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Fatsa'nın (Ordu, Türkiye) Yerel Kışlık Armutları*

Local Winter Pears of Fatsa District (Ordu, Türkiye)

Alev Yılmaz [1], **Saim Zeki Bostan** [2]

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Öz: Bu çalışmanın amacı Fatsa (Ordu) ilçesinde uzun yıllardır yetiştirlmekte olan yerel armut çeşitleri içerisinden ümitvar olan kışlık çeşitleri belirleyip pomolojik yönden tanımlamaktır. Önce ilçede kışlık yerel armut çeşitlerin bulunduğu yerler belirlenerek çalışmaya başlanmıştır. Bunun sonucunda 8 çeşit ve aynı isimle adlandırılmış fakat farklı özelliklere sahip olduğu görülen 30 genotip olmak üzere toplam 38 çeşit belirlenmiştir. Çalışmada önemli meyve ve yaprak pomolojik özellikleri değerlendirilmiştir. Bunun için meyvelerde fiziksel, kimyasal, görsel ve duyusal analizler ile yapraklarda fiziksel ölçümler yapılmıştır. Analiz ve değerlendirmeler meyve ağırlığının 45.1 g (Çörtük)-307.1 g (Kışlık 11), meyve eninin 44.3 mm (Çörtük)-84.9 mm (Kışlık 11), meyve boyunun 43.3 mm (Çörtük)-87.6 mm (Kışlık 12), pH değerinin 3.3 (Kışlık 19)-5.5 (Bal Armut 5), suda çözünür kuru maddenin %9.1 (Kışlık 13)-%12.8 (Hicucur) ve titre edilebilir asidin %1.3 (Bal Armut 4)-%13.6 (Benekli), yaprak eninin 35.9-59.5 mm, yaprak boyunun 45.3-83.3 mm, yaprak sapı uzunluğunun 22.5-65.7 mm ve yaprak sapı kalınlığının 0.5-1.2 mm arasında olduğunu ortaya koymuştur. Pomolojik özelliklere göre yapılan genel kalite değerlendirmesi, sırasıyla 'Kışlık 23', 'Kışlık 12', 'Bal Armut 3', 'Keş Armut', 'Hicucur' ve 'Susak Boğaz' yerel kışlık armut çeşitlerinin gelecekteki çeşit ıslahı çalışmalarında kullanılmaya değer olduğunu ortaya koymuştur.

Anahtar Kelimeler: *Pyrus communis*, Armut, Kışlık Çeşit, Yerel Çeşit, Pomoloji

&

Abstract: The aim of this study was to identify and pomologically describe the promising winter varieties among the local pear varieties that have been grown in Fatsa (province of Ordu, Türkiye) district for many years. Firstly, the study was started by determining the locations of winter local pear varieties in the district. As a result, a total of 38 varieties were identified, including 8 varieties and 30 genotypes named with the same name but with different characteristics. Important fruit and leaf pomological characteristics were evaluated in the study. For this purpose, physical, chemical, visual and sensory analyses were performed on the fruits and leaves. Analyses and evaluations revealed that fruit weight was 45.1 g (Çörtük)-307.1 g (Kışlık 11), fruit width was 44.3 mm (Çörtük)-84.9 mm (Kışlık 11), fruit length was 43.3 mm (Çörtük)-87.6 mm (Kışlık 12), pH value was 3. 3 (Kışlık 19)-5.5 (Bal Armut 5), soluble solid contents 9.1% (Kışlık 13)-12.8% (Hicucur) and titratable acid content 1.3% (Bal Armut 4)-13.6% (Benekli), leaf width 35.9-59.5 mm, leaf length 45.3-83.3 mm, petiole length 22.5-65.7 mm and petiole thickness 0.5-1.2 mm. The general quality evaluation according to pomological characteristics revealed that local winter pear varieties 'Kışlık 23', 'Kışlık 12', 'Bal Armut 3', 'Keş Armut', 'Hicucur' and 'Susak Boğaz' are worthy to be used in next variety breeding studies.

Keywords: *Pyrus communis*, Pear, Winter Variety, Local Variety, Pomology

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* Bu makale Alev YILMAZ'ın Yüksek Lisans Tezinden üretilmiştir.

GİRİŞ

Armut Rosaceae familyasının Maloideae (Pomoideae) alt familyası *Pyrus* cinsine ait olup Avrupa, ılıman Asya ve Kuzey Afrika'nın dağlık bölgelerinde dağılım gösteren, en az 26 yaygın olarak tanınan birincil tür ve 10 doğal olarak oluşan türler arası melez taksonu olan bir meyve türüdür. Armut ıslahı için potansiyel gen havuzundaki genetik erozyon riskini değerlendirmek için *Pyrus* türlerinin yabani popülasyonlarının mevcut dağılımı, durumu ve genetik çeşitliliği hakkında daha kapsamlı bilgiye ihtiyaç vardır. Ekonomik açıdan önemli özellikler için toplanan ve yerel germplazmı karakterize etme ve değerlendirme çabaları gibi, in situ ve ex situ koruma için daha fazla çaba gösterilmelidir. Hem germplazm zengini hem de germplazm eksikliği olan ülkelerin bakış açıları ve ihtiyaçları göz önünde bulundurularak daha fazla uluslararası iş birliği ve genetik kaynaklara erişim arzu edilen bir durumdur (Bell ve Itai, 2010). Dünya çapında yetiştirilen en önemli meyve türlerinden biri olan armudun 75-80 civarında türü bulunup bunlar içerisinde mevcut armut türleri arasında ayrım yapmayı zorlaştıran bazı melezler de bulunmaktadır. Bu karmaşıklığın ortadan kaldırılması ancak yapılacak araştırmalara bağlıdır. Dünyanın farklı ekolojilerinde meyve pomolojik özellikleri bakımından birbirinden oldukça farklı çok sayıda armut kültür çeşidi, yerel çeşit ve genotipleri mevcuttur. Özellikle bakir halde olanları henüz ıslah edilemediklerinden az sayıdaki kültür çeşidi ile üretim gerçekleştirilmektedir (Quinet ve Wesel, 2019).

Pyrus communis L. yüksek besin ve ekonomik değerine sahip önemli bir ılıman iklim meyvesidir (Draga vd., 2023). Armutlar, sağlığa faydaları bilinen önemli biyoaktif bileşikler olan fitokimyasalların, özellikle de fenoliklerin iyi bir kaynağı olup meyvenin anatomik kısımları önemli miktarda şeker, organik asit, polifenol ve triterpenoid içermektedir. Bunlar meyve kalitesinin korunmasında ve besleyici değerin belirlenmesinde önemli rol oynarlar (Kolniak-Ostek, 2016). Hatta bazı yerel çeşitlerin fenolik bileşiklerinin standart armut çeşitlerine göre daha zengin olduğu ve bu nedenle armut yetiştiriciliği açısından dikkate alınması gerektiği de belirtilmiştir (Öztürk vd., 2015).

Armut popülasyonundaki türlerin farklılığı ve dağılımları için yapılan incelemelerde çoğunlukla bölgeye ait envanter ve sayımları kullanılmaktadır. Popülasyonda kendiliğinden oluşan melezlemeler yoluyla çok sayıda türden türe gen aktarımı olmakta bu da türlerin ayırt edilmesini zorlaştırmaktadır. Bundan dolayı yabani armut türlerinin coğrafi dağılımını belirlemek güçleşmektedir. Kültür çeşitlerinin yabani akrabaları, ıslah programlarında stres faktörlerine karşı dayanım ya da tolerans için ümitvar gen kaynakları olabilirler (Volk ve Cornille, 2019). Popülasyondan böyle kaynakların toplanarak oluşturulduğu koleksiyonlar araştırma ve ıslah programlarının başarıya ulaşmasında ihtiyaç duyulan materyali içerebilirler. Doğal olarak bunu sağlamak için işe bu materyalleri sağlamakla başlamak gerekir. İşte bu amaçla yapılacak fenotipik ve genotipik tanımlamalar gen bankasına önemli katkı verebilecektir (Postman, 2019).

Yüksek kaliteli meyve, tüm yetiştirme programlarının temel hedefidir ve tat, doku, görünüm, sululuk, raf ömrü ve fizyolojik bozuklukların görülme sıklığı gibi çok çeşitli nitelikleri kapsar. En önemli nitelik, büyük ölçüde meyve tadı ve dokusuna bağlı olan gıda kalitesidir (da Silva vd., 2018). Avrupa armudu ıslahçıları, uzun hasat mevsiminin, kırmızı kabuk rengi, iyi meyve büyüklüğü, lezzet, gelişmiş dokusal özellikler, depolama yeteneği gibi meyve karakterlerini hedefleme eğilimindedir. Avrupa dışındaki ülkelerin bazı temel ıslah amaçlarına bakıldığında; uzun hasat mevsimi, en az üç ay gibi uzun bir depolama yeteneği, yüksek meyve kalitesi, erken olgunlaşma, iri meyve, hasatta ve depolamadan sonra yenilebilme, yüksek lezzet, yüksek verim, yüksek iç kalitesi, kırmızı kabuk rengi çeşitliliği, farklı şekil ve tat, lekesiz kabuk gibi amaçlar öne çıkmaktadır (Brewer ve Volz, 2019).

Önemli bir armut üreticisi olan ve köklü bir meyvecilik kültürüne sahip olan Türkiye çok farklı iklim ve toprak özelliklerinin görülmesi, göç yolları üzerinde bulunması, uzun yıllar tohumla çoğaltma alışkanlığı ve meyveciliğe olan yakın ilgi gibi nedenlerle birçok meyve türünde olduğu gibi armut için de çok değerli ve zengin gen kaynaklarına sahiptir. Dolayısıyla Türkiye hem kültür çeşitleri hem de bunların yabanileri açısından zengin bir gen varlığına sahiptir. Farklı coğrafyaları içeren bu varlık içerisinde hatırı sayılır düzeyde çalışmalar ve araştırmalar yürütülmüş olsa da güncel ıslah amaçları için gerekli olan gen kaynaklar henüz yeterli değildir.

Bu çalışma da gen kaynakları koleksiyonuna bir katkı sunmak hedefiyle bu bakımdan zengin bir tür ve çeşit popülasyonuna sahip bölgelerinden biri olan Karadeniz bölgesinde Ordu ili ilçelerinden biri olan Fatsa ilçesinde yerel kışlık armut çeşitlerinin ortaya çıkarılması ve pomolojik özellikleri yönünden tanımlanması amaçlanmıştır.

MATERYAL VE METOT

Bu çalışma Fatsa ilçesinde doğal popülasyonda belirlenmiş yerel armut çeşitlerinde 2018 ve 2019 yıllarında yürütülmüştür.

Çalışma öncesinde, Tarım ve Orman İlçe Müdürlüğü'nden yerel çeşitler ve bulundukları yerler ön bilgi alınarak konuda tecrübeli üreticilerle irtibata geçilmiş ve sonrasında arazi gezileri ile çalışma alanları belirlenmiştir. Buna göre araştırma 12 farklı lokasyonda yürütülmüştür (Şekil 1).

Şekil 1. Fatsa ilçesi mahalleleri ve çalışma alanları.
Figure 1. Fatsa district neighborhoods and study areas.

2018 yılında hasattan önce yapılan arazi gezilerinde yörede en fazla yetiştirilen 8 adet kışlık yerel armut çeşidi belirlenmiş fakat meyve özellikleri farklı olup da aynı isimle anılan bazı genotiplerin de olduğu fark edilmiş ve böylece çalışmaya toplamda 38 çeşit dahil edilmiştir. Bu çeşitler Bal, Benekli, Cöra, Çörtük, Hicucur, Keş, Susak Boğaz ve Kışlık olup Bal çeşidinde 5 ve Kışlık çeşidinde de 27 farklı çeşit belirlenmiştir. Aynı çeşitlere 1'den itibaren numaralandırma yapılmıştır.

2018 ve 2019 yıllarında belirlenen 38 çeşide ait ağaçlardan meyvelerin hasat olumunda ağacı temsil edecek şekilde alınan 20'şer meyve ve yaprak örneği pomolojik analizleri yapılmak üzere Ordu Üniversitesi Bahçe Bitkileri Bölümü laboratuvarına götürülmüş ve değerlendirmeler yapılmıştır.

Meyvelerde pomolojik analizlerden, fiziksel özellikler olarak, meyve ağırlığı (g), meyve eni (mm), meyve boyu (mm), meyve sapı uzunluğu (mm), meyve sapı kalınlığı (mm), meyve eti sertliği (kg cm^{-2}), meyve kabuğu kalınlığı (mm), karpel sayısı, çekirdek sayısı; kimyasal özellikler olarak, suda çözünür kuru madde miktarı, pH ve titreedilebilir asitlik; duyusal özellikler olarak, aroma, tat, meyve eti yapısı, meyve sululuk durumu ve yeme kalitesi; görsel analizler olarak, meyve kabuk rengi, meyve kabuğunun yüzey yapısı,

meyve kabuğunda paslılık durumu, meyve eti rengi ve dış kalite; yaprak özellikleri olarak, yaprak eni (mm), yaprak boyu (mm), yaprak sap uzunluğu (mm) ve yaprak sap kalınlığı (mm) belirlenmiştir.

Yerel kışlık armut çeşit ve genotiplerinde pomolojik özelliklerin belirlenmesinde UPOV (International Union for The Protection of New Varieties of Plants) (UPOV, 2000), Öztürk (2010) ve Çelikel Çubukçu (2015)'den yararlanılmıştır.

Meyve ağırlığı 0.01 g hassasiyetteki terazi ile (Radwag AS 220/C/2, Polonya), meyve ve yapraklardaki boyut ve kalınlık ölçümlerinde 0.01 mm'ye duyarlı dijital kumpas (Insize 150 mm 1102-150, Almanya), meyve eti sertliği ölçümünde 11.0 mm uçlu el penetrometresi (Effegi FT 327, İtalya), pH'nın belirlenmesinde masa tipi dijital pH metre (HI9321, Hanna, ABD) ve suda çözünür kuru madde miktarının belirlenmesinde de el refraktometresi (Greinorm 0-80 Brix, Almanya) kullanılmıştır. Titreedilebilir asitlik, titrasyon yöntemiyle belirlenmiş ve malik asit cinsinden hesaplanmıştır. Duyusal ve görsel analizler degüstasyon yöntemiyle yapılmıştır.

Her bir özelliğe ait sonuçlar iki yılın ortalaması olarak standart sapma değerleriyle birlikte hesaplanmıştır.

BULGULAR VE TARTIŞMA

Yerel kışlık armut çeşit ve genotiplerinde hasat tarihleri ilk yıl 16 Ekim-11 Kasım, ikinci yıl 19-23 Ekim tarihleri arasında değişim göstermiştir (Çizelge 1).

Çizelge 1. Yerel kışlık armut çeşitlerinin hasat tarihleri.
Table 1. Harvest dates of local winter pear varieties.

