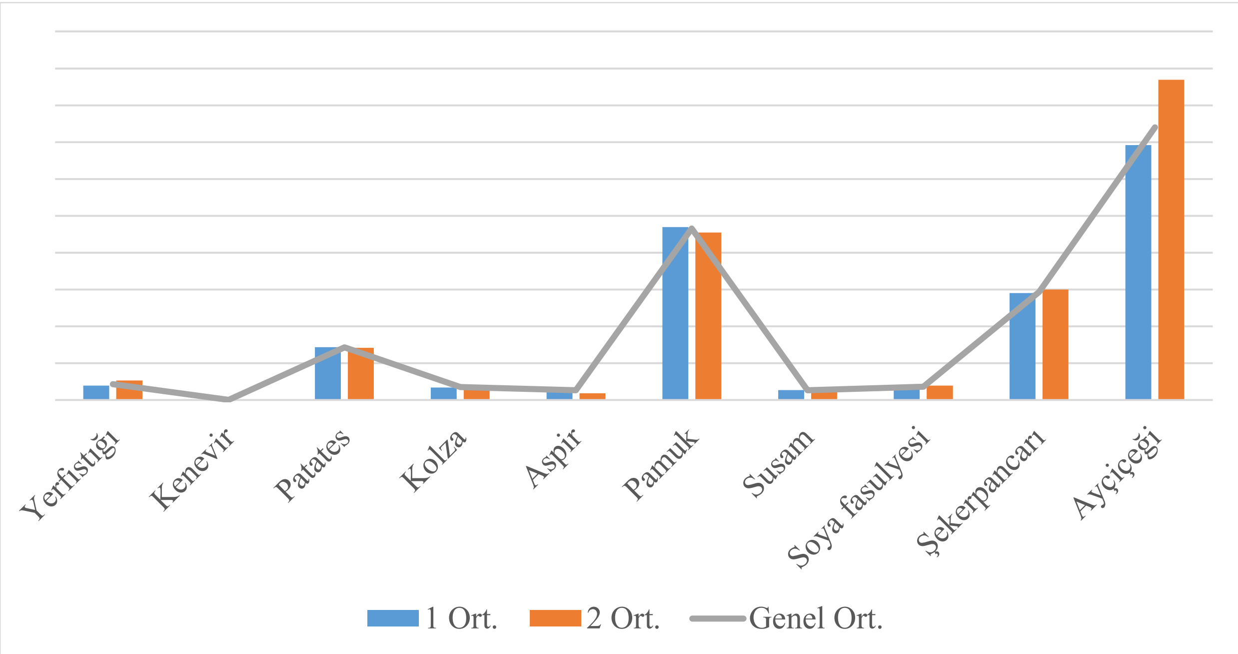
Şekil 5. *Bazı endüstri bitkilerinin üretim alanına ait endeks değerlerinin grafiği*
Figure 5. *Graph of index values of production area of some industrial plants*

Tablo 16 ve Şekil 6'da bazı endüstri bitkilerinin hasat edilen alanlarının pandemi öncesi ve sonrası değişimlerine ait tanımlayıcı istatistikler verilmiştir. Pandemiden önceki yıllarda yüksek olan patates, aspir, pamuk ve susam alanları pandemiden sonraki yıllarda azalmıştır. Yerfıstığı, kenevir, kolza, soya fasulyesi, şeker pancarı ve ayçiçeği hasat alanları ise pandemiden sonraki yıllarda artmıştır. Eryiğit (2011) Iğdır'da yapmış olduğu çalışmada son yıllarda iklim rejiminde meydana gelen değişimlerin ve ovadaki endüstriyel tarımın şeker pancarı, ayçiçeği ve kolza tarımının lehine gelişmesinin pamuk tarımında büyük azalma meydana getirdiği sonucuna varmıştır.

Tablo 16. *Bazı endüstri bitkilerinin covid 19 pandemi öncesi ve sonrası üretim alanı (h)*
Table 16. *Production area (h) of some industrial crops before and after covid 19 pandemic*

Yıllar		Yerfıstığı	Kenevir	Patates	Kolza	Aspir	Pamuk	Susam	Soya fasulyesi	Şeker pancarı	Ayçiçeği
1	Ort.	39367,50	8,625	142978,88	33799,00	29857,38	469268,25	26984,50	35469,88	290431,63	692094,75
	Std. s.	3831,765	16,0351	14815,643	9958,179	11265,162	34520,938	1713,918	3908,522	39154,570	65004,375
	Std. h.	1354,733	5,6693	5238,121	3520,748	3982,836	12204,995	605,962	1381,871	13843,231	22982,517
2	Ort.	52798,33	78,667	141850,00	37890,67	18600,00	454907,33	25016,00	39009,67	299937,33	869398,00
	Std. s.	6344,312	100,4855	5303,116	3056,242	6619,519	108781,212	646,782	4460,003	32345,908	128449,932
	Std. h.	3662,890	58,0153	3061,755	1764,522	3821,781	62804,862	373,420	2574,984	18674,919	74160,603
Genel	Ort.	43030,45	27,727	142671,00	34914,91	26787,18	465351,64	26447,64	36435,27	293024,09	740450,18
	Std. s.	7595,063	57,1823	12631,506	8656,592	11191,344	56972,396	1727,825	4172,020	36084,933	114527,880
	Std. h.	2289,998	17,2411	3808,542	2610,061	3374,317	17177,824	520,959	1257,911	10880,017	34531,455