Çeşit	2018	2019	Çeşit	2018	2019
Bal armut 1	16.10.2018	23.10.2019	Kışlık 10	20.10.2018	20.10.2019
Bal armut 2	16.10.2018	23.10.2019	Kışlık 11	20.10.2018	20.10.2019
Bal armut 3	20.10.2018	23.10.2019	Kışlık 12	20.10.2018	20.10.2019
Bal armut 4	21.10.2018	23.10.2019	Kışlık 13	21.10.2018	20.10.2019
Bal armut 5	31.10.2018	23.10.2019	Kışlık 14	31.10.2018	20.10.2019
Benekli	11.11.2018	19.10.2019	Kışlık 15	31.10.2018	23.10.2019
Cöra	21.10.2018	19.10.2019	Kışlık 16	31.10.2018	20.10.2019
Çörtük	05.11.2018	19.10.2019	Kışlık 17	05.11.2018	20.10.2019
Hicucur	31.10.2018	19.10.2019	Kışlık 18	11.11.2018	20.10.2019
Keş armut	20.10.2018	19.10.2019	Kışlık 19	11.11.2018	20.10.2019
Kışlık 1	17.10.2018	19.10.2019	Kışlık 20	11.11.2018	20.10.2019
Kışlık 2	17.10.2018	19.10.2020	Kışlık 21	11.11.2018	20.10.2019
Kışlık 3	17.10.2018	19.10.2019	Kışlık 22	11.11.2018	20.10.2019
Kışlık 4	17.10.2018	20.10.2019	Kışlık 23	11.11.2018	23.10.2019
Kışlık 5	17.10.2018	20.10.2019	Kışlık 24	11.11.2018	20.10.2019
Kışlık 6	20.10.2018	20.10.2019	Kışlık 25	11.11.2018	20.10.2019
Kışlık 7	20.10.2018	20.10.2019	Kışlık 26	11.11.2018	20.10.2019
Kışlık 8	20.10.2018	20.10.2019	Kışlık 27	11.11.2018	20.10.2019
Kışlık 9	20.10.2018	20.10.2019	Susak Boğaz	21.10.2018	19.10.2019

İncelenen bütün yerel kışlık armut çeşitlerinde karpel sayısı 5 olarak belirlenmiş olup meyve pomolojik özelliklerine ait ortalama değerler belirlenmiştir (Çizelge 2).

Bütün çeşitlerin ortalaması olarak meyve ağırlığı, meyve eni, meyve boyu, meyve sapı uzunluğu, meyve eti sertliği ve çekirdek sayısı, sırasıyla 176.1 g, 67.8 mm, 74.3 mm, 31.8 mm, 4.9 kg cm^{-2} ve 9.7 olmuştur. Çeşitler içerisinde Kışlık 11 en ağır, Çörtük de en hafif meyveli bulunmuştur. İncelenen pomolojik özelliklerden, meyve ağırlığı 45.1 (Çörtük)-307.1 g (Kışlık 11), meyve eni 44.3 mm (Çörtük)-84.9-4.1 mm (Kışlık 11), meyve boyu 43.3 (Çörtük)-87.6 mm (Kışlık 12), meyve sapı uzunluğu 19.8 (Kışlık 5)-46.0 mm (Hicucur), ve meyve eti sertliği 2.8 (Susak Boğaz)-7.3 kg cm^{-2} (Kışlık 6) arasında değişim göstermiştir. Ortalama çekirdek sayısı ise 8.3-10 arasında değişirken, 7 çeşit 10 çekirdek, 17 çeşit 9.0-9.9 arasında ve 3 çeşit 8.3-8.9 arasında ortalama çekirdek sayısına sahip bulunmuştur (Çizelge 2).

Bütün çeşitlerin ortalaması olarak suda çözünür kuru madde oranı %10.3, pH 3.9 ve titreedilebilir asitlik %8.3 bulunmuştur. Çeşitler içerisinde en yüksek suda çözünür kuru madde oranına Hicucur sahip

olmuştur. Suda çözünmüş kuru madde %9.1 (Kışlık 13)-12.8 (Hicucur), pH 3.3 (Kışlık 19)-5.5 (Bal Armut 5) ve titreedilebilir asitlik %1.3 (Bal Armut 4)-13.6 (Benekli) arasında değişim göstermiştir. 13 çeşitte suda çözünür kuru madde değeri ortalama değerden (%10.3) daha az, 25 çeşitte %10.3 ve üzerinde; pH değeri 23 çeşitte ortalama değerden (3.9) daha düşük, 15 çeşitte 3.9 ve üzerinde ve titreedilebilir asitlik değeri de 15 çeşitte ortalama değerden (%8.3) küçük, 23 çeşitte %8.3 ve üzerinde bulunmuştur (Çizelge 2).

Çizelge 2. Yerel kışlık armut çeşitlerinin pomolojik özellikleri.
Table 2. Fruit characteristics of local winter pear varieties.

Çeşit	MA	ME	MB	MSU	MES	ÇS	SÇKM	pH	TA
Bal armut 1	101.6±23.6	57.0±4.0	66.8±6.9	25.6±6.7	4.7±1.7	10.0±0.0	12.4±0.5	5.1±0.1	4.1±1.2
Bal armut 2	206.0±46.0	71.1±5.8	77.5±9.7	33.7±9.9	3.7±2.2	10.0±0.0	10.8±2.5	4.3±0.2	6.1±0.4
Bal armut 3	164.6±31.9	68.7±5.2	68.2±6.5	39.3±9.2	5.3±1.5	10.0±0.0	11.6±0.9	4.9±0.1	2.2±0.0
Bal armut 4	134.0±35.7	63.4±6.2	74.3±5.1	26.5±4.6	4.2±1.2	9.7±0.7	11.9±0.6	5.3±0.6	1.3±0.1
Bal armut 5	77.2±19.0	52.7±5.0	56.9±7.1	27.6±6.5	3.5±1.2	9.4±1.4	11.8±0.6	5.5±0.3	1.5±0.1
Benekli	226.6±53.4	73.5±6.5	82.2±7.8	36.6±5.7	6.7±2.5	9.6±0.8	10.2±0.7	3.6±0.0	13.6±0.5
Cöra	117.9±30.2	60.1±4.1	68.4±8.3	23.6±3.4	5.5±0.6	9.5±1.4	9.4±2.1	3.7±0.2	6.9±0.5
Çörtük	45.1±16.4	44.3±5.4	43.3±6.7	38.4±4.8	5.9±2.2	10.0±0.0	10.4±2.5	4.1±1.1	8.5±4.3
Hicucur	138.2±25.2	65.1±5.5	63.7±4.0	46.0±7.6	5.1±0.8	9.4±1.1	12.8±0.3	4.3±0.7	2.7±0.1
Keş armut	173.1±37.3	66.3±5.9	74.2±7.3	20.9±4.3	4.6±1.3	9.6±1.9	10.6±1.1	3.8±0.1	5.8±0.1
Kışlık 1	126.1±71.7	59.1±11.4	71.5±12.9	31.1±3.9	5.2±1.7	9.7±1.4	12.7±2.3	3.6±0.3	11.6±0.5
Kışlık 2	121.7±20.9	57.9±5.8	81.7±9.6	25.9±5.7	3.4±0.6	10.0±0.0	12.2±0.5	3.8±0.2	9.1±0.2
Kışlık 3	172.2±82.9	69.5±8.6	63.9±9.4	22.6±3.8	6.0±1.2	8.9±2.9	11.0±1.4	3.8±0.1	8.0±1.4
Kışlık 4	244.6±59.9	76.6±6.8	81.2±10.3	21.6±6.8	5.6±0.8	8.3±2.5	11.2±0.3	3.9±0.1	10.6±2.3
Kışlık 5	196.8±78.8	71.9±9.9	74.2±11.1	19.8±3.8	5.5±0.7	9.8±0.7	12.7±0.8	3.8±0.2	11.3±1.7
Kışlık 6	98.5±23.4	57.2±5.8	65.0±5.7	34.2±4.2	7.3±1.2	9.9±0.4	11.0±0.3	3.5±0.0	11.8±3.0
Kışlık 7	150.6±30.6	64.6±5.3	69.8±8.7	32.1±14.6	5.5±0.9	9.7±1.0	9.6±1.1	3.8±0.2	11.1±2.7
Kışlık 8	179.5±48.2	68.5±7.0	75.9±6.6	36.7±8.1	6.1±1.1	9.9±0.5	9.3±1.4	3.4±0.1	11.0±0.2
Kışlık 9	173.5±36.7	68.6±6.2	75.0±6.3	36.2±7.6	6.0±1.3	9.8±0.6	10.2±0.1	3.6±0.2	11.0±1.1
Kışlık 10	179.8±56.9	69.6±7.3	69.7±11.2	22.6±2.8	6.9±1.9	10.0±0.0	10.2±3.3	3.9±0.1	8.4±0.3
Kışlık 11	307.1±27.9	84.9±4.1	81.2±5.6	30.8±4.7	4.3±0.8	9.7±1.3	12.7±0.2	3.9±1.0	10.0±9.3
Kışlık 12	289.0±80.1	79.0±8.3	87.6±12.8	26.9±8.8	4.6±2.5	10.0±0.0	10.2±1.3	4.2±0.4	6.5±1.8
Kışlık 13	125.2±39.6	61.9±6.9	65.8±8.3	22.2±3.3	4.7±0.9	9.5±1.3	9.1±0.1	4.0±0.1	5.8±0.8
Kışlık 14	210.9±43.1	76.2±10.0	80.3±7.2	37.7±6.7	4.3±2.1	9.0±1.5	11.1±0.1	3.4±0.1	11.4±0.0
Kışlık 15	147.6±26.2	65.1±6.0	73.4±5.9	32.8±3.4	4.7±1.4	9.9±0.5	9.4±2.2	3.7±0.2	9.5±1.0
Kışlık 16	189.6±50.7	69.7±6.1	78.9±8.1	30.8±6.2	4.4±1.2	9.7±1.0	9.6±0.2	3.7±0.0	12.1±0.4
Kışlık 17	216.1±48.1	73.5±6.1	80.6±6.0	35.8±5.2	5.3±1.4	8.8±1.9	11.0±0.7	3.6±0.2	11.1±0.7
Kışlık 18	216.7±67.2	73.6±8.8	79.5±8.8	34.8±4.2	4.3±1.1	9.9±0.4	12.7±0.7	3.6±0.2	11.2±1.8
Kışlık 19	207.2±34.6	74.5±4.3	75.4±6.1	31.3±3.1	3.5±1.2	9.6±1.0	11.7±1.9	3.3±0.5	11.5±1.1
Kışlık 20	135.5±20.4	63.0±4.9	71.0±6.3	40.8±6.4	5.0±1.0	10.0±0.0	9.6±1.3	3.5±0.5	8.8±1.8
Kışlık 21	204.8±50.4	71.6±7.1	81.2±7.8	34.0±6.3	4.6±1.6	10.0±0.0	10.3±0.6	3.6±0.2	9.0±0.2
Kışlık 22	200.7±26.9	71.9±3.7	80.6±5.4	36.9±4.9	4.9±1.6	9.6±1.8	11.7±1.2	3.5±0.4	8.2±2.6
Kışlık 23	267.2±44.0	81.4±5.1	86.5±4.3	36.4±6.5	3.9±0.9	10.0±0.0	10.4±0.6	3.6±0.1	7.6±0.3
Kışlık 24	187.4±48.9	70.3±7.8	75.7±7.6	36.6±4.3	3.7±0.9	9.8±0.6	9.8±1.8	3.9±0.4	10.0±0.1
Kışlık 25	161.9±22.0	65.7±3.3	76.0±6.1	38.7±6.1	4.4±1.6	9.9±0.4	10.6±1.8	3.4±0.6	8.7±0.4
Kışlık 26	229.4±63.5	73.6±7.5	81.0±7.5	38.2±7.2	3.6±1.6	9.9±0.4	11.2±1.1	3.5±0.3	10.0±0.5
Kışlık 27	191.2±35.8	68.6±5.4	81.4±7.8	34.9±5.4	6.9±1.1	10.0±0.0	9.3±0.1	4.0±0.1	6.4±0.1
Susak Boğaz	174.8±54.8	67.9±9.6	85.5±9.6	25.9±10.5	2.8±1.8	9.9±0.5	10.6±2.2	4.7±0.2	2.4±0.4

MA : Meyve ağırlığı (g)
ME : Meyve eni (mm)
MB : Meyve boyu (mm)
MSU : Meyve sapı uzunluğu (mm)
MSK : Meyve sapı kalınlığı (mm)
MES : Meyve eti sertliği (kg cm^{-2})
MKK : Meyve kabuğu kalınlığı (mm)
ÇS : Çekirdek sayısı
SÇKM : Suda çözünür kuru madde (%)
TA : Titreedilebilir asitlik (%)

Görsel analizlerde, çeşitlerin meyve kabuk renklerinde 3 farklı grubun oluştuğu ve bunlardan en fazla "yeşilimsi sarı" rengin 20 çeşitte, "yeşil" rengin 16 çeşitte ve "sarı" rengin 2 çeşitte görüldüğü belirlenmiştir. Meyvelerin yüzey yapısı bakımından en fazla çeşit sayısı "düz" grupta 25 çeşitle, sonra "pürüzlü" grupta 10 çeşitle ve en az "girintili-çıkıntılı" grupta 3 çeşitle temsil edilmiştir. Meyve kabuğunda paslılık özelliği, sırasıyla 12 çeşitte "orta", 10 çeşitte "çok", 8'er çeşitte de "az" ve "yok veya çok az" olarak gözlemlenmiştir. Meyve et rengi incelendiğinde, 31 çeşidin "krem" renkli grubu, 6 çeşidin "beyaz" renkli grubu ve 1 çeşidin de "krem-beyaz" renkli grubu temsil ettiği belirlenmiştir. Yani çeşitlerin nerdeyse tamamı "krem" renkli

meyve etine sahip olmuştur. Meyvenin albenisi bakımından önemli bir kriter olan dış kalite 18 çeşitte "iyi", 17 çeşitte "orta", 2 çeşitte "kötü" ve 1 çeşitte de "çok iyi" özellik kazanmıştır (Çizelge 3).

Çizelge 3. Yerel kışlık armut çeşitlerinin görsel özellikleri.
Table 3. Visual characteristics of local winter pear cultivars.

Çeşit	MKR	MYY	MKP	MER	DK
Bal armut 1	Yeşil	Pürüzlü	Orta	Krem	Orta
Bal armut 2	Yeşilimsi Sarı	Düz	Orta	Krem-Beyaz	İyi
Bal armut 3	Yeşil	Düz	Orta	Krem	İyi
Bal armut 4	Yeşilimsi Sarı	Pürüzlü	Orta	Krem	Orta
Bal armut 5	Yeşilimsi Sarı	Düz	Az	Krem	Orta
Benekli	Yeşilimsi Sarı	Düz	Orta	Krem	İyi
Cöra	Yeşilimsi Sarı	Pürüzlü	Çok	Krem	Orta
Çörtük	Yeşilimsi Sarı	Düz	Orta	Krem	Orta
Hicucur	Yeşilimsi Sarı	Düz	Az	Krem	İyi
Keş armut	Yeşilimsi Sarı	Girintili Çıkıntılı	Çok	Krem	Kötü
Kışlık 1	Yeşil	Pürüzlü	Orta	Krem	Orta
Kışlık 2	Yeşilimsi Sarı	Pürüzlü	Çok	Beyaz	Orta
Kışlık 3	Yeşilimsi Sarı	Girintili Çıkıntılı	Yok-Çok Az	Beyaz	Kötü
Kışlık 4	Sarı	Pürüzlü	Çok	Beyaz	Orta
Kışlık 5	Yeşilimsi Sarı	Pürüzlü	Çok	Beyaz	Orta
Kışlık 6	Yeşil	Düz	Yok-Çok Az	Krem	Orta
Kışlık 7	Yeşil	Düz	Yok-Çok Az	Krem	İyi
Kışlık 8	Yeşil	Düz	Yok-Çok Az	Krem	İyi
Kışlık 9	Yeşil	Pürüzlü	Çok	Krem	Orta
Kışlık 10	Yeşilimsi Sarı	Pürüzlü	Az	Krem	İyi
Kışlık 11	Yeşilimsi Sarı	Düz	Yok-Çok Az	Krem	İyi
Kışlık 12	Yeşilimsi Sarı	Girintili Çıkıntılı	Çok	Beyaz	Orta
Kışlık 13	Yeşilimsi Sarı	Düz	Çok	Krem	Orta
Kışlık 14	Yeşilimsi Sarı	Düz	Orta	Krem	İyi
Kışlık 15	Yeşil	Düz	Orta	Krem	İyi
Kışlık 16	Yeşil	Düz	Az	Krem	İyi
Kışlık 17	Yeşil	Düz	Az	Krem	İyi
Kışlık 18	Yeşil	Düz	Orta	Krem	Orta
Kışlık 19	Yeşil	Düz	Yok-Çok Az	Krem	İyi
Kışlık 20	Yeşilimsi Sarı	Düz	Az	Krem	Orta
Kışlık 21	Yeşilimsi Sarı	Düz	Orta	Krem	İyi
Kışlık 22	Yeşil	Düz	Yok-Çok Az	Krem	İyi
Kışlık 23	Yeşil	Düz	Az	Krem	Çok İyi
Kışlık 24	Yeşil	Düz	Çok	Krem	Orta
Kışlık 25	Yeşil	Pürüzlü	Çok	Krem	Orta
Kışlık 26	Yeşilimsi Sarı	Düz	Orta	Krem	İyi
Kışlık 27	Yeşilimsi Sarı	Düz	Az	Krem	İyi
Susak Boğaz	Sarı	Düz	Yok-Çok Az	Beyaz	İyi

MKR : Meyve kabuk rengi
MYY : Meyve yüzey yapısı
MKP : Meyve kabuğunda paslılık
MER : Meyve et rengi
DK : Dış kalite

Duyusal analiz sonucunda, yerel kışlık çeşitleri tat bakımından 5 gruba ayrılarak, 1 tanesi "çok tatlı", 7 tanesi "tatlı", 13 tanesi "az tatlı", 1 tanesi "tatsız" ve 16 tanesi "ekşimsi"; aroma bakımından 3 gruba ayrılarak, 20 tanesi "iyi", 16 tanesi "orta" ve 2 tanesi "kötü"; meyve et yapısı bakımından 3 gruba ayrılarak, 6 tanesinde "iyi", 16 tanesinde "orta" ve 16 tanesinde "kumlu"; meyve sululuk durumu bakımından 4 gruba ayrılarak, 8 tanesinde "çok sulu", 24 tanesinde "sulu", 5 tanesinde "orta sulu" ve 1 tanesinde de "az sulu" ve yeme kalitesi bakımından 3 gruba ayrılarak, 1 çeşitte "çok iyi", 26 çeşitte "iyi" ve 11 çeşitte "orta" olarak değerlendirilmiştir (Çizelge 4).

Çizelge 4. Yerel kışlık armut çeşitlerinin görsel özellikleri.
Table 4. Sensory characteristics of local winter pear cultivars.

Çeşit	T	A	MEY	MSD	YK	Çeşit	T	A	MES	MSD	YK
Bal armut 1	Az Tatlı	Orta	İyi	Sulu	İyi	Kışlık 10	Ekşimsi	Orta	Orta	Çok Sulu	İyi
Bal armut 2	Ekşimsi	İyi	Orta	Sulu	Çok İyi	Kışlık 11	Ekşimsi	İyi	Orta	Sulu	İyi
Bal armut 3	Tatlı	Orta	Orta	Sulu	İyi	Kışlık 12	Az Tatlı	Orta	İyi	Çok Sulu	İyi
Bal armut 4	Çok Tatlı	İyi	Orta	Sulu	İyi	Kışlık 13	Az Tatlı	Orta	Orta	Sulu	İyi
Bal armut 5	Tatlı	Orta	Orta	Orta Sulu	Orta	Kışlık 14	Ekşimsi	İyi	Kumlu	Çok Sulu	İyi
Benekli	Ekşimsi	İyi	Orta	Çok Sulu	İyi	Kışlık 15	Ekşimsi	İyi	Kumlu	Sulu	İyi
Cöra	Az Tatlı	Orta	Kumlu	Orta Sulu	Orta	Kışlık 16	Az Tatlı	İyi	Orta	Sulu	İyi
Çörtük	Tatlı	Orta	İyi	Orta Sulu	İyi	Kışlık 17	Az Tatlı	İyi	Orta	Sulu	İyi
Hicucur	Tatlı	İyi	Kumlu	Sulu	İyi	Kışlık 18	Ekşimsi	Orta	Kumlu	Sulu	İyi
Keş armut	Tatlı	İyi	Orta	Çok Sulu	İyi	Kışlık 19	Az Tatlı	İyi	İyi	Çok Sulu	İyi
Kışlık 1	Ekşimsi	Orta	İyi	Çok Sulu	Orta	Kışlık 20	Ekşimsi	Orta	Orta	Sulu	İyi
Kışlık 2	Tatlı	İyi	Orta	Sulu	İyi	Kışlık 21	Ekşimsi	İyi	Orta	Sulu	İyi
Kışlık 3	Az Tatlı	Orta	Kumlu	Sulu	İyi	Kışlık 22	Ekşimsi	İyi	Kumlu	Sulu	Orta
Kışlık 4	Ekşimsi	İyi	Kumlu	Sulu	Orta	Kışlık 23	Az Tatlı	İyi	Kumlu	Sulu	İyi
Kışlık 5	Az Tatlı	Orta	Kumlu	Sulu	Orta	Kışlık 24	Az Tatlı	İyi	Kumlu	Sulu	Orta
Kışlık 6	Az Tatlı	Kötü	Kumlu	Az Sulu	Orta	Kışlık 25	Ekşimsi	İyi	Orta	Sulu	İyi
Kışlık 7	Ekşimsi	Kötü	Kumlu	Orta Sulu	Orta	Kışlık 26	Tatsız	Orta	Kumlu	Sulu	Orta
Kışlık 8	Ekşimsi	İyi	Orta	Sulu	İyi	Kışlık 27	Ekşimsi	Orta	Kumlu	Çok Sulu	İyi
Kışlık 9	Az Tatlı	Orta	Kumlu	Orta Sulu	Orta	Susak Boğaz	Tatlı	İyi	İyi	Sulu	İyi

T : Tat
A : Aroma
MEY : Meyve et yapısı
MSD : Meyve sululuk durumu
YK : Yeme kalitesi

Yaprak ölçümleri yaprak eninin çeşitlere göre 35.9-59.5 mm, yaprak boyunun 45.3-83.3 mm, yaprak sapı uzunluğunun 22.5-65.7 mm ve yaprak sapı kalınlığının 0.5-1.2 mm arasında olduğunu ortaya koymuştur (Çizelge 5).

Çizelge 5. Yerel kışlık armut çeşitlerinin yaprak özellikleri.
Table 5. Leaf characteristics of local winter pear varieties.

Çeşit	YE (mm)	YB (mm)	YSU (mm)	YSK (mm)	Çeşit	YE (mm)	YB (mm)	YSU (mm)	YSK (mm)
Bal armut 1	38.0±7.0	56.0±10.5	40.6±13.9	0.7±0.1	Kışlık 10	35.9±4.8	55.3±5.3	34.9±5.6	0.7±0.1
Bal armut 2	43.4±7.6	71.0±16.7	37.6±7.4	0.8±0.3	Kışlık 11	59.5±6.8	74.6±6.8	51.2±10.0	0.6±0.1
Bal armut 3	45.9±6.5	68.4±10.4	42.5±8.6	0.7±0.1	Kışlık 12	43.1±14.6	60.7±18.5	35.2±16.2	1.0±0.3
Bal armut 4	44.5±6.9	54.6±9.2	31.7±7.3	0.9±0.1	Kışlık 13	41.6±7.8	51.0±7.8	36.5±10.1	0.9±0.3
Bal armut 5	42.7±7.9	53.6±6.9	36.0±9.8	0.7±0.1	Kışlık 14	54.1±10.6	75.1±10.9	54.6±12.6	1.0±0.1
Benekli	57.6±7.2	83.3±7.2	65.7±14.5	1.2±0.1	Kışlık 15	39.3±11.5	59.5±11.0	38.7±11.9	0.7±0.1
Cöra	39.0±5.5	61.8±10.6	31.2±6.5	0.9±0.1	Kışlık 16	42.2±5.7	60.5±9.6	45.9±11.4	0.6±0.1
Çörtük	42.8±7.6	61.0±10.9	33.1±9.8	0.8±0.1	Kışlık 17	50.4±6.9	67.2±14.0	44.6±14.3	1.0±0.2
Hicucur	54.1±6.2	70.0±5.6	53.1±11.9	0.9±0.1	Kışlık 18	46.3±9.6	64.9±11.5	38.0±15.4	0.9±0.1
Keş armut	38.7±7.7	66.4±11.8	38.0±8.6	0.9±0.2	Kışlık 19	45.5±11.2	65.1±15.0	39.6±14.7	0.8±0.2
Kışlık 1	43.5±7.5	52.7±9.9	33.4±14.0	0.7±0.2	Kışlık 20	41.3±7.6	67.7±7.4	22.5±4.9	1.0±0.1
Kışlık 2	35.9±5.2	45.3±9.3	30.3±13.1	0.5±0.1	Kışlık 21	46.1±9.1	68.8±6.6	46.5±11.7	0.9±0.2
Kışlık 3	47.9±8.1	66.1±9.8	41.1±12.6	0.7±0.2	Kışlık 22	50.8±4.9	66.4±8.6	51.5±11.7	1.0±0.2
Kışlık 4	45.3±4.7	72.6±11.1	43.5±13.2	1.0±0.3	Kışlık 23	48.5±5.2	66.4±7.4	41.0±10.0	0.8±0.2
Kışlık 5	39.8±3.4	60.6±9.1	45.4±9.7	0.6±0.1	Kışlık 24	44.1±9.9	64.1±19.5	30.9±15.4	0.9±0.2
Kışlık 6	49.3±10.6	64.3±15.3	36.8±11.5	0.7±0.1	Kışlık 25	49.3±4.5	68.6±7.9	47.9±7.4	1.0±0.2
Kışlık 7	48.8±7.0	61.3±9.8	44.2±10.4	0.6±0.1	Kışlık 26	46.3±8.5	66.8±10.0	42.0±11.2	0.7±0.2
Kışlık 8	46.5±7.8	66.2±9.4	36.3±8.6	0.7±0.2	Kışlık 27	55.6±6.7	74.4±9.1	39.1±8.2	1.1±0.1
Kışlık 9	47.9±9.6	65.9±13.2	28.7±8.0	1.0±0.3	Susak Boğaz	46.5±6.5	71.0±12.5	40.2±10.8	0.8±0.1

YE : Yaprak eni
YB : Yaprak boyu
YSU : Yaprak sapı uzunluğu
YSK : Yaprak sapı kalınlığı

Türkiye dünyada önemli üretici ülkelerden birisi olsa da uluslararası pazarların aradığı kalite, verim ve uzun hasat sezonu için çeşit sayısı yeterli düzeyde değildir. Her ne kadar son yıllarda modern yetiştiricilik kapsamında kapama bahçeler oluşturulmuş olsa da bir kısım üretim insanların kendi ya da yöresel ihtiyaçları karşılayacak düzeyde düzensiz bahçelerde bulunan yerel çeşitlerden sağlanmaktadır. Yerel çeşitler bir taraftan meyve ıslahçılarının ilgisini çekerken bunlarla yapılan düzensiz üretim ülkenin

uluslararası ticaret bakımından çok kabul görmemektedir. Bu yüzden yerel çeşitlerimizden standart çeşit olabilecek adayların bir an evvel ortaya çıkarılması ve çeşit standardizasyonuna gidilmesi hem uluslararası pazarlarda rekabet gücümüze katkı sağlayacak hem de değerli gen kaynaklarının yok olmasının önüne geçilmiş olunacaktır.

Türkiye'de hem üretici seleksiyonları hem düzenli ıslah çalışmaları hem de pomolojik incelemeler uzun yıllar önce başlatılmış ve halen devam etmektedir. Bu çalışmalar sonucunda birçok yerel armut çeşitleri ıslah edilerek korunmaya alınmıştır. Bunlardan bazıları ıslah çalışmalarına materyal olarak sunulurken bazılarına da standart çeşit özelliği kazandırılmıştır. Özellikle son 15 yılda ülkemizin farklı coğrafyalarında yürütülmüş çalışmalar ıslah materyali zenginliğini de artırmıştır (Bostan, 2009; Yakut ve Özrenk, 2009; Özkaplan, 2010; Özrenk vd., 2010; Öztürk, 2010; Uzunismail, 2010; Çiftçi vd., 2011; Karadeniz ve Çorumlu, 2012; Bostan ve Acar, 2012; Öz, 2012; Öztürk ve Demirsoy, 2013; Öz ve Aslantaş, 2015; Az, 2015; Bağbozan, 2015; Gültekin, 2015; Bostan ve Çelikel-Çubukçu, 2016; Ertaş, 2016; Kılıç ve Bostan, 2016; Orman ve Yarılgaç, 2016; Yiğit Büyük ve Pırlak, 2016; Cevahir ve Bostan, 2017; Oturmak vd., 2017; Polat ve Bağbozan, 2017; Akın ve Bostan, 2018; Bayındır vd., 2018; Cevahir ve Bostan, 2018; Çelikel-Çubukçu ve Bostan, 2018; Kalkisim vd., 2018; Sağır ve Aygün, 2018; Balta vd., 2019; Bayındır vd., 2019a; Bayındır vd., 2019b; Yayla, 2019; Karakaya vd., 2020; Turalı, 2020; Bostan ve Top, 2021; Kalkışım vd., 2021; Gerçekcioğlu ve Adıbelli, 2023).