1: covid 19 pandemisinden önce; 2: covid 19 pandemisinden sonra; Ort: Ortalama; Std. s.: standart sapma; Std. h.: Standart hata



Şekil 6. *Bazı endüstri bitkilerinin covid 19 pandemi öncesi ve sonrası üretim alanı*
Figure 6. *Production area of some industrial plants before and after covid 19 pandemic*

SONUÇ VE ÖNERİLER

Yerfıstığı, kenevir, patates, kolza, pamuk, susam, şeker pancarı ve ayçiçeği gibi bitkilerinin verim değerlerinde pandemiden önceki yıllara ve pandemiden sonraki yıllara ait ortalamalar kıyaslandığında artış olduğu, aspir ve soya fasulyesinde ise düşüş olduğu belirlenmiştir. Özellikle şeker pancarı ve patatesteki artış çok yüksek olarak gerçekleşmiştir. Pandemi öncesine göre pandemiden sonra yerfıstığı, kenevir, patates, kolza, susam, soya fasulyesi, şeker pancarı ve ayçiçeği üretiminde artış olurken aspir ve pamuk üretiminde ise azalma olmuştur. Pandemiden önceki yıllarda yüksek olan patates, aspir, pamuk ve susam alanları pandemiden sonraki yıllarda azalmıştır. Yerfıstığı, kenevir, kolza, soya fasulyesi, şeker pancarı ve ayçiçeği hasat alanları ise pandemiden sonraki yıllarda artmıştır.

COVID-19 pandemisi, tarım sektöründe birçok alanı olduğu gibi endüstri bitkilerinin verim, üretim ve hasat edilen alan değerlerini de etkilemiştir, Pandeminin bu bitkilerin üretim süreçlerine etkileri şu şekilde özetlenebilir:

Pandemi nedeniyle uygulanan kısıtlamalar ve karantina önlemleri, tarım işçilerine erişimi zorlaştırmış ve özellikle hasat döneminde işgücü sıkıntısına yol açmıştır, Tarım sektöründe sıkça çalıştırılan mevsimlik ve göçmen işçilerin hareketliliği kısıtlanmış, bu da üretim ve hasat süreçlerinde aksamalara neden olmuştur. Gübre, ilaç, tohum gibi tarımsal girdilerin temininde yaşanan aksaklıklar ve maliyet artışları, üreticilerin verimliliğini olumsuz etkilemiştir, Lojistik ve nakliye hizmetlerinde yaşanan kesintiler, ürünlerin pazara ulaşmasını zorlaştırmış ve gecikmelere yol açmıştır. Pandemi sürecinde küresel ve yerel talepte yaşanan dalgalanmalar, üretim planlamasında belirsizliklere yol açmıştır, Özellikle ihracata yönelik üretim yapan çiftçiler, belirsizlikler nedeniyle üretim miktarlarını ayarlamakta zorlanmıştır, Ürün fiyatlarında yaşanan dalgalanmalar, çiftçilerin ekonomik planlamalarını zorlaştırmış ve üretim kararlarını etkilemiştir. Pandemi sürecinde gıda güvenliği ve kendi kendine yeterlilik konuları ön plana çıkmıştır. Bu durum, bazı çiftçilerin endüstri bitkilerinden gıda ürünlerine yönelmesine neden olmuştur. Pandemi sürecinde bazı üreticiler, yüksek belirsizlik nedeniyle endüstri bitkileri yerine daha hızlı gelir getiren veya temel gıda maddeleri üretimine yönelmiştir. Bu durum, endüstri bitkileri için ayrılan ekim alanlarında azalmaya neden olmuştur. Sosyal mesafe önlemleri nedeniyle tarım faaliyetlerinin uzaktan yönetimi ve tarım teknolojilerinin kullanımı arttı, bu teknolojiler, bazı üreticilerin daha verimli ekim ve hasat yapmasına olanak tanımış, ancak yaygınlıkları sınırlı kalmıştır.

Bu sonuçlar ışığında;

Hükümetin ve tarım örgütlerinin üreticilere yönelik finansal destek paketleri, pandeminin ekonomik etkilerini hafifletmeye yardımcı olmuştur dolayısıyla bu hizmetlerin devam ettirilmesi gerekmektedir. Tedarik zincirindeki aksaklıkları gidermek ve üreticilerin girdilere erişimini kolaylaştırmak için yapılan iyileştirmeler ve lojistik desteklerin devam ettirilmesi gerekmektedir. Çiftçilere yönelik eğitim ve bilinçlendirme programları, modern tarım tekniklerinin ve teknolojilerinin kullanımı konusunda bilgi sağlanmasına devam edilmelidir. Tarım teknolojilerinin yaygınlaştırılması ve dijital çözümlerin benimsenmesi, verimliliği artırmak ve işgücü eksikliğini gidermek için adım atılmalıdır. Çiftçilerin piyasa dalgalanmalarına karşı daha dayanıklı olması için üretim ve ekim alanlarının çeşitlendirilmesi sağlanabilir. Pandemiyle birlikte artan iklim değişikliği farkındalığı, iklime dayanıklı bitki türlerinin ve üretim tekniklerinin geliştirilmesini teşvik etmelidir. Pandemi, Türkiye'de endüstri bitkileri üretimini birçok açıdan etkilemiş, işgücü ve tedarik zinciri sorunları, pazar belirsizlikleri ve değişen ekim alanları, üretim ve verimlilik üzerinde belirleyici olmuştur. Bu süreçte, tarım sektörünün dayanıklılığını artırmak ve gelecekte benzer krizlere hazırlıklı olmak için tarım teknolojilerinin benimsenmesi, eğitim ve destek politikalarının güçlendirilmesi önemlidir.