Fatsa'da yerel çeşitlerle armut yetiştiriciliği çok eskilere dayanmakta olup bunlar kökeni kesin olarak bilinmeyen önemli gen kaynaklarıdır. Zamanla üreticiler arasında aşı gözü ya da aşı kalemi alınarak ya da doğrudan birbirlerinden fidan temin edilerek yetiştiricilik yörede yaygınlaşmış ve bu sayede dolaylı olarak da üretici seleksiyonu yapılmış ve bugüne kadar gelmiştir. Fakat bu çeşitlerle yapılan yetiştiricilik modern kapama bahçeler şeklinde olmayıp bahçelerde münferit halde özellikle de fındık bahçeleri içerisinde, arazi sınırlarında, evlerin çevresinde, yol kenarlarında bulunmakta ve bunlarda bakım işlemleri yapılmamaktadır. Bu çeşitlere ait meyvelerden bir kısmı sofralık olarak aile ihtiyacında değerlendirilebildiği gibi gösterişli olanları semt pazarlarında satılabilmektedir. Albenisi düşük olanların bir kısmı da işlenerek, pekmez, pestil ve reçel gibi ürünlere dönüştürülmektedir.

Çalışmamızda armutta ıslah amaçlarında da öne çıkan özelliklerden meyve ağırlığı, irilik, albeni, et yapısı, hasat sonu ömrü ve tüketim şekilleri yönünden yerel kışlık armut çeşitleri değerlendirilmiştir.

Buna göre 'Kışlık' çeşidi hem yöredeki pazarlarda satılabilmekte hem aile tüketiminde değerlendirilmekte hem de pekmezi yapılabilmekte olup meyveleri de şubata kadar adi koşullarda muhafaza edilebilmektedir. Araştırmamızda 'Kışlık' çeşit içerisinden 'Kışlık 23' çeşidinin dış kalite, irilik ve meyve yüzeyi bakımından; 'Kışlık 12' çeşidinin irilik, sululuk, yeme kalitesi ve meyve eti yapısı bakımından öne çıktığı görülmüştür.

Yörede 'Bal Armut' çeşitleri 'Kışlık' çeşitler gibi değerlendirilmekte olup en fazla bir ay süreyle saklanabilmektedir. Bu grupta 'Bal Armut 3' çeşidi tat, tat, meyve yüzeyi, sululuk, yeme kalitesi ve dış kalite bakımından dikkat çekmekte fakat iç kararmasına karşı hassasiyet göstermektedir. Bu arada bu durum bazı tüketiciler tarafından arzu edilmektedir.

Çok sulu olması ve tadı yeme kalitesi iyi olmasıyla öne çıkan 'Keş Armut' çeşidinin meyvelerinin içleri hasatta sonra iki haftaya kadar kararmakta olup bu da 'Kışlık' ve 'Bal Armut 3' gibi değerlendirilmekte ve tüketilmektedir.

Yöre halkınca şekli ve tadı yönüyle çok tutulan 'Hicucur' ve 'Susak Boğaz' çeşitleri düzgün bir meyve yüzeyine, iyi dış kaliteye, yeme kalitesine ve tada sahip olup sulu çeşitlerdir. Reçeli de yapılabilen 'Hicucur' çeşidi şubata kadar adi şartlarda muhafaza edilebilirken, 'Susak Boğaz' en fazla 30 güne kadar dayanabilmektedir. Fakat bu çeşit semt pazarlarında en fazla görülen çeşittir.

SONUÇ

Kontrolsüz koşullarda ve kültürel uygulamalardan mahrum çeşitlerle ilgili yapılan bu çalışma öncelikle değerli kaynakların ortaya çıkarılması bakımından yararlı olmuştur. Bu haliyle ön çalışma niteliği taşımaktadır. Dolayısıyla gelecekteki ıslah çalışmaları için değerlendirilebilir.

Değerlendirmelerimize göre, 'Kışlık 23', 'Kışlık 12', 'Bal Armut 3', 'Keş Armut', 'Hicucur' ve 'Susak Boğaz' çeşitlerinin gelecek vadettiği ve hem yöre hem bölge ve hem de ülke armut çeşitliliğine katkı sunabilme potansiyelleri bakımından standartlaştırma konusunda çalışmalara başlanılması önerilebilir.

ÇIKAR ÇATIŞMASI

Yazarlar çalışma konusunda herhangi bir çıkar çatışması olmadığını beyan ederler.

YAZAR KATKISI

Yazarların makaleye katkısı eşit düzeydedir.

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Kivi Odun Çeliklerinin Köklenmesi Üzerine IBA ve Putresin Uygulamalarının Etkisi

The Effect of IBA and Putrescine Treatments on Rooting of Kiwifruit Hardwood Cuttings

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Öz: Bu çalışma, Hayward kivi çeşidine ait odun çeliklerinin köklenmesi üzerine farklı indol bütirik asit (IBA) ve putresin (Put) dozları ve onların kombine etkisini belirlemek amacıyla yürütülmüştür. Uygulamalara bağlı olarak, canlı çelik oranı %70.1 (2000 ppm IBA) ile %93.3 (2000 ppm IBA+800 ppm Put), köklenme oranı %33.3 (2000 ppm IBA) ile %76.8 (4000 ppm IBA), kalluslanma oranı tüm uygulamalarda %100 olarak tespit edilmiştir. Kök sayısı 1.4 (Kontrol) ile 4.7 (2000 ppm IBA ve 4000 ppm IBA), kök uzunluğu 17.9 mm (2000 ppm IBA) ile 35.5 mm (4000 ppm IBA+800 ppm Put), kök çapı 0.83 mm (4000 ppm IBA+800 ppm Put) ile 1.03 mm (Kontrol) ve köklenme düzeyi 1.0 (Kontrol) ile 2.4 (4000 ppm IBA+800 ppm Put) arasında belirlenmiştir. Sürgün sayısı ve yaprak sayısı bakımından uygulamalar arasındaki önemli farklılıklar bulunmamıştır. Çalışma sonucunda, 4000 ppm IBA uygulamasının kivi odun çeliklerinde köklenme üzerine önemli bir etkisi belirlenmiştir. Bunun yanında Put uygulaması ise köklenme özelliklerini, özellikle kök uzunluğu ve köklenme kalitesini önemli düzeyde teşvik etmiştir.

Anahtar kelimeler: Kivi, Köklenme, Kalluslanma, Kök Uzunluğu, Köklenme Düzeyi

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Abstract: This study was carried out to determine the effects of different indole butyric acid (IBA) and putrescine (Put) doses and their combined effects on rooting of hardwood cuttings of Hayward kiwifruit cultivar. Depending on the treatments, live cutting ratio was 70.1% (2000 ppm IBA) and 93.3% (2000 ppm IBA+800 ppm Put), rooting ratio was 33.3% (2000 ppm IBA) and 76.8% (4000 ppm IBA), callus ratio was 100% in all treatments. Root number was determined between 1.4 (Control) and 4.7 (2000 ppm IBA and 4000 ppm IBA), root length was determined between 17.9 mm (2000 ppm IBA) and 35.5 mm (4000 ppm IBA+800 ppm Put), root diameter was determined between 0.83 mm (4000 ppm IBA+800 ppm Put) and 1.03 mm (Control) and rooting level was determined between 1.0 (Control) and 2.4 (4000 ppm IBA+800 ppm Put). No significant differences were found among the treatments in terms of shoot number and leaf number. As a result of the study, it was determined that 4000 ppm IBA treatment had a significant effect on rooting in kiwifruit hardwood cuttings. In addition, Put treatment promoted rooting characteristics, especially root length and rooting quality, at a significant level.

Keywords: Kiwifruit, Rooting, Callusing, Root Length, Rooting Level

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GİRİŞ

Kivi, Actinidiaceae familyasına ait olup, böceklerle tozlanan dioik bir meyve türüdür. Bitkisi güçlü, odunsu, tırmanıcı özelliktedir ve destek sistemleri kullanılarak yetiştirilir. Anavatanı Yeni Zelanda olup, dünyanın birçok yerinde ticari olarak yetiştirilir (Debersaques ve Mekers, 2010). Dünya kivi üretiminde Çin 2.380.304 ton üretimle ilk sırada yer almaktadır. Onu 603.522 ton ile Yeni Zelanda, 523.120 ton ile İtalya, 320.270 ton ile Yunanistan, 294.571 ton ile İran, 114.533 ton ile Şili ve 100.772 ton ile Türkiye takip etmektedir (FAO, 2024).

Kivi, Türkiye'ye son 30-35 yılda girmiş ve yoğun bir ilgi görmüştür. Türkiye'de kivi ekonomik anlamda Karadeniz, Marmara, Akdeniz ve Ege bölgelerinde yetiştirilir. Üretim miktarı bakımından Marmara bölgesi ilk sırada yer almakta olup, bunu Karadeniz ve Akdeniz bölgeleri takip etmektedir (İslam vd., 2022). Bu bölgelerde Yalova, Bursa, Mersin, Samsun, Ordu, Rize ve Sakarya illeri kivi üretimi bakımından ön plana çıkmaktadır. Son 10 yıla ait veriler incelendiğinde, Türkiye kivi üretim alanlarının (4.198 ha) 1.94 ve buna paralel olarak üretim miktarının ise 2.83 kat arttığı görülmektedir (TÜİK, 2024). Bu durum üreticilerin kivi yetiştiriciliğini tercih ettiklerini açıkça ortaya koymakta olup, yeni tesis edilen bahçelerin sayısı her geçen gün artmaktadır. Kivi üretimine olan yoğun ilgi bu türde fidan talebinin artmasına neden olmuştur (Zenginbal ve Özcan, 2014).

Kivi generatif ve vejetatif yöntemlerle çoğaltılabilmektedir. Generatif çoğaltma daha çok anaç üretimi ve ıslah çalışmalarında kullanılır. Bu yöntemle elde edilen bireylerin %80'i erkek, %20'si dişi olmakta ve cinsiyetleri çiçeklenme dönemine kadar bilinememektedir (Zenginbal ve Özcan, 2003; Ali vd., 2017). Kivide fidan üretimi amacıyla yaygın olarak aşı, çelik ve doku kültürü yöntemleri tercih edilir. Bu yöntemlerden özellikle çelikle çoğaltma basit, ucuz ve pratiktir. Kivi yeşil yarı-odun ve odun çelikleriyle çoğaltılabilir. Ancak, erken dönemde alınan yeşil ve yarı odun çeliklerin yeteri miktarda depo maddesi içermemesi, olumsuz iklim koşullarına ve mantari hastalıklara karşı dayanımlarının az olması nedeniyle (Samancı, 1990), çoğaltmada çoğunlukla odun çelikleri tercih edilir (Zengibal ve Özcan, 2013; Karabulut, 2017).

Çeliklerde kök oluşumu üzerine çeşit, genotip, bitki büyüme düzenleyiciler, çelik tipi, çelik alma zamanı, çelik yaşı, köklendirme ortamı ve bunların yanında sıcaklık, ışık, nem gibi birçok faktör etki etmektedir (Cristofori vd., 2010; Zenginbal ve Özcan, 2013; Balta vd., 2023a). Bu faktörler arasında, bitki büyüme düzenleyiciler çeliklerde köklenmeyi artırmak amacıyla birçok meyve türünde yaygın olarak kullanılır (Zenginbal vd., 2006a, 2006b; Balta vd., 2019). Özellikle zor köklenen türlerde, bitki büyüme düzenleyicileri çeliklerde kök oluşumunu hızlandırmakta, kök sayısı ve kalitesini artırarak daha homojen bir köklenme sağlamaktadır. Bu anlamda, birçok meyve türünde oksin grubu bitki büyüme düzenleyicilerinden IBA (indol bütirik asit), IAA (indol asetik asit) ve NAA (naftalen asetik asit) yaygın olarak kullanılır (Zenginbal ve Özcan, 2014; Çelik vd., 2015; Balta vd., 2023b). IBA, oksini yıkan enzimler tarafından daha yavaş parçalanmakta ve bunun sonucunda çeliklerde kök oluşumunu teşvik etmektedir. IBA, kök apikal meristem boyutunun düzenlenmesi, yan kök gelişimi ve adventif köklerin oluşumu dâhil olmak üzere kök gelişiminin farklı süreçleri üzerine olumlu bir etkiye sahiptir (Frick ve Strader, 2018).

Son yıllarda poliaminler (putresin, spermidin, spermin), gümüş nitrat ve 1-MCP (1-metilsiklopropan) gibi maddeler de çelikle çoğaltma çalışmalarında kullanılmaktadır (Contessa vd., 2011a, 2011b; Balta vd., 2023a). Poliaminler, hücresel farklılaşma ve gelişme ile primer, lateral ve adventif kök oluşumun uyarılması gibi çeşitli fizyolojik süreçler üzerine önemli rol oynar. Poliaminlerden putresin, IBA ile kombine olarak kullanıldığında erken köklenmeyi teşvik etmekte ve köklenme özellikleri üzerine önemli bir etki yapmaktadır (Lee vd., 2009; Sahari vd., 2022). Putresinin bu etkisi, farklı araştırıcılar tarafından fındık (Cristofori vd., 2010; Balta vd., 2023b), zeytin (Aslmoshtaghi vd., 2014) ve GF677 şeftali×badem anacında (Karimi ve Yadollahi, 2012) belirlenmiştir.

Kivide çelikle çoğaltma üzerine yapılan çalışmalarda köklenme üzerine IBA (Karabulut, 2017; Zenginbal ve Özcan, 2014), IAA (Çakalli vd., 2017), NAA (Kim vd., 2016), salisilik asit (Karabulut, 2017) ve bakteri (Eşitken vd., 2003) uygulamalarının etkisinin araştırıldığı görülmektedir. Buna karşılık köklenmeyi olumlu yönde etkilediği ve kök kalitesini iyileştirdiği birçok araştırıcı tarafından rapor edilen putresinin kivide çelikle çoğaltma üzerine etkisinin araştırıldığı herhangi bir çalışmaya rastlanılmamıştır. Bu çalışmada

Hayward kivi çeşidine ait odun çeliklerinin köklenme oranı ve köklenme özellikleri üzerine IBA ve putresin uygulamalarının etkisini belirlemek amacıyla yürütülmüştür.

MATERYAL VE METOT

Materyal

Araştırma, 2023-2024 yılları arasında Sakarya Uygulamalı Bilimler Üniversitesi Tarım Bilimleri ve Teknolojileri Eğitimi Merkezi Uygulama ve Araştırma Alanında bulunan yüksek plastik tünel içerisinde yürütülmüştür. Çalışmada materyal olarak Hayward kivi çeşidine ait odun çelikleri kullanılmıştır. Araştırmada kullanılan kivi çelikleri Arifiye ilçesinde bulunan teknik ve kültürel uygulamaların düzenli olarak yapıldığı bir üretici bahçesinden temin edilmiştir.

Metot

Hayward kivi çeşidine ait odun çelikleri kış dinlenme periyodunda 18 Ocak 2024 tarihinde alınmış ve nemli bir beze sarılarak, hava almayacak şekilde streç filmle kaplanıp naylon poşet içerisinde dikim zamanına (26 Mart 2024) kadar +4°C'de buzdolabında 2.5 ay süreyle muhafaza edilmiştir. Çelik alınan bitkilerin hastalık ve zararlılardan ari olmasına dikkat edilmiştir. Çelikler, üzerinde 3 göz olacak şekilde 20-25 cm boyda, bazal kısmı gözün hemen altından düz, üst kısmı ise gözün hemen üstünden 45°'lik eğimle kesilerek hazırlanmıştır. Hazırlanan çelikler mantari enfeksiyonlara karşı fungusitle dezenfekte edilmiştir.

Çalışmada Hayward çeşidine ait odun çeliklerinin köklenmesi üzerine IBA ve putresin uygulamalarının etkileri araştırılmıştır. Bu amaçla hazırlanan çeliklere kontrol, 2 farklı IBA dozu (2000 ppm ve 4000 ppm) ve IBA dozları ile kombine olarak 2 farklı putresin dozu (800 ppm ve 1600 ppm) uygulanmıştır. IBA ve putresin dozlarının seçiminde kivide ve farklı meyve türlerinde yapılan çelikle çoğaltma çalışmaları referans alınmıştır (Zenginbal vd., 2006a; Karimi ve Yadollahi, 2012; Balta vd., 2023a). Çalışma tesadüf parselleri deneme desenine göre 3 tekerrürlü ve her tekerrürde 20 çelik olacak şekilde planlanmıştır. Bu kapsamda her bir uygulama için 60, toplamda ise 420 çelik kullanılmıştır. Hazırlanan çelikler 7 gruba ayrılmış, birinci grup çeliklere herhangi bir uygulama yapılmamış ve diğer gruplara aşağıdaki (Çizelge 1) uygulamalar yapılmıştır.

Çizelge 1. Kivi odun çeliklerine uygulanan IBA ve putresin dozları.
Table 1. IBA and putrescine doses treated kiwifruit hardwood cuttings.

Kod	Uygulama	Açıklama
U-1	Kontrol	Herhangi bir uygulama yapılmamıştır.
U-2	2000 ppm IBA	5 sn süre ile 2000 ppm IBA çözeltisine daldırılmıştır.
U-3	4000 ppm IBA	5 sn süre ile 4000 ppm IBA çözeltisine daldırılmıştır.
U-4	2000 ppm IBA+800 ppm putresin	20 dk süreyle 800 ppm putresin çözeltisine ve ardından 5 sn süre ile 2000 ppm IBA çözeltisine daldırılmıştır.
U-5	2000 ppm IBA+1600 ppm putresin	20 dk süreyle 1600 ppm putresin çözeltisine ve ardından 5 sn süre ile 2000 ppm IBA çözeltisine daldırılmıştır.
U-6	4000 ppm IBA+800 ppm putresin	20 dk süreyle 800 ppm putresin çözeltisine ve ardından 5 sn süre ile 4000 ppm IBA çözeltisine daldırılmıştır.
U-7	4000 ppm IBA+1600 ppm putresin	20 dk süreyle 1600 ppm putresin çözeltisine ve ardından 5 sn süre ile 4000 ppm IBA çözeltisine daldırılmıştır.

Çelikler, içerisi iri tarım perliti ile dolu alttan ısıtmalı köklendirme tavalarına sıra arası ve sıra üzeri 10×10 cm mesafelerde, 2/3'lük kısmı köklendirme ortamında olacak şekilde dikilmiştir. Köklendirme ortamında gerekli nemin sağlanması için mistleme ünitesi kullanılmış ve 4 saatte bir 2 dk. mistleme yapılmıştır. Köklendirme ortamı sıcaklığı 21°C±1.0 ve sera içi oransal nemi ise %70-90 olarak ayarlanmıştır. Çelikler dikimden 100 gün sonra köklendirme ortamından sökülmüş ve aşağıdaki özellikler incelenmiştir.

İncelenen Özellikler

Canlı Çelik Oranı (%): Her bir uygulamadaki ölü çeliklerin sayısının canlı çeliklerin sayısına oranlanmasıyla hesaplanmıştır (Zenginbal ve Özcan, 2013; Zenginbal ve Özcan, 2014).

Kalluslanma Oranı (%): Kallus oluşumun meydana geldiği çelikler gözlem yoluyla belirlenmiş ve % olarak ifade edilmiştir (Zenginbal ve Özcan, 2013; Zenginbal ve Özcan, 2014).

Köklenme Oranı (%): Kök oluşumunun gerçekleştiği çeliklerin sayısının toplam çelik sayısına oranlanması ile belirlenmiştir (Zenginbal ve Özcan, 2013; Zenginbal ve Özcan, 2014).

Kök Sayısı (adet çelik^{-1}): Köklenen çeliklerin bazal kısmındaki ana kökler dikkate alınarak tespit edilmiştir (Zenginbal ve Özcan, 2013; Zenginbal ve Özcan, 2014).

Kök Uzunluğu (mm): Her bir köklenen çelikteki ana köklerin uzunluğu 0.01 mm'ye duyarlı dijital kumpas (Mitutoyo, Japonya) yardımıyla ölçülmüştür (Zenginbal ve Özcan, 2013; Zenginbal ve Özcan, 2014).

Kök Çapı (mm): Her bir köklenen çelikteki ana köklerin çapı kökün orta noktasından 0.01 mm'ye duyarlı dijital kumpas (Mitutoyo, Japonya) yardımıyla ölçülmüştür (Zenginbal ve Özcan, 2013; Zenginbal ve Özcan, 2014).

Köklenme Düzeyi: Kök oluşumunun gerçekleştiği çeliklerde 1-4 (1-zayıf, 2-orta, 3-iyi, 4-çok iyi) skalasına göre belirlenmiştir.

Sürgün Sayısı (adet çelik^{-1}): Her bir uygulamadaki çeliklerde oluşan sürgünler sayılmış ve ortalaması alınmıştır (Balta vd., 2013a).

Yaprak Sayısı (adet çelik^{-1}): Her bir uygulamadaki çeliklerde oluşan yapraklar sayılmış ve ortalaması alınmıştır (Karabulut, 2017).

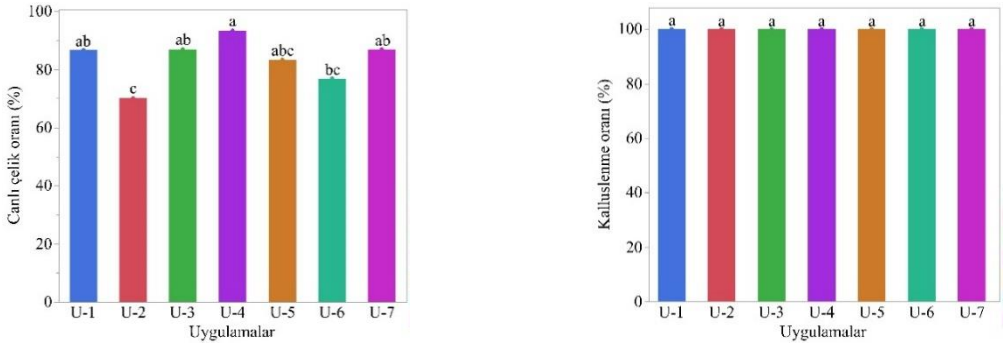
İstatistiki Analizler

Veriler, JMP 16.0 (deneme sürümü) istatistik paket programı kullanılarak değerlendirilmiştir. Uygulamalar arasındaki farklılıklar %5 önem seviyesinde Tukey çoklu karşılaştırma yöntemine göre belirlenmiştir.

BULGULAR VE TARTIŞMA

Canlı Çelik Oranı (%)

Uygulamaların canlı çelik oranı üzerine etkisi önemli bulunmuştur ($p<0.05$). En yüksek canlı çelik oranı U-4 (%93.3) uygulamasında, en düşük ise U-2 (%70.1) uygulamasında tespit edilmiştir (Şekil 1).



Şekil 1. IBA ve putresin uygulanan 'Hayward' kivi odun çeliklerinde canlı çelik ve kalluslanma oranları.

Figure 1. Survived cuttings ratio and callusing ratio of Hayward kiwifruit hardwood cuttings treated IBA and putrescine.

(U-1: Kontrol; **U-2:** 2000 ppm IBA; **U-3:** 4000 ppm IBA; **U-4:** 2000 ppm IBA+800 ppm putresin; **U-5:** 2000 ppm IBA+1600 ppm putresin; **U-6:** 4000 ppm IBA+800 ppm putresin; **U-7:** 4000 ppm IBA+1600 ppm putresin)

Hayward kivi çeşidine ait odun çeliklerinin köklenmesi üzerine yapılan çalışmalarda canlı çelik oranı %62.7-93.33 arasında belirlenmiştir (Zenginbal vd., 2006b; Zenginbal ve Özcan, 2013; Ali vd., 2017). Birçok araştırıcı kivi odun çeliklerinde kontrole kıyasla IBA uygulamasının canlı çelik oranını arttırdığını bildirmiştir (Cangi vd., 2001; Zenginbal vd., 2006b; Ali vd., 2017). Aksine, Zenginbal ve Özcan (2013) kivi

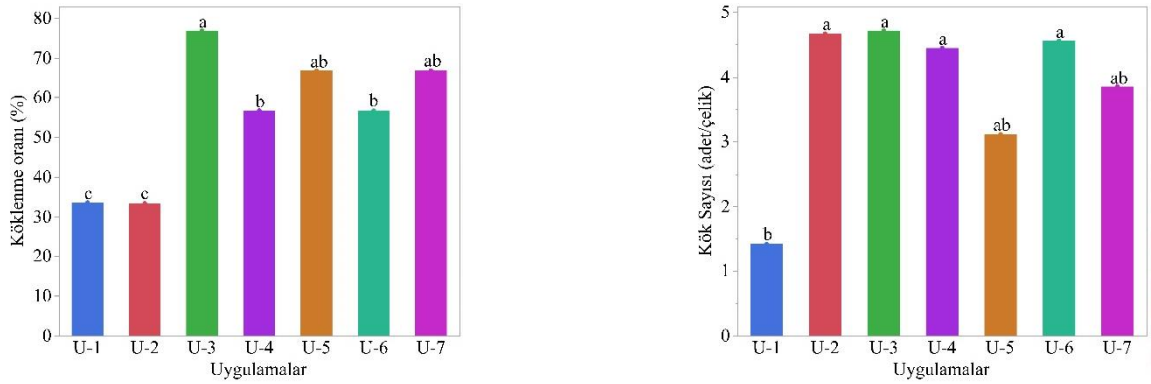
odun çeliklerinde en yüksek canlı çelik oranını kontrol grubu çeliklerde rapor etmiştir. Bunun yanında, bazı araştırıcılar fındık çeliklerinde putresin uygulamasının canlı çelik oranını azalttığını (Contessa vd., 2011a; Balta vd., 2023a), Balta vd. (2023b) ise artırdığını bildirmiştir. Mevcut çalışmada da kontrole kıyasla en yüksek canlı çelik oranı 2000 ppm IBA+800 ppm putresin uygulamasında belirlenmiştir. Canlı çelik oranı bakımından görülen bazı farklılıklar ortam neminden ve çeliklerdeki doğal oksin içeriğinden kaynaklı olabilir (Baul vd., 2010).

Kalluslanma Oranı (%)

Kalluslanma oranı üzerine IBA ve putresin uygulamalarının etkisi önemsiz bulunmuştur ($p<0.05$). Kalluslanma oranı tüm uygulamalarda %100 olarak belirlenmiştir (Şekil 1). Kivi odun çeliklerinde kalluslanma oranı %85.0-96.6 arasında belirlenmiş ve IBA dozu arttıkça kalluslanma oranının artış gösterdiği tespit edilmiştir (Ali vd., 2017). Bunun yanında IBA ve putresin uygulamalarının farklı meyve türlerine ait çeliklerde kalluslanma oranını arttırdığı rapor edilmiştir (Cristofori vd., 2010; Khaleghi ve Alivapour, 2024).

Köklenme Oranı (%)

Köklenme oranı üzerine çeşit, genotip, çelik alma zamanı, çelik tipi, çelik yaşı, bitki büyüme düzenleyicileri, sıcaklık, nem, ışık, köklendirme ortamı gibi birçok faktör etki etmektedir (Cristofori vd., 2010; Zenginbal ve Özcan 2014; Balta vd., 2023a). Uygulamalara bağlı olarak köklenme oranı önemli ölçüde farklılık göstermiştir ($p<0.05$). En yüksek köklenme oranı U-3 (%76.8) uygulamasında belirlenirken, en düşük U-1 (%33.3) uygulamasında tespit edilmiştir. En yüksek köklenme oranına sahip U-3 uygulamasını U-5 (%66.8) ve U-7 (%66.8) uygulamaları izlemiştir (Şekil 2). İlgili araştırmalarda kivi odun çeliklerinde köklenme oranı %22.7-74.7 arasında rapor edilmiştir (Zenginbal vd., 2006b; Zenginbal ve Özcan, 2013, Ali vd., 2017). Farklı araştırıcılar kivi odun çeliklerinde IBA dozu arttıkça köklenme oranının arttığını ve en yüksek köklenme oranının 4000 ve 6000 ppm IBA dozlarında olduğunu bildirmişlerdir (Cangi vd., 2001; Zenginbal vd., 2006b). Bunun yanında IBA+putresin kombinasyonun fındık çeliklerinde köklenme oranını arttırdığı rapor edilmiştir. Benzer sonuçlar GF677 şeftali×badem anacı ve zeytin çeliklerinde de bildirilmiştir (Karimi ve Yadollahi, 2012; Khaleghi ve Alavipour, 2024). IBA'nın, oksini yıkan enzimler tarafından daha yavaş parçalandığı ve bunun sonucunda çeliklerde kök oluşumu teşvik ettiği rapor edilmiştir (Frick ve Strader, 2018). Poliaminlerin ise hücre bölünmesini, bunun yanında çeliklerde primer, lateral ve adventif kök oluşumunu arttırdığı bildirilmiştir (Liu vd., 2006; Lee vd., 2009). Genel olarak değerlendirildiğinde, mevcut çalışmada köklenme oranı IBA ve putresin uygulamalarıyla artmış ve bu özellik bakımından elde edilen sonuçlar araştırıcıların bulgularıyla uyumlu bulunmuştur.