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The Application of Nanotechnology on Plant Nutrition and Agriculture: A Review

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Abstract

Nanotechnology is one of the most versatile emerging technologies, based on producing and utilizing structures of materials possessing dimensions less than 100 nanometers. It is an interdisciplinary field, and its applications in various sciences and industries are expanding rapidly. Industrial agriculture is among the important experiencing swift advancements in nanotechnology. Industrial sectors have seen swift advancements in nanotechnology, which have led to significant advancements in various branches of this industry. In the field of soil science, nanotechnology is being used for effective plant nutrition management through the use of nanofertilizers, controlling soil-borne diseases with nanopesticides, remediation of salinity and removal of pollutants from soil using nanoparticles and porous nanosorbents, enhancing soil moisture retention capacity through superabsorbent nanomaterials, stabilizing erodible soils using nanosilicates and nanopolymers, and providing various chemical and biosensors for precise soil measurement. Despite all these capabilities, the application of nanotechnology in soil faces challenges such as uncertainty lack of knowledge regarding the environmental risks, complex behavior in heterogeneous soil environments, and expensive synthesis and analytical methods of nanomaterials.

Keywords: Nanotechnology; Plant nutrition; Soil; Agriculture

INTRODUCTION

Nanotechnology encompasses a set of techniques, descriptive processes, and material applications at the nanometer scale. It includes three main branches: nanomaterials, nanotools and nanosensors. A nanometer is equivalent to a very tiny unit of measurement (10-9 meters) and the control of matter inside the range of 1 to 100 nanometers is typically the focus of nanotechnology (Tarafdar et al., 2013).

Nanotechnology has gained significant attention and expanded its application in various fields, including agriculture, in the past decade. Given the mismatch between population growth and food requirements, the importance of nanotechnology as an interdisciplinary and pioneering science becomes evident. It possesses the capability to boost the performance of farming products throughout, cultivation, harvesting, and storage processes, as well as optimize production conditions and food preservation. In fact, approximately 70% of the top 10 priorities for nanotechnology in the world are directly or indirectly related to agricultural sciences (Mukhopadhyay, 2014).

Nanotechnology in food and agriculture

It offers new solutions for improving food security and is capable of revolutionizing diverse aspects of farming. Utilizing nanotechnology is considered a novel approach to enhance food security (Musavi and Rezaei, 2011; Tarafdar and Raliya, 2011).

Nanotechnology has created new and emerging potential applications in the field of agricultural sciences. With this knowledge, it is possible to improve current product management methods. Nanoscience is described, certainly in the America, as innovation and experimentation aimed at

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understanding, manipulating, and measuring materials at the atomic and molecular levels (Reynolds, 2003).

Nanotechnology, as an interdisciplinary field, can have a broad spectrum of uses in the farming industry, leading to significant outcomes such as increased harvest yield, reduced utilization of plant nutrients and insecticides, an extended shelf-life of agricultural products, and perhaps a transformative impact on all stages, inputs, and agricultural tools, aiming for improvement (Pandey, 2020).

Moavini and Khairi (2011) demonstrated a significant impact of titanium dioxide nanoparticles on corn performance. Another experiment, a combination of silica nanoparticles (SiO2) and silver nanoparticles enhanced the functionality of nitrate enzyme in soya beans and enhanced water and nutrient absorption and utilization (Lu et al., 2002).

Furthermore, Mazahernia et al. (2010) viewed significant improvements in various parameters when utilizing iron rust nanoparticles in contrast with conventional iron rust contained in a greenhouse experiment. The application of iron oxide nanoparticles resulted in increased iron concentration in plants, length of spikes, plant height and grain weight per spike, total straw weight, total weight of grain and straw, thousand grain weight and grain weight in wheat. This increase in performance could be attributed to the unique properties of nanoparticles, their higher solubility, lightness and small size, as well as the increased chances of root interaction with nanoparticles compared to conventional iron oxide particles. Additionally, Salehi and Tameshkan (2008) observed that treatment with silver nanoparticles (50 mg/L) led to an increase in germination percentage, length of both stem and root and ultimately improved wheat establishment.

Soil is considered a primary resource for agricultural production, and therefore, preserving its health and fertility is of utmost importance for sustainable food production. It is crucial to maintain the optimal levels of nutrients and moisture in the soil while minimizing the existence of pollutants like heavy metals and toxins. Nanotechnology can significantly contribute to improving this process (Kianian, 2006).

Nanotechnology in fertilizers

Nanotechnology, as an emerging technology, plays a crucial role in optimizing conventional agricultural administrative methods. Through the utilization of nanotechnology in the design and development of nanofertilizers and nano-delivery systems for plant roots, remarkable achievements can be made in increasing the efficiency of chemical fertilizer use. This can lead to significant outcomes such as increased crop yield, reduced production costs, and environmental protection (Nikbakht et al., 2014).