Şekil 2. IBA ve putresin uygulanan 'Hayward' kivi odun çeliklerinde köklenme oranı ve kök sayısı.
Figure 2. Rooting ratio and number of roots in Hayward kiwifruit hardwood cuttings treated IBA and putrescine.
(U-1: Kontrol; **U-2:** 2000 ppm IBA; **U-3:** 4000 ppm IBA; **U-4:** 2000 ppm IBA+800 ppm putresin; **U-5:** 2000 ppm IBA+1600 ppm putresin; **U-6:** 4000 ppm IBA+800 ppm putresin; **U-7:** 4000 ppm IBA+1600 ppm putresin)

Kök Sayısı (adet çelik^{-1})

Kök sayısı üzerine IBA ve putresin uygulamalarının etkisi önemli bulunmuştur ($p<0.05$). En yüksek kök sayısı U-2 ve U-3 (her iki uygulamada da 4.7 adet) uygulamalarında belirlenmiştir. En düşük ise U-1 (1.4)

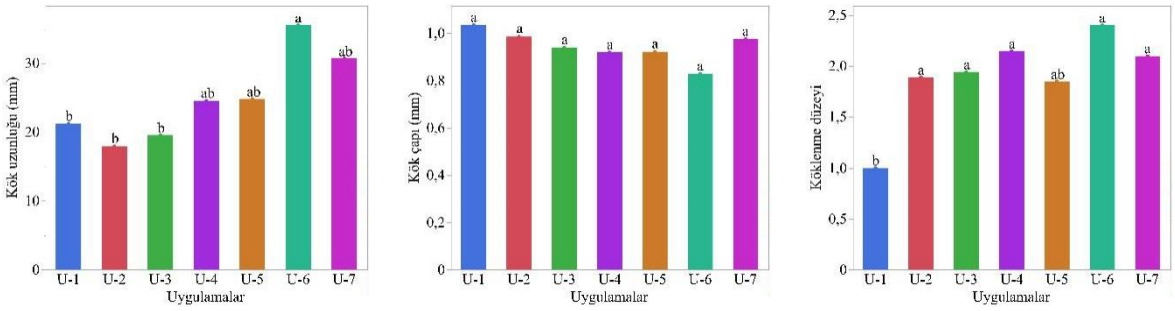
uygulamasında tespit edilmiştir (Şekil 2). Farklı araştırıcılar Hayward kivi odun çeliklerinde kök sayısını 3.09-14.10 arasında bildirilmiştir (Cangi vd., 2001; Zenginbal vd., 2006b; Ali vd., 2017). Kivi odun çeliklerinin kök sayısı üzerine IBA uygulamasının olumlu etki yaptığı ve en yüksek kök sayısının 4000 ve 6000 ppm IBA uygulamalarından elde edildiğini rapor etmişlerdir (Cangi vd., 2001; Zenginbal vd., 2006b). Bunun yanında putresin uygulamasının farklı meyve türlerine ait çeliklerde kök sayısını artırdığı bildirilmiştir (Cristofori vd., 2010; Karimi ve Yadollahi, 2012; Balta vd., 2023b; Khaleghi ve Alavipour, 2024). Benzer şekilde mevcut çalışmada da kontrol uygulamasına göre IBA ve putresin uygulamaları çeliklerde kök sayısını artırmıştır. Buna karşılık kök sayısı verileri araştırıcıların bulgularından düşük bulunmuştur. Kök sayısı bakımından görülen farklılıkların ana bitkinin yaşı, beslenme durumu ile çeliklerdeki depo maddesi birikimi ve doğal oksin içeriğinden kaynaklı olabilir (Zenginbal ve Özcan, 2013; Balta vd., 2023b).

Kök Uzunluğu ve Kök Çapı (mm)

Uygulamaların kök uzunluğu üzerine etkisi önemli iken, kök çapı üzerine etkisi önemsiz bulunmuştur ($p<0.05$). En yüksek kök uzunluğu U-6 (35.5 mm) uygulamasında belirlenirken, en düşük U-2 (17.9 mm) uygulamasında tespit edilmiştir. Uygulamalara bağlı olarak kök çapı 0.83 (U-6)-1.03 (U-1) mm arasında değişiklik göstermiştir (Şekil 3). Farklı araştırıcılar kivi odun çeliklerinde kök uzunluğunu 2.89-10.50 mm ve kök çapını ise 0.31-1.25 mm arasında belirlemişlerdir. Araştırıcılar aynı zamanda kontrole kıyasla IBA uygulamasının kök uzunluğu ve kök çapını artırdığını bildirmişlerdir. IBA dozu arttıkça kök uzunluğu ve kök çapının da artış gösterdiğini, ancak kök çapındaki artışın istatistiki olarak önemsiz olduğunu rapor etmişlerdir (Zenginbal ve Özcan, 2013; Ali vd., 2017). Bunun yanında farklı meyve türlerinde putresin uygulamasının kök uzunluğunu artırdığı bildirilmiştir (Karimi ve Yadollahi, 2012; Balta vd., 2023a). Kök çapı bakımından elde edilen bulgular araştırıcıların bulgularıyla uyumlu iken, kök uzunluğu bakımından elde edilen bulguların daha yüksek olduğu belirlenmiştir. Ayrıca kontrole kıyasla IBA uygulamalarında daha düşük kök uzunluğu belirlenirken, IBA+putresin kombinasyonunun kök uzunluğunu önemli ölçüde artırdığı belirlenmiştir. Bu bakımdan putresin uygulaması kök uzunluğu üzerine olumlu sonuçlar vermiştir. Kök uzunluğu bakımından görülen bazı farklılıklar putresin uygulamasının kök oluşumu ve gelişimi üzerine olan olumlu etkisinden kaynaklı olabilir (Lee vd., 2009; Cristofori vd., 2010).

Köklenme Düzeyi

Köklenme düzeyi üzerine IBA ve putresin uygulamalarının etkisi önemli bulunmuştur ($p<0.05$). Uygulamalara bağlı olarak köklenme düzeyi 1.0 (U-1) ile 2.4 (U-6) arasında belirlenmiştir (Şekil 3).



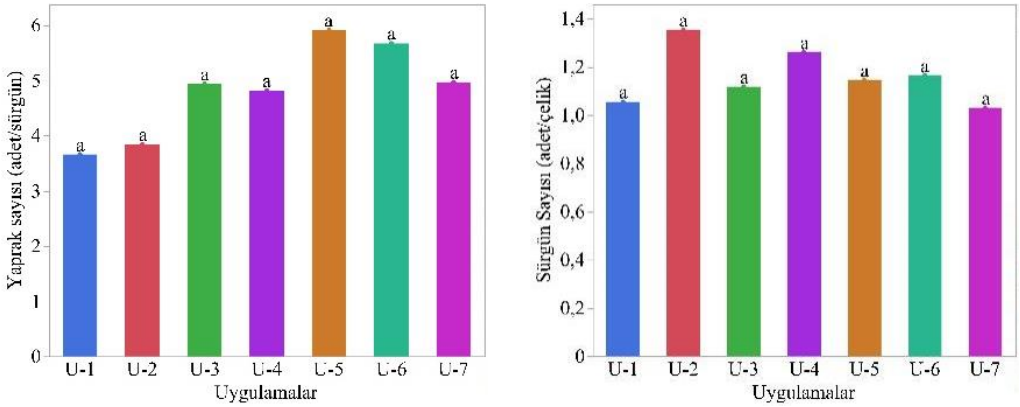
Şekil 3. IBA ve putresin uygulanan 'Hayward' kivi odun çeliklerinde kök uzunluğu, kök çapı ve köklenme düzeyi.
Figure 3. Root length, root diameter, and rooting level in 'Hayward' kiwifruit hardwood cuttings treated IBA and putrescine.
(U-1: Kontrol; **U-2:** 2000 ppm IBA; **U-3:** 4000 ppm IBA; **U-4:** 2000 ppm IBA+800 ppm putresin; **U-5:** 2000 ppm IBA+1600 ppm putresin; **U-6:** 4000 ppm IBA+800 ppm putresin; **U-7:** 4000 ppm IBA+1600 ppm putresin)

Kivi odun çelikleri üzerine yapılan farklı araştırmalarda köklenme düzeyi 1.1-3.4 (Zenginbal vd., 2006a), 1.5-3.5 (Zenginbal vd., 2006b) ve 0.0-3.77 (Zenginbal ve Özcan, 2013) arasında bildirilmiştir. Yapılan çalışmalarda IBA uygulamasının köklenme düzeyini artırdığı ve en yüksek köklenme düzeyinin 4000 ve 6000 ppm IBA uygulamalarından elde edildiği belirtilmiştir. Fındık çeliklerinin köklenmesi üzerine putresin uygulamalarının etkisinin incelendiği çalışmalarda kontrole kıyasla putresin uygulamasının köklenme düzeyini artırdığı rapor edilmiştir (Balta vd., 2023a, 2023b). Mevcut çalışmada da köklenme

düzeyi kontrole kıyasla IBA ve putresin uygulanmış çeliklerde daha yüksek bulunmuştur. Ayrıca köklenme düzeyi verileri araştırıcılar tarafından rapor edilen değerler arasında yer almıştır.

Sürgün ve Yaprak Sayısı (adet çelik^{-1})

Sürgün ve yaprak sayısı üzerine uygulamaların etkisi önemsiz bulunmuştur ($p<0.05$). Uygulamalara bağlı olarak sürgün sayısı 1.0 (U-7)-1.4 (U-2) arasında belirlenmiştir. Yaprak sayısı ise 3.7 (U-1) ile 5.9 (U-5) arasında değişmiştir (Şekil 4). Kivi çeliklerinde sürgün sayısı üzerine IBA ve putresin uygulamaların etkisinin araştırıldığı bir çalışmaya rastlanılmamıştır. Bunun yanında kivi odun çeliklerinin yaprak sayısı üzerine IBA uygulamalarının önemli bir etkisinin olmadığı ve yaprak sayısının en düşük kontrolde (7.47), en yüksek ise 4000 ppm IBA (8.17) uygulamasında olduğu bildirilmiştir (Karabulut, 2017). Farklı bir araştırmada IBA ve putresin uygulamalarının Foşa fındık çeşidine ait çeliklerde sürgün ve yaprak sayısını artırdığı tespit edilmiştir (Balta vd., 2023b). Aksine, Balta vd. (2023a) IBA ve putresin uygulanan Tombul fındık çeşidine ait çeliklerde kontrole göre daha düşük sürgün ve yaprak sayısı bildirmişlerdir. Yaprak sayısı bakımından elde edilen bulgular Karabulut (2017)'un bulgularıyla benzerlik göstermektedir. Sürgün sayısı bakımından elde edilen sonuçlar ise Balta vd. (2023b)'nın bulgularıyla uyumlu bulunmuştur. Genel olarak değerlendirildiğinde sürgün ve yaprak sayısı üzerine uygulamaların etkisi önemsiz olsa bile, IBA ve putresin uygulamalarının bu özellikler üzerine olumlu bir etkisinin olduğu belirlenmiştir.



Şekil 4. IBA ve putresin uygulanan uygulanan 'Hayward' kivi odun çeliklerinde sürgün sayısı ve yaprak sayısı.

Figure 4. *Number of shoots and leaf in 'Hayward' kiwi hardwood cuttings treated IBA and putrescine.*

(U-1: Kontrol; **U-2:** 2000 ppm IBA; **U-3:** 4000 ppm IBA; **U-4:** 2000 ppm IBA+800 ppm putresin; **U-5:** 2000 ppm IBA+1600 ppm putresin; **U-6:** 4000 ppm IBA+800 ppm putresin; **U-7:** 4000 ppm IBA+1600 ppm putresin)

SONUÇ

Hayward kivi çeşidine ait odun çeliklerinin köklenmesi üzerine farklı IBA ve putresin dozları ve onların kombinasyonlarının etkisinin araştırıldığı çalışmada, incelenen birçok özellik üzerine uygulamaların önemli etkileri belirlenmiştir. Uygulamalara bağlı olarak, köklenme oranı ve kök sayısı bakımından en iyi sonuçlar 4000 ppm IBA uygulamasından elde edilmiştir. IBA ve putresin dozlarının artışına bağlı olarak köklenme oranı da artış göstermiştir. Özellikle 2000 ppm IBA uygulamasına göre, bu dozun putresin dozlarıyla (800 ve 1600 ppm) kombine edilmiş olanlarında köklenme oranı sırasıyla %58 ve %100 artmıştır. Buna karşılık, 4000 ppm IBA uygulamasında ise tersi bir durum belirlenmiştir. Kök uzunluğu ve köklenme kalitesi üzerine 4000 ppm IBA+800 ppm putresin kombinasyonu kayda değer sonuçlar vermiştir. Diğer uygulamalar ile kıyaslandığında bu özellikler üzerine putresin uygulamasının önemli bir etkisinin olduğu görülmüştür. Nitekim 2000 ve 4000 ppm IBA uygulamalarına göre, bu dozların putresin dozlarıyla (800 ve 1600 ppm) kombine edilmiş olanlarında daha yüksek kök uzunluğu ve köklenme kalitesi tespit edilmiştir. Sonuç olarak, 4000 ppm IBA uygulamasının kivi odun çeliklerinde köklenme oranını artırdığı, putresinin ise IBA ile birlikte kombine olarak kullanıldığında köklenme özelliklerini (özellikle kök uzunluğu ve köklenme kalitesi) teşvik ettiği belirlenmiştir.

ÇIKAR ÇATIŞMASI

Yazarlar arasında herhangi bir çıkar çatışması yoktur.

YAZAR KATKISI

Yazarlar makaleye eşit katkı sağlamıştır.

TEŞEKKÜR

Bu çalışma Sakarya Uygulamalı Bilimler Üniversitesi Bilimsel Araştırma Projeleri Koordinatörlüğü tarafından 127-2023 nolu proje ile desteklenmiştir.

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Research Article

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Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Valley Natural Storage in Kütdiken Lemon is as Effective as Volcanic Natural Storage*

Kütdiken Limonu'nda Vadi Doğal Depolama, Volkanik Doğal Depolama Kadar Etkilidir

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Abstract: Increasing food demand is a pressing issue due to global food waste and population growth. In Türkiye, high humidity in the volcanic storage of Ortahisar leads to significant postharvest losses of lemons. This study aims to highlight the storage advantages of Kütdiken lemons by comparing the conditions in Bolu's wide valley with those in Ortahisar. The lemons were stored in three environments: a mechanized cold storage, volcanic tuff storage, and valley storage in Bolu. Temperature and humidity were monitored with data loggers, while weight loss, decay rate, and quality characteristics were assessed periodically.The results indicated that both storage duration and environment significantly impact Kütdiken lemons. On the 30th day, weight loss was 6.03%, increasing to 10.27% by the 120th day. The lowest weight loss occurred in controlled conditions (5.90%), while the highest (6.64%) was in valley storage. The decay rate was lowest at 2.12% in controlled storage and highest at 2.74% in valley storage. Juice content was measured at 30.16% on day 30 and 35.06% on day 120, with volcanic storage yielding the lowest juice content (30.92%) and controlled storage the highest (32.79%). In conclusion, Bolu's favorable climate and logistical ease to markets like Istanbul and Ankara suggest that natural valley storage for lemons could be a viable alternative. Establishing natural storage facilities in this region could enhance capacity and competitiveness.