Nitrogen, phosphorus, and potassium are three essential nutrients for plants and are supplied through the utilization of chemical fertilizers. However, the present forms of these fertilizers has the ability to leach 80 to 90% of phosphorus, 50 to 70% of potassium, 40 to 70% of nitrogen into the environment, especially when the particle size is larger than 100 nanometers. These leached nutrients are not absorbable by plants (Askari et al., 2020).

Studies have shown that the application of nano-based fertilizers significantly improves measured traits, including growth-related parameters such as increased shoot and root weight, the number of lateral branches, leaf count, leaf surface area, chlorophyll index, as well as qualitative traits such as protein content, peroxidase enzyme activity and the content of essential nutrients like nitrogen, phosphorus, potassium, calcium, sodium and magnesium in plant aerial parts (Hosseini et al., 2019).

The utilization areas regarding nanotechnology in soil knowledge include various fields, and one of them is plant nutrition. Nanotechnology offers several advantages in this regard, such as precise supply of required plant nutrients, increasing the efficiency of fertilizer utilization and making otherwise inaccessible nutrients available in the rhizosphere. Additionally, it enables the controlled release of fertilizers at the appropriate time for plants, either through root uptake or foliar spraying. This can contribute to reducing the deleterious environmental impact of fertilizer use in agriculture, which has always been a concern (Rai et al., 2015).

Over the past fifty years, advancements in chemical materials technology have brought about a revolution in agricultural production (Vasilevski, 2003).

With the onset of industrial agriculture, which relied on high-yielding crop varieties and the use of chemical fertilizers, agricultural production underwent significant changes and experienced substantial growth. However, the alterations caused in nature due to human interventions in water, soil and air, as a result of using various chemical substances to enhance plant productivity, along with the consumption form of approximately ten times more energy per unit of output compared to the past century, led to the search for new methods in agricultural production (Aladjadjiyan, 2007; Vasilevski, 2003).

The utilization of standard chemical fertilizers has received scrutiny because of their detrimental influences on ecology and food standards. Nanofertilizers, as an alternative to traditional fertilizers, gradually release nutrients in a controlled manner. This prevents groundwater contamination. By employing nanotechnology in the design and production of nanofertilizers, new opportunities have emerged to enhance nutrient uptake efficiency and reduce environmental conservation expenses (Naderi and Abedi, 2012).

Some advantages of using nanofertilizers compared to conventional fertilizers include increased efficiency and quality of food resources due to faster nutrient absorption, reduced loss of fertilizers through leaching and complete nutrient uptake by plants throughout the growing season. Nanofertilizers can release nutrients at an optimal rate, improving soil quality and enhancing plant nutrition. Additionally, it has contributed to the reduction of soil pollution and overall plant health (Naderi and Danesh-Shahreki, 2011).

One of the foremost uses of nanotechnology is the use of nanofertilizers for plant nutrition. By utilizing nanoparticles, particles that are three-dimensionally smaller than 100 nm, controlled-release fertilizers or fertilizers with enhanced properties can be produced. Nanoparticles, due to their unique surfaces, higher density, and increased reactive sites on the particle surface, exhibit high reactivity. These characteristics facilitate the absorption of fertilizers and nanoscale pesticides produced at the nanoscale (Wiswanafhan, 2009).

The nutrition of plants and soil fertility are closely interconnected. The soil should contain an adequate amount of essential nutrients and be able to effectively supply these nutrients to plants. One way to ensure the availability of nutrition in the soil is through the use of appropriate fertilizers. The application of fertilizers not only increases yield production but should enhance the quality of agricultural products. Another important aspect is to avoid environmental pollution caused by fertilizers, as it can pose risks to human, animal, and plant health. Nanotechnology, with its ability to modify and impact the formulation of fertilizers and produce materials with unique properties, can contribute significantly to this field. The use of nanotechnology in fertilizer production can lead to increased amount and level of agricultural commodities while reducing environmental deterioration. The advantages of using these nanofertilizers include:

Formulation Modification: By altering the formulation of fertilizers, it is possible to produce smart fertilizers that release nutrients according to the plant's absorption pattern. This allows for precise nutrient delivery and improves nutrient utilization by plants. Efficient nutrient delivery: nanofertilizers can be produced with nano-sized nutrient particles, enhancing their solubility and distribution in the soil. This results in improved nutrient availability and increased nutrient uptake efficiency by plants.

Reduced Nutrient Loss: The utilization nanofertilizers can diminish nutrient losses through leaching in some cases. The use of nitrogen and phosphate fertilizers can be reduced by up to 50%, leading to a decrease in pollution caused by excessive use of chemical fertilizers.

Enhanced Plant Resistance: Nanofertilizers provide plants with adequate nutrition, increasing their resistance to environmental stress and diseases. This can reduce the need for chemical pesticides and reduce chemical inputs.

Long-Term Soil Interactions: Nanofertilizers can interact with soil microorganisms over an extended period. This can improve soil health and nutrient cycling, promoting sustainable agriculture.

Cost-Effectiveness: The use of nanofertilizers can be economically viable due to reduced fertilizer consumption and increased nutrient use efficiency. By harnessing the potential of nanotechnology in fertilizer production, it is possible to enhance nutrient availability, improve crop yields, reduce environmental pollution and promote sustainable agricultural practices (Kianian, 2006).

Nanotechnology in pesticites

In all countries around the world, synthetic pesticides are primarily produced for pest control in agriculture. The use of these pesticides and their application methods lead to environmental pollution. However, with the help of nanotechnology and the development of new formulations for pesticides, the performance can be enhanced and therefore, the consumption the use of pesticides can be diminished. The utilization of nanosuspensions to increase the efficiency of various types of pesticides, including herbicides, fungicides, insecticides, and rodenticides, has received significant attention (Tsuji, 2001).

The utilization of nano-science in farming is currently in its nascent point, even on a global scale. Nanoscience has contributed to the development and improvement of cost-effective applications of nanotechnology for promoting plant growth. Nanoparticles and nanocapsules serve as effective tools for the controlled distribution of pesticides and fertilizers. As a result, they reduce environmental consequences (Nair et al., 2010).

Pesticides are carried by wind and enter the air, posing risks to human respiratory systems. Nanotechnology addresses the problems associated with pesticides by increasing profitability and reducing the adverse effects, transforming them into highly beneficial products. One of these technologies involves the manufacturing of chemical fertilizers and pesticides employing nanocapsules and nanoparticles. The distinctive properties of nanoparticles, for instance, a large surface region and high reactivity, led to the extensive utilization in various industrial and commercial sectors (Ma et al., 2010). Nanotechnology plays a significant role in improving existing management practices in crop production. Agricultural chemicals, through processes such as leaching, photo degradation, hydrolysis and microbial decomposition, only reach a trivial percentage or fraction to their target site. Therefore, repeated applications are required for effective control, which can result in undesirable consequences like water and soil contamination (Nair et al., 2010).

Nanotechnology in soil fertility

Nanotechnology offers potential solutions to enhance the health and fertility of soil. For instance, nanomaterials can be utilized to deliver nutrients to the flora in a more managed and efficient fashion, ensuring that the required amounts are virtually equal to available. They can also raise the moisture retention capability for the soil and reducing the need for excessive irrigation. Additionally, nanotechnology can be a useful tool in reducing the levels of contaminants in the soil by facilitating their removal or transformation into less harmful forms (Kianian, 2006).

Agricultural practitioners strive to increase production per unit area of agricultural products to satisfy the dietary needs of the multiplying human population. However, improper soil management practices such as excessive tilling, improper tilling practices on the sloppy agricultural lands, unbalanced and excessive use of chemical fertilizers, lack of organic matter incorporation, burning of crop residues and irrigation with polluted water sources have gradually led to the deterioration of soil standard and fertility and transforming them into undesirable and polluted soils (Kianian, 2011).

Indeed, the use of specific soil amendments, such as nano-scale amendments, can perform a crucial part in improving soil conditions and preventing soil degradation. These amendments have the potential to improve soils' physical, chemical and biological conditions and overall soil quality parameters (Nazari, and Tag-Abadi Ebrahimi, 2005). Here are some advantages of nano-scale materials to the soil amendments.

Nanozeolites

Nanozeolites are valuable materials with wide applications in refining processes, as well as in agricultural and environmental engineering. Nanozeolites possess complex structures with extensive interconnecting channels in their crystalline framework. These channels provide ample empty area for cation attraction and substitution. Some reports indicate that the inside facet region of these channels can achieve numerous square of hundred meters per gram of zeolite mineral, yielding zeolites, one of the most effective ion-exchange agents.

The advantages of using nanozeolites in agriculture include:

High Porosity and Water Absorption: Nanozeolites have high porosity, enabling them to absorb and retain water efficiently in the soil. They can improve water-holding capacity, especially in sandy soils, and help evenly distribution of water.

Soil Amendment in Sandy Soils: Nanozeolites can improve the structure of sandy soils, enhancing their water retention capacity and preventing excessive drainage.

Improved Soil Aeration: Nanozeolites can enhance soil aeration by improving soil porosity and preventing compaction, thereby promoting root development and overall plant growth.

Heavy Metal Adsorption and Soil Remediation: Nanozeolites have the ability to adsorb including metals of high density like lead, chromium, nickel, cadmium etc. They could be environmentally and economically feasible tool in the remediation of contaminated soils by trapping and immobilizing these pollutants. Demirkiran et al. (2016) compared adsorption capacities of zeolite-clinoptilolites with oil sorption.

Nutrient Combination and Slow-Release Fertilizer: Nanozeolites can be combined with nutrients and function as slow-release fertilizers. They can retain and gradually release essential nutrients to plants, promoting efficient nutrient uptake and reducing nutrient losses.

It is important to note that the application of nanozeolites in agriculture should be based on careful consideration of specific soil conditions, crop requirements, and potential environmental impacts. Proper dosage and application methods should be followed to ensure optimal results and minimize any adverse effects.

Overall, the utilization of nanozeolites in agriculture holds promise for improving soil properties, water management, nutrient availability and soil remediation, contributing to sustainable agricultural practices and conserving the soils for environmental standpoint (Kianian, 2017).