Keywords: Kütdiken Lemon, Natural Storage, Volcanic Storage, Weight Loss, Fruit Quality

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Öz: Artan gıda talebi, küresel gıda israfı ve nüfus artışı nedeniyle önemli bir sorun haline gelmiştir. Türkiye'de, Ortahisar'daki volkanik depolama alanında yüksek nem, limonlarda önemli postharvest kayıplara yol açmaktadır. Bu çalışma, Kütdiken limonlarının depolama avantajlarını, Bolu'nun geniş vadi koşulları ile Ortahisar'daki koşulları karşılaştırarak vurgulamayı amaçlamaktadır. Limonlar, üç farklı ortamda depolanmıştır: mekanize soğuk depolama, volkanik tüf depolaması ve Bolu'daki vadi depolaması. Sıcaklık ve nem, veri kayıt cihazları ile izlenmiş, ağırlık kaybı, bozulma oranı ve kalite özellikleri belirli aralıklarla değerlendirilmiştir. Sonuçlar, hem depolama süresinin hem de ortamın Kütdiken limonları üzerinde önemli etkileri olduğunu göstermiştir. 30. günde ağırlık kaybı %6.03, 120. günde ise %10.27'ye çıkmıştır. En düşük ağırlık kaybı kontrollü koşullarda (%5.90), en yüksek kayıp ise vadi depolamasında (%6.64) gözlemlenmiştir. Bozulma oranı, kontrollü depolamada %2.12 ile en düşük, vadi depolamasında %2.74 ile en yüksek olmuştur. Meyve suyu içeriği, 30. günde %30.16, 120. günde ise %35.06 olarak ölçülmüştür; volkanik depolama en düşük meyve suyu içeriğini (%30.92) verirken, kontrollü depolama en yüksek (%32.79) içeriği sağlamıştır. Sonuç olarak, Bolu'nun uygun iklimi ve İstanbul ile Ankara gibi pazarlara lojistik kolaylığı, limonlar için doğal vadi depolamasının uygun bir alternatif olabileceğini göstermektedir. Bu bölgede doğal depolama tesislerinin kurulması, kapasiteyi artırarak rekabetçiliği geliştirebilir.

Anahtar Kelimeler: Kütdiken Limonu, Doğal Depolama, Volkanik Depolama, Ağırlık Kaybı, Meyve Kalitesi

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INTRODUCTION

More than 1.3 billion tons of food are lost or wasted annually worldwide. With the increasing population, wastage is increasing. By 2050, it is predicted that the world population will be 9.7 billion and the need for food will increase by 60% in parallel. This is why food safety emerges as an issue that needs urgent intervention (United Nations [UN] Türkiye, 2025). The high cost of cold storage on the product due to high energy inputs has increased the demand for natural cold storage. Temperature and humidity cannot be controlled during the storage of products in naturally cooled warehouses. These warehouses store mostly root vegetables, apples, lemons, and potatoes (Özdemir and Çandır, 2017).

A total of 70% of lemon fruits in Turkey are grown in Mersin. Lemons suitable for storage are harvested in December and stored in ordinary warehouses on the Mersin coastline until March, and when the weather warms up, they are transported to Ortahisar town of Nevşehir province Ürgüp district or to naturally cooled warehouses in the highlands close to the production area. Approximately 85% of the lemons produced are stored in Ortahisar (Canan and Ağar, 2006). The temperature values of Ortahisar warehouses are very suitable for lemon storage, but other quality criteria and post-harvest losses are quite high. The reason for this is the high relative humidity in the warehouses and the insufficient evacuation of the warehouse air (Canan et al., 2015). Ortahisar is a town built on volcanic tuff soils erupted by Mount Erciyes. The feature of tuff is although it is soft enough that any person can open a large cave with a hand pickaxe; It hardens after contact with air and allows very useful caves to be made (Canan and Ağar, 2006).

Kütdiken lemon is in the Feminello subgroup of the Eureka group. This variety, like all lemons, originates in Italy. However, there is no information about his being brought to Turkey. Over time, it has become a lemon variety unique to Turkey and is the most produced lemon type in our country. The udder part is underdeveloped, the shell is tightly attached to the smooth and shiny flesh. It is the most superior and high-quality variety in the world in terms of internal quality, water, and odor characteristics. It is high quality. It is a high-yielding variety that does not show periodicity and is the most stored lemon in Turkey. The trees grow in medium strength, and the distribution of fruits on the tree is uniform (Kafa, 2015). Lemon fruit (*Citrus limon*) is one of the commonly consumed fruits used directly or in soft drinks, alcoholic beverages, and meals (Shimizu et al., 2019). Lemon polyphenols prolong life, delay aging lesions, and reduce obesity. Lemon fruit is also rich in citric acid, vitamin C, and polyphenols, which have benefits such as alleviation of fatigue (Kajimoto et al., 2007) and lipid-lowering effects (Miyake et al., 2006; Hiramitsu et al., 2014).

Bolu province, which has a lot of suitable valleys for natural storage, is 743 m above sea level with an annual average temperature of 10.4 °C. Nevşehir Province, where Ortahisar is located, has an altitude of 1260 m and an average temperature of 10.7 °C (General Directorate of Meteorology, 2025), with a volcanic rhizosphere. Generally, the temperature 2 m below is equal to the annual average temperature above the ground and is generally constant throughout the year (Kader, 2002). Considering the example of Bolu and Nevşehir with this principle, it is thought that Bolu is equal to or slightly more advantageous than Nevşehir in terms of underground storage temperatures. If natural storage is combined with electricity and technological facilities, the energy costs needed will be less.

This study aimed to determine the possibility of reflecting the aforementioned superior features of a valley in Bolu province to natural storage by comparing it with the natural storage of Kütdiken lemon, which is the most stored and traded variety in Türkiye, in Ortahisar conditions.

MATERIAL AND METHOD

The Kütdiken lemon (*Citrus lemon*) variety was used in the experiment. This variety is convenient for storage and transportation. Due to its suitability for long-term storage, it can be stored until the export demand rises. Fruit skin color is light green-yellow or lemon yellow. The bark is smooth, shiny, and tightly attached. The mammary part is not well developed and is not obvious. Its fruits are elliptical. It contains 32.96% fruit juice at maturity. The acid rate is 7.16%. The number of seeds per fruit is 10-11. It has a strong tree canopy and is a mid-season variety. The fruits best suited for storage are those harvested before the November rains. Harvest continues until February under favorable conditions (Tuzcu, 1990).

Since there is no natural cold storage in Bolu yet, the underground warehouse used as a potato storage 2 meters below was considered as cold storage in this study. The average temperature is around 10 ℃, and humidity varies between 85-95%. These warehouses are completely earthen and surrounded by wood. Since the village houses have been replaced by reinforced concrete structures today, the number of such warehouses is gradually decreasing.

Lemon fruits were purchased from an orchard in Mersin (Erdemli) region from approximately 20 years old trees grafted on *Citrus* (*Citrus aurantium*) trees on 1 January. Fruits were separated according to their color, size, and quality. Approximately the same color, medium-sized, and undamaged fruits were selected and placed in wooden boxes, which are commercial crates commonly used for storage in the market.

In the experiments, the cold storage in controlled conditions at Bolu Abant Izzet Baysal University (BAIBU), the ordinary warehouse in Ortahisar as the volcanic tuff storage, and the valley storage in Bolu were used. Temperature and humidity are recorded with data loggers (DS102 Heat and Humidity Datalogger, Ecowitt, Hong Kong) in the warehouses, including on-site. Thermomechanical storage is kept constant at 10 ℃ for lemon. Since it is not controlled in ordinary warehouses, humidity control was not carried out in the controlled warehouse either. The fruits were stored for 120 days, and analyses were conducted every 30 days.

The lemons included in the experiment were numbered before being put into the warehouses and their initial weights were weighed one by one with a precision digital scale (Precisa 125 ASCS, Switzerland). During the storage period in the warehouse, 10 fruits were taken once a month and weighed again and the weight loss was calculated according to the formula below (1).

$$\text{Weight Loss (\%)} = [(\text{Initial Weight (g)} - \text{Final Weight (g)}) \times 100] \times [\text{Initial Weight (g)}]^{-1} \quad (1)$$

The fruits taken during the storage period were examined and the decay rate (DR) was recorded as the total amount of rotten fruit. The amount of rotten fruit counted was calculated as the estimated percentage of total fruit according to the formula below (2).

$$\text{DR (\%)} = [\text{Rotten Fruits (pieces)} \times 100] \times (\text{Total Fruits})^{-1} \quad (2)$$

In the monthly counting and measurement processes, the green capsule fruits (GCF) were counted and the percentage of the total number of fruits in the box was calculated according to the formula below (3).

$$\text{GCF (\%)} = [\text{Number of GCF} \times 100] \times (\text{Total Number of Fruits})^{-1} \quad (3)$$

The weight of the pulp was subtracted from the initial period of the fruit and the percentage divided by the weight of the fruit taken as a sample was calculated according to the formula below(4).

$$\text{Fruit Juice(\%)} = [(\text{Fruit Weight} - \text{Pulp Weight}) \times 100] \times \text{Fruit Weight}^{-1} \quad (4)$$

After the pulp was filtered, 1 ml of the extract from the filtrate was immersed in the glass electrode sample of the pH meter (pH3110, WTW, Germany) and titrated with 0.1 N NaOH until the pH value was 8.1 with continuous stirring using a magnetic stirrer (Dündar and Pekmezci, 1991), and was calculated with the equation below.

TA (g/100ml) = [NaOH spent x Normality of NaOH x factor of NaOH x 0.007 x100] x [Amount of Sample Taken (ml)]$^{-1}$ (5)

The solible solid (SS) was determined by a hand-type refractometer (Atago N-20 Brix 0-20 %, Japan) after the pulp was filtrated. The maturity index (%) was calculated by dividing the SS to the TA and multiplying by 100 (Cemeroğlu, 1992).

The visiual quality (VQ) of lemon fruits at the end of the storage period was evaluated by ten different sensory panelists, who scored them from 1 to 5 in terms of the general view. Visual Quality, a scale of 1 indicating the worst and 5 is the best.

Color properties were determined according to CIELAB with a hand-type colorimeter (NR60CP, 3Nh Tech, Shenzen, China).

The experiment was designed in factorial design with two factors, storage duration and storage conditions in triplicates. Data were subjected to two-way ANOVA to determine the significance of the factors and their interaction. When F was significant, data were subjected to Tukey's post-hoc test (HSD) to compare means. The interrelationship between traits and factors were determined by a principal component analysis (PCA). Correlations among the traits were determined by Pearson's pairwise correlations using "corrplot" package of R Studio (Wei and Simko, 2017).

RESULTS AND DISCUSSION

The average storage temperature gradually increased from 7.57 ℃ to 9.20 ℃ from January to May in the warehouse in the volcanic region (Ortahisar). The relative humidity values in the same warehouse varied between 95.60% (January; 0th day) and 98.70% (May; 120th day). While the temperature values in the warehouse in the valley (Bolu) were 8.10 ℃ on average in January, it reached an average of 13.50 ℃ in May. The relative humidity in this warehouse varied between 69.24% (January) and 81.00% (March; 60th day). The temperature and relative humidity values of the warehouses during the study are presented in Table 1.

Table 1. Temperature (Temp; ℃) and relative humidity (RH; %) values in different storages during experiment.
Çizelge 1. Deney sırasında farklı depolardaki sıcaklık (Temp; ℃) ve bağıl nem (RH; %) değerleri.

			Valley warehouse		Volcanic warehouse
Months		Temp (℃)	RH (%)	Temp (℃)	RH (%)
January	Min	9.40	76.00	8.60	99.00
	Max	6.60	60.00	7.00	68.00
	Avg	8.10	69.24	7.57	95.60
February	Min	13.00	81.00	9.50	99.00
	Max	6.50	71.00	7.00	70.00
	Avg	9.20	76.83	7.80	97.40
March	Min	13.90	78.11	11.00	99.00
	Max	9.70	73.00	5.10	91.00
	Avg	11.88	81.00	8.60	98.32
April	Min	15.40	84.00	11.50	99.00
	Max	11.20	64.00	6.70	91.00
	Avg	13.02	73.73	9.01	98.00
June	Min	15.80	82.00	13.90	99.00
	Max	12.60	70.00	9.20	84.00
	Avg	13.50	76.82	9.20	98.70

*Commercial warehouse is a mechanized cold storage. The temperature was kept constant at 10 ℃.

The changes observed in weight loss during the storage of Kütdiken lemon are given in Table 2. Weight loss significantly varied according to the storage periods. The mean weight loss was 6.03% on the 30th day, 7.19% on the 60th day, 8.04% on the 90th day, and 10.27% on the 120th day. Although the weight loss varies between warehouses, there was no significant difference. In addition, the highest average weight loss occurred in valley natural warehouse at 6.64%, while the lowest weight loss (5.90%) was in controlled conditions. The storage period and warehouse interactions were significant in terms of weight loss. The

lowest weight loss was in controlled conditions in all storage periods, while the highest values were altered between valley and volcanic storages throughout the storage periods (Table 2).

Table 2. Kutdiken lemon pomological parameters in different storages at postharvest.
Çizelge 2. Kutdiken limonunun hasat sonrası farklı depolardaki pomolojik parametreleri.