Nanobiochars

Nanobiochar is among the emerging prospects in nanotechnology for soil amendments. Biochar is considered a renewable source produced from plant biomass or any other organic waste materials, such as residues from textile factories, tanneries, any kind of agricultural biomasses, etc. In this process, the waste materials are transformed into biochar through pyrolysing at a temperature mainly between 300-700oC. This bio-based compound possesses a unique microstructure and high surface area.

Nanobiochar holds multifaceted importance due to its utilization of waste materials, cost-effectiveness and its environmentally friendly nature. The production of biochar from organic residues helps in waste management and contributes to the circular economy. It offers several benefits in agriculture and soil improvement:

Carbon Sequestration: Biochar acts as a carbon sink by sequestering carbon from biomass, reducing greenhouse gas emissions and mitigating climate change.

Soil Amendment: Nanobiochar improves soil fertility, structure, and water-holding capacity. It enhances soil microbial activity, nutrient retention, and nutrient availability for plants. It can be used to amend the acidity problem in soils.

Water Management: Nanobiochar helps in regulating soil moisture levels by increasing water retention capacity and reducing water evaporation. It can contribute to drought mitigation and water conservation efforts.

Nutrient Cycling: Nanobiochar acts as a reservoir for essential nutrients, preventing them from leaching and improving nutrient use efficiency. It promotes nutrient cycling and reduces nutrient losses from agricultural systems.

Soil Microbial Activity: Nanobiochar enables a favorable environment for beneficial soil organisms, mainly microorganisms, and enhancing soil biological activity and promoting plant growth. The application of nanobiochar as a soil conditioner offers a sustainable approach to enhance soil fertility, enhance yield efficiency and contribute to environmental conservation. However, it is important to consider factors such as biochar production methods, feedstock selection and application rates to optimize its benefits and minimize any potential negative impacts on soil health or the environment.

Overall, nanobiochar holds promises as a bio-based soil amendment that utilizes waste materials, offers cost-effectiveness and provides ecological benefits, contributing to the sustainable management of agricultural systems. Therefore, by utilizing nanotechnology in the production of nanobiochar and enhancing its chemical properties, it is possible to harness its features for improving soil quality, increasing crop yield, enhancing the absorption of toxic substances and mitigating climate change. The advantages of using nanobiochar when produced and applied to the soil include (Kianian, 2017).

Carbon Sequestration and Increased Soil Organic Matter: Nanobiochar aids in carbon storage within a specific soil, contributing for the extended element carbon sequestration. It also increases the percentage of soil organic matter, enhancing soil fertility and structure.

Improved Soil Aeration: Nanobiochar enhances soil aeration by improving soil porosity and promoting the movement of soil-air within the profile. This helps in creating a favorable environment for root growth and microbial activity.

Adsorption of Various Pollutants: Nanobiochar has a high surface area and porosity, allowing it to effectively adsorb various organic, inorganic and industrial pollutants. This leads to their reduced release into the environment and helps in conditioning the plant growth.

Enhanced Nutrient and Water Absorption: Nanobiochar has the ability to retain and slowly release nutrients, making them more available to plants. It also increases soil water retention capacity, reduces water stress on plants and enhances water resource utilization.

By enhancing the potential of nanobiochar through nanotechnology, it is possible to address soil degradation, enhance agricultural productivity and mitigate environmental pollution. However, it is crucial to carry out studies towards optimizing the production techniques, determining appropriate application rates and evaluating the protracted effects of nanobiochar on soil healthy and ecosystem sustainability.

Nanohydrogels

Nanohydrogels are hydrophilic polymer networks with high water absorption capacity. Structurally, hydrogels can be classified into anionic, cationic and amphiphilic based on their properties. Most of these materials respond to environmental stimuli such as pH, light, electric fields and more. These unique characteristics have resulted in a broad spectrum of uses for hydrogels, especially in agriculture (Kianian, 2017).

Creating an environment for plant growth that can store nutrients and water for extended periods and gradually release them to plants is one of the main functions of hydrogels, particularly nano-hydrogels. The benefits of using these materials can be summarized as follows:

Water Absorption: Nanohydrogels have nanoscale pores that allow them to absorb water up to several hundred times of their weight. They can retain supplying moisture for an extended period, decreasing the frequency and requirement of irrigation.

Water Retention in Soil: Nanohydrogels enhance water retention capacity in the soil, reducing water consumption for irrigation in the long run. This can be particularly beneficial in arid or drought-prone regions for maximizing benefit of the off-season precipitation.

Nutrient Storage and Gradual Release: Hydrogels have the ability to store nutrients within their structure and gradually release them for plant uptake. This ensures a steady supply of nutrients to the plants and reduces nutrient leaching.

Application in Greenhouses and Apartments: Nanohydrogels can be used in various settings, including greenhouses and city gardening, where water availability and efficient nutrient management are crucial. By utilizing nanohydrogels in agriculture, it is possible to enhance the performance of water utilization upgrade nutrient availability and create a favorable growth environment for plants. However, it is important to consider factors such as the appropriate dosage, compatibility with other agricultural inputs and potential environmental impacts when implementing nano-hydrogels in farming practices.

Nanosensors

Nanosensors are sensors with nanoscale dimensions that measure physical or chemical changes and convert them into electrical signals. Due to their nanoscale size, nanosensors exhibit high precision and sensitivity, allowing them to identify extremely small gas levels within the environment. Nanotechnology sensors are highly fragile, but accurate and sensitive devices able to identify and reacting to biological, physical and chemical triggers.

The small size of nanosensors provides several advantages. First, it allows for a wider specific surface area increasing the interaction between the sensor and the target analyze. This enhances the sensor's sensitivity and responsiveness. Second, the nanoscale dimensions enable nanosensors to be integrated into various systems and devices, including wearable technology, environmental monitoring systems and medical diagnostic tools.

Nanosensors possess a broad spectrum of uses across various fields. In environmental monitoring, they can discern and measure air pollutants, water contaminants, and hazardous substances with high precision. In healthcare, nanosensors can be used for early diagnosis of diseases, drug delivery monitoring, and real-time health monitoring. Additionally, nanosensors find applications in food safety, industrial process monitoring and security systems (Kianian, 2017).

The development of nanosensors opens up new possibilities for advanced sensing technologies, enables more accurate and efficient monitoring and control of our surroundings. However, challenges such as fabrication techniques, integration into complex systems, and ensuring long-term stability and reliability still need to be addressed for widespread adoption of nanosensors in practical applications (Ma et al., 2010). Some applications of various nanosensors in soil include:

Monitoring Soil Temperature: Nanosensors can be used to measure and monitor the temperature of the soil. This information is important for understanding the soil's thermal properties and the impact of it on plant growth and microbial activity.

Controlling and Monitoring Soil Moisture: Soil moisture sensors are utilized for measurement and monitor the humidity level in the soil. This data helps in efficient irrigation management and preventing over-irrigation or deficient-irrigation of plants.

Observing and Monitoring Crop Conditions and Nutrient Levels: Nanosensors can be used to monitor various parameters related to crop growth, such as pH levels, nutrient concentrations and electrical conductivity. This information helps farmers optimize fertilizer application and adjust cultivation practices accordingly. This practice has a specific significance for the hydroponic systems.

Detecting Soil Contamination: Nanosensors can be used to detect and assess soil contamination by pollutants, heavy metals or harmful chemicals. This information is crucial for environmental monitoring and ensuring soil health and quality.

Assessing Plant Growth Hormones: Nanosensors can be employed to measure and monitor the levels of plant growth hormones, like gibberellins and cytokines in the soil. This data aids in understanding plant development, growth patterns, and responses to external stimuli. By utilizing various sensors, farmers and researchers can gain valuable insights into soil conditions, make informed decisions regarding crop management and implement sustainable agricultural practices (Ma et al., 2010).

Nanotechnology in genetic

The utilization of nanotechnology on genetic improvement of plants and animals can enhance the resistance of plants against diseases and other biotic and abiotic stresses. Nanotechnological advancements, particularly in fundamental studies of cellular pathology, will strengthen them and prolong their lifespan in cultivation and consumption locations. It can also accelerate their growth and enable them to thrive in adverse environments such as saline, water-deficient conditions or even colder climates. The possibility of making plants drought-tolerant exists (Zhang et al., 2015).

Nanotechnology in environment

Furthermore, in the waste of water and water industry, the development of nanoscience can bring about significant transformations in water supply and related sectors. The applications of nanoscience for water purification pollution control, optimal utilization of groundwater, and improvement of water structures are among the features that the water and wastewater industry aims to achieve through nanotechnology (Dhawi et al., 2009).

CONCLUSION

In a study titled "Investigating the impact of nanotechnology product production and acceptance on sustainable agriculture from the perspective of agricultural researchers", Mousavi et al. (2009) concluded that the application and position of nanoproducts have a significant and positive relationship with the sustainability of agriculture, as well as the promotion and economic benefits of using nanoproducts. The researcher suggested that nanotechnology has the potential to address pollution, deforestation, hunger, and drought. Musavi and Rezaei (2011) concluded that nanoproducts can provide durable, new, productive, safer, cost-effective, abundant, flexible, environmentally friendly and sustainable consumer goods, as well as contribute to agricultural productivity for larger populations.

Nanotechnology can play a highly effective role in agriculture and natural resources in various areas such as rapid detection of plant diseases, identification and removal of pesticide residues in agricultural products, intelligent delivery of drugs and toxins. It can be used in livestock, aquaculture, water purification, textile industry and genetic engineering of plants and animals (Ditta, 2012).

Currently, there are approximately 200 active nanotechnology research companies worldwide and it is expected that their number will rapidly increase along with the emergence of more advanced and complex applications of this technology (Dhawi et al., 2009). It would be better to use a novel research for the number of nanotechnology companies.

The use of nanotechnology to mitigate the adverse effects of pesticides in agriculture primarily involves substituting hazardous and future pesticides with non-toxic metallic and non-metallic nanoparticles, increasing the efficiency and reducing the dosage of conventional pesticides by combining them with nanoparticles, targeting the effect of pesticides on the intended species and controlling their release through the utilization of nanoparticles, nanosuspensions, nanocoatings, and nanoporous materials. Nanoparticles have been developed to combat various pests such as insecticides, acaricides and pathogenic agents. These nanoscale particles are used to carry pesticides and enhance their efficacy. The active ingredient of pesticides is gradually released, which not only provides economic benefits but also contributes to environmental safety by preventing soil erosion, reducing plant burn and minimizing toxicity to humans (Adhikari, 2013).

The use of nanotechnology has garnered attention in terms of modifying the physical properties and reducing the erodibility of soil through various nanoscale amendments. Modifying soil properties, including water retention capacity, has been reported using nanoscale zeolites, natural nanoporous materials and synthetic nanomaterials. These nanomaterials contribute to enhance the soil-water retention and other physical characteristics of soil (Jatav and De, 2013).

The use of these materials in soil, especially in sandy soils, can increase water holding capacity, reduce irrigation and fertilization costs, revive the biological activity of desert regions and improve the success of irrigation and afforestation programs in dry and semi-arid areas. Additionally, it can help mitigate the effects of drought stress (Karimi et al., 2009).

Metal oxide nanoparticles, porous nanostructures, nanoclays and nanoring bio-polymers are among the materials that have been used to enhance the structure of soil and stabilize loose sand particles to control soil erosion (Hatefi et al., 2016).

In an investigation, silicon, palladium, copper and gold nanoparticles did applied for the earth within two forms: during seed planting in the soil and 15 days prior to seed planting. The findings indicated that when the soil amended with nanoparticles for a duration of 15 days, after which the seeds were sown, a rise in the stem-to-root proportion was observed in relation to the nanoparticles when contrast to the standard. This points out that nanoparticles might lack a straightforward impact influencing plant development but might also act through indirect mechanisms (Shah and Belozerova, 2009).

In an experiment, the application of iron oxide nanoparticles significantly enhanced the "iron levels within" plants in contrast to the standard and the control. This is likely due to the properties of nanoparticles, including higher solubility and increased contact surface with plant roots. However, due to increased competition among plant roots for the absorption of iron, zinc, copper and manganese levels decreased with higher concentrations of nanoparticles. The reduction of zinc, copper, and manganese concentration in plants were lower in the control treatment (Mazahernia et al., 2010).

Nanotechnology has great potential for various applications in soil science, including the utilization for nanofertilizers to plant growth, nanopesticides on pests and plant controlling illness nanosorbents for water and soil purification, nanomaterials for soil water management, nanocoatings for soil protection and nanosensors for accurate measurement of chemical and biological variables in soil. Considering the aspects of risk, toxicity and compatibility with living systems, the use of nanotechnology can lead to desirable outcomes such as enhancing the efficiency of agricultural operations, guaranteeing nutritional safety and promoting conscious and lasting farming practices in emerging nations and area. Chemical fertilizers are commonly used through foliar application on aerial parts of plants or broadcast in the soil for root uptake. However, due to issues like drainage, overflow and vaporization, alone a minor portion within effective nutrient components attain the desired stage, that is significantly "lower than the least required amount" by the vegetation. Consequently, repeated application regarding chemical fertilizers is necessary to achieve effective control over the plant's nutritional status, but this continuous practice can lead to undesirable side effects such as water and soil pollution.

Hence, it enhances to design and advance innovative methods for producing fertilizers that possess features such as regulated discharge of components in reaction to particular "stimuli, enhanced targeted operation, reduced ecological harm, and straightforward and secure" element delivery. This way, the repetitive application of chemical fertilizers can be avoided.

Nanofertilizers can be produced containing low amounts of nutrients at the nanoscale, which enhances their solubility and dispersibility in the soil, leading to improved nutrient absorption efficiency by plants. Reduced nutrient loss: the use of nanofertilizers reduces nutrient loss through leaching. In some cases, the consumption of nitrogen and phosphate fertilizers can be reduced by up to 50%, resulting in a decrease in environmental contamination resulting from the excessive utilization of chemical fertilizers. Due to adequate nutrition and availability of essential elements, plants become more resilient to environmental stress and diseases, leading to a reduced need for chemical pesticides and insecticides.

Nanofertilizers facilitate long-term interactions with soil microorganisms. The reduced fertilizer consumption associated with nanofertilizers provides economic benefits.

In summary, the use of nanofertilizers offers several advantages, including customized formulation, improved nutrient utilization, reduced nutrient loss and enhanced plant resistance. These benefits contribute to more sustainable agricultural practices and environmental protection. Overall, the utilizing nanotechnology in fertilizers production can contribute to the improvement of plant nutrition, soil fertility, and environmental sustainability.

This current the article is an overview paper and the research method used is library study and online exploration in information databases. The data and information of this review have been collected through studying various sources and references.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this study.

CONFLICTS of INTEREST

The authors declare there is no conflict of interest.

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DÜZELTME

Journal of Agriculture Dersisi 2023 yılı 6. cilt 2. Sayı'sında "Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions" başlıklı makale bir tezden üretilmiş olup, tezin eş danışmanı olan Prof. Dr. Rafet ASLANTAŞ 3. Yazar olarak, sorumlu yazar tarafından unutularak eklenmemiştir. Makale yazarları aşağıdaki şekilde düzeltilmiştir.

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Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions

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ERRATUM

The article titled "Polyphenol Oxidase Enzyme Activity of Mulberries Grown in Iğdir Ecological Conditions" in Volume 6, Issue 2 of the Journal of Agriculture Dersisi 2023 was produced from a thesis, and Prof. Dr. Rafet ASLANTAŞ, who is the co-advisor of the thesis, was not added as the 3rd author by the responsible author. The authors of the article have been corrected as follows.

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