		WL (%)	DR (%)	FGC (%)	FJ (%)	TA(%)
Storages						
Controlled		5.90 ± 0.89 ns	2.12 ± 0.53ns	66.18 ± 5.55 a	32.79 ± 0.64ns	7.43 ± 0.38ns
Valley		6.64 ± 0.98	2.74 ± 0.57	74.81 ± 4.11 ab	32.20 ± 0.83	7.76 ± 0.34
Volcanic		6.38 ± 0.93	2.67 ± 0.55	75.22 ± 4.08 b	30.92 ± 0.51	7.73 ± 0.33
Storage periods (day)						
0		0.00 ± 0.00 d	0.00 ±0.00 b	100.00 ± 0.00 a	30.16 ± 0.00 c	9.46 ± 0.00 a
30		6.03 ± 0.25 c	2.00 ±0.17 ab	79.18 ± 2.46 b	30.16 ± 0.57 c	7.45 ± 0.13 c
60		7.19 ± 0.27 b	2.87 ±0.20 a	67.34 ± 2.57 c	31.12 ± 0.89 bc	5.89 ± 0.10 e
90		8.04 ± 0.31 b	3.65 ±0.13 a	59.71 ± 2.01 cd	33.35 ± 0.49 ab	8.64 ± 0.10 b
120		10.27 ± 0.25 a	4.02 ±1.16 a	54.11 ± 3.96 d	35.06 ± 0.84 a	6.75 ± 0.16 d
Storages × Storage periods						
0	-	0.00 ± 0.00 f	0.00 ± 0.00 ns	100.00 ± 0.00 a	30.16 ± 0.00 bcd	9.46 ± 0.00 a
	Controlled	5.72 ± 0.59 e	1.34 ± 0.03	72.15 ± 4.04 bcd	31.95 ± 0.51 bcd	7.45 ± 0.12 cd
30	Valley	6.35 ± 0.12 cde	2.42 ± 0.08	82.00 ± 2.89 abc	29.00 ± 0.74 d	7.60 ± 0.29 c
	Volcanic	6.02 ± 0.51 de	2.25 ± 0.10	83.40 ± 3.23 ab	29.52 ± 0.76 cd	7.30 ± 0.29 cd
	Controlled	6.37 ± 0.22 cde	2.11 ± 0.08	60.02 ± 5.79 de	32.97 ± 1.90 a-d	5.54 ± 0.08 f
60	Valley	7.87 ± 0.35 cd	3.21 ± 0.19	71.40 ± 0.92 bcd	31.44 ± 1.32 bcd	6.10 ± 0.12 ef
	Volcanic	7.34 ± 0.32 cde	3.28 ± 0.10	70.60 ± 2.08 bcd	28.96 ± 0.15 d	6.03 ± 0.03 ef
	Controlled	7.42 ± 0.25 cde	3.18 ± 0.08	55.45 ± 3.87 de	34.15 ± 1.24 abc	8.43 ± 0.07 b
90	Valley	8.34 ± 0.90 bc	3.90 ± 0.12	60.40 ± 3.84 de	33.26 ± 0.11 a-d	8.86 ± 0.17 ab
	Volcanic	8.37 ± 0.11 bc	3.88 ± 0.05	63.30 ± 1.71 cd	32.64 ± 0.84 a-d	8.64 ± 0.19 b
	Controlled	9.98 ± 0.65 ab	3.95 ± 2.28	43.30 ± 9.15 e	34.72 ± 1.58 ab	6.28 ± 0.18 ef
120	Valley	10.65 ± 0.45 a	4.16 ± 2.40	60.25 ± 3.04 de	37.15 ± 1.33 a	6.76 ± 0.05 de
	Volcanic	10.17 ± 0.17 ab	3.95 ± 2.28	58.78 ± 2.59 de	33.31 ± 0.65 a-d	7.21 ± 0.22 cd
ANOVA						
$F_{(Storages)}$		0.57ns	0.08ns	0.94ns	1.73ns	2.26ns
$F_{(Period)}$		273.56***	7.11***	72.54***	15.32***	258.42***
$F_{(Period×Storage)}$		4.35*	0.54ns	9.47***	5.01*	6.67**

Note: Each value is presented as the mean ± standard error of three replicates. Within each column, means followed by different symbols indicate significant differences according to the LSD test at $p < 0.05$, where ***, **, * denote significant differences at $p \leq 0.0001$, 0.001, and 0.05 levels, respectively. WL: Weight loss, RF Rotten fruit, FGC: Green capsuled fruit, FJ: Fruit juice, TA: Titratable acidity

Decay rate (DR), also known as decay losses, during storage is as crucial as weight loss. As the storage period of lemons extends, an increase in DR is observed (Table 2). The minimum decay loss occurred in the controlled warehouse (2.12%), while the maximum decay loss was identified in the natural warehouse (2.74%), and no significant difference in DR among warehouses was found. Upon scrutinizing Table 2, DR are highest in 120th day (4.02%) and lowest in 30th day (2%), with a significant difference between months. Furthermore, decay losses increased with prolonged storage.

Another storage criterion, the quantity of green-capsuled fruit (FGC), being high, signifies a reduction in commercial losses. A significant portion of the decay in *Citrus* fruits occurs after the green capsule turns brown. Throughout storage, all fruits for each application and repetition were examined, and green-capsuled, brown, and dried fruits, as well as those without capsules, were identified. The rates of green-capsuled fruit were determined. Changes in the quantity of green-capsuled fruit during the storage of the Kütdiken lemon variety are presented in Table 2. The most significant decrease in the proportion of FGC occurs in 30th day (79.18%), with the initial rate of 100% FGC dropping to approximately 54.11% in 120th day. The green-capsuled fruit rates were calculated 79.18% in 30th day, 67.34% in 60th day, 59.72% in 90th day, and 54.11% in 120th day. At the end of the storage period, the average rate in volcanic warehouse was measured as the highest at 75.22%, while the lowest was recorded in the controlled warehouse at an average

of 66.18%. The difference between warehouses is significant ($p < 0.05$), indicating that the reduction in the proportion of FGC is slower in the controlled warehouse.

The results demonstrate that the fruit juice content (FJ) of Kütdiken lemons significantly varies over the storage period, as detailed in Table 2 ($p < 0.05$). On the 30th day, the FJ was measured at 30.16%, reaching 35.06% by the 120th day. Although controlled storage showed the highest FJ at 32.79%, while volcanic storage exhibited the lowest at 30.92%, there was no statistically significant difference in FJ levels among the different storage conditions ($p < 0.05$). This indicates that while the storage period influences the FJ, the type of storage does not produce a significant differential effect.

Table 3. Kutdiken lemon's pomological parameters in different storages at postharvest.
Çizelge 3. Kutdiken limonunun hasat sonrası farklı depolardaki pomolojik parametreleri.

		SS (%)	SS/TA	VQ (1-5)
Storages				
Controlled		9.98 ± 0.22ns	1.40 ± 0.09ns	3.93 ± 0.21ns
Valley		9.87 ± 0.17	1.31 ± 0.07	3.67 ± 0.21
Volcanic		10.12 ± 0.21	1.35 ± 0.08	4.47 ± 0.17
Storage periods (day)				
0		9.30 ± 0.00 b	0.98 ± 0.00 d	5.00 ± 0.00 a
30		10.42 ± 0.26 a	1.40 ± 0.03 b	4.11 ± 0.26 b
60		10.72 ± 0.20 a	1.82 ± 0.04 a	3.67 ± 0.17 b
90		10.18 ± 0.11 a	1.18 ± 0.02 c	3.78 ± 0.28 b
120		9.33 ± 0.18 b	1.39 ± 0.04 b	3.56 ± 0.24 b
Storages × Storage periods				
0	-	9.30 ± 0.00 cd	0.98 ± 0.00 f	5.00 ± 0.00 a
30	Controlled	10.93 ± 0.47 ab	1.47 ± 0.08 bc	4.00 ± 0.00 ab
	Valley	10.40 ± 0.50 a-d	1.37 ± 0.03 cde	3.33 ± 0.33 b
	Volcanic	9.93 ± 0.29 a-d	1.36 ± 0.04 cde	5.00 ± 0.00 a
60	Controlled	10.66 ± 0.07 abc	1.92 ± 0.02 a	4.00 ± 0.00 ab
	Valley	10.33 ± 0.33 a-d	1.70 ± 0.06 ab	3.33 ± 0.33 b
	Volcanic	11.16 ± 0.43 a	1.85 ± 0.06 a	3.67 ± 0.33 ab
90	Controlled	10.00 ± 0.00 a-d	1.19 ± 0.01 def	3.33 ± 0.33 b
	Valley	10.00 ± 0.00 a-d	1.13 ± 0.02 ef	3.33 ± 0.33 b
	Volcanic	10.53 ± 0.24 abc	1.22 ± 0.05 c-f	4.67 ± 0.33 ab
120	Controlled	9.00 ± 0.23 d	1.44 ± 0.07 cd	3.33 ± 0.67 b
	Valley	9.33 ± 0.33 cd	1.38 ± 0.05 cd	3.33 ± 0.33 b
	Volcanic	9.66 ± 0.33 bcd	1.34 ± 0.08 cde	4.00 ± 0.00 ab
ANOVA				
$F_{(\text{Storage conditions})}$		0.94ns	4.25*	10.18***
$F_{(\text{Storage period})}$		15.71***	127.60***	12.59***
$F_{(\text{Period x condition})}$		1.74ns	1.27ns	2.23ns

Note: Each value is presented as the mean ± standard error of three replicates. Within each column, means followed by different symbols indicate significant differences according to the LSD test at $p < 0.05$, where ***, **, * denote significant differences at $p \leq 0.0001$, 0.001, and 0.05 levels, respectively. SS: Soluble Solids, SS/TA: Soluble Solids / Titratable Acidity, VQ: Visual Quality, a scale of 1 indicating the worst and 5 is the best.

Changes in the titratable acidity are presented in Table 2. Upon examining the results of the analysis of variance for the changes in titratable acidity, a significant difference is observed among months ($p < 0.05$), while there is no significant difference among warehouses. The titratable acidity is highest at the beginning, calculated as 9.46%, and lowest in 60th day with 5.89%. Titratable acidity decreased in 30th day and 60th day, increases again in 90th day, and decreases again in 120th day. From a warehouse perspective, controlled warehouse was at 7.43%, valley natural warehouse at 7.76%, and volcanic warehouse at 7.73% (Table 2).

The soluble solid (SS) was calculated as an average of 10.42% in 30th day, 10.72% in 60th day, 10.18% in 90th day, and 9.33% in 120th day, which was not significant. The highest SS was measured in volcanic

warehouse as 10.12%, while the lowest was in valley natural warehouse as 9.87%. Although different amounts of SS were measured among warehouses, the differences were not significant (Table 3).

The SS to acidity ratio (SS/TA) is one of the maturity factors in fruits. This ratio, initially 0.98, was observed at its highest in 60th day as 1.92 in the controlled warehouse. The average SS/TA ratio was highest in the controlled warehouse (1.40) and lowest in the valley natural warehouse (1.31). However, no significant difference was observed among warehouses (Table 3).

Lemons stored in the volcanic warehouse exhibited a better visual quality (VQ) but scores were not significantly different. The VQ score decreased with prolonged storage. The value, initially 5, has decreased to 3.56 by the 120th day of storage. Even on the 120th day, the overall appearance of all lemons remains in good condition (Table 3).

The color values of Kütdiken lemon (L*, a*, b*, hue^{o}, Chroma*) did not change significantly among warehouses. The L* value initially was 68.19, then increased slightly to 73.15 on the 30th day, rapidly decreased to 24.60 on the 60th day, remained at a similar level around 24.79 on the 90th day, and increased again to 72.38. The a* value initially was 12.52 and remained the same at 13.36 on the 30th day, rapidly decreased to 1.15 on the 60th day, remained at a similar level around 1.22 on the 90th day, and increased again to 15.84. The b* value initially was 48.48, slightly increased to 53.17 on the 30th day, rapidly decreased to 0.63 on the 60th day, remained at a similar level around 0.70 on the 90th day, and increased again to 47.98. The Chroma* value initially was 75.52, slightly decreased to 55.23 on the 30th day, rapidly decreased to 1.32 on the 60th day, remained at a similar level around 1.41 on the 90th day, and increased again to 50.59 on the 120th day. The hue value initially was 50.08, then slightly increased to 76.18 on the 30th day, rapidly increased to 208.75 on the 60th day, remained at a similar level around 209.59 on the 90th day, and then decreased again to 71.59 (Table 4).

Table 4. Kutdiken lemon's colorimetric parameters in different storages at postharvest.
Çizelge 4. Kutdiken limonunun hasat sonrası farklı depolardaki kolorimetrik parametreleri.

		L*	a*	b*	Chroma*	hue^{o}
Storages						
Controlled		51.82 ± 5.97ns	10.45 ± 2.44ns	30.40 ± 6.57ns	37.60 ± 8.22ns	121.67 ± 19.24ns
Valley		53.09 ± 6.23	8.56 ± 1.68	30.54 ± 6.53	37.00 ± 8.07	123.52 ± 18.80
Volcanic		52.96 ± 6.21	7.44 ± 1.47	29.63 ± 6.37	35.84 ± 7.94	124.52 ± 18.72
Storage periods (day)						
0		68.19 ± 0.28 b	12.52 ± 0.04 a	48.48 ± 0.18 b	75.52 ± 0.09 a	50.08 ± 0.17 c
30		73.15 ± 1.31 a	13.36 ± 2.71 a	53.17 ± 0.92 a	55.23 ± 1.28 b	76.18 ± 2.57 b
60		24.60 ± 0.03 c	1.15 ± 0.02 b	0.63 ± 0.01 c	1.32 ± 0.02 d	208.75 ± 0.68 a
90		24.79 ± 0.02 c	1.22 ± 0.02 b	0.70 ± 0.02 c	1.41 ± 0.02 d	209.59 ± 0.61 a
120		72.38 ± 1.17 a	15.84 ± 0.71 a	47.98 ± 1.49 b	50.59 ± 1.37 c	71.59 ± 1.07 b
Storages × Storage						
0	-	68.19 ± 0.56 a	12.52 ± 0.08 ab	48.48 ± 0.36 ab	75.52 ± 0.18 a	50.08 ± 0.34 c
30	Controlled	70.64 ± 3.39 a	20.44 ± 6.94 a	55.27 ± 2.00 a	59.79 ± 0.92 b	69.89 ± 6.85 b
	Valley	73.81 ± 1.83 a	11.17 ± 0.60 ab	52.31 ± 0.22 ab	53.47 ± 0.17 c	77.94 ± 0.67 b
	Volcanic	75.00 ± 0.85 a	8.47 ± 0.33 bc	51.94 ± 1.66 ab	52.43 ± 1.73 c	80.70 ± 0.33 b
60	Controlled	24.57 ± 0.01 b	1.15 ± 0.04 c	0.62 ± 0.01 c	1.31 ± 0.03 d	208.21 ± 1.00 a
	Valley	24.53 ± 0.01 b	1.21 ± 0.01 c	0.63 ± 0.02 c	1.36 ± 0.00 d	207.45 ± 0.64 a
	Volcanic	24.70 ± 0.06 b	1.10 ± 0.03 c	0.65 ± 0.02 c	1.28 ± 0.02 d	210.60 ± 1.21 a
90	Controlled	24.80 ± 0.05 b	1.22 ± 0.03 c	0.71 ± 0.04 c	1.42 ± 0.05 d	210.23 ± 0.58 a
	Valley	24.83 ± 0.03 b	1.19 ± 0.04 c	0.71 ± 0.03 c	1.40 ± 0.01 d	210.41 ± 1.36 a
	Volcanic	24.75 ± 0.01 b	1.26 ± 0.03 c	0.67 ± 0.02 c	1.42 ± 0.02 d	208.13 ± 0.82 a
120	Controlled	70.88 ± 2.60 a	16.94 ± 1.03 ab	46.92 ± 3.52 b	49.94 ± 3.24 c	69.94 ± 1.93 b
	Valley	74.10 ± 0.61 a	16.69 ± 0.27 ab	50.58 ± 0.61 ab	53.26 ± 0.59 c	71.73 ± 0.33 b
	Volcanic	72.16 ± 2.58 a	13.87 ± 1.41 ab	46.43 ± 2.97 b	48.56 ± 2.38 c	73.09 ± 2.74 b
ANOVA						
$F_{(Storages)}$		1.21ns	3.36*	0.62ns	2.92ns	2.42ns
$F_{(Period)}$		968.62***	43.47***	1143.25***	2487.29***	4333.62***
$F_{(Period×Storage)}$		0.65ns	2.23ns	0.95ns	3.24**	1.61ns

Note: Each value is presented as the mean ± standard error of three replicates. Within each column, means followed by different symbols indicate significant differences according to the LSD test at $p < 0.05$, where ***, **, * denote significant differences at $p \leq 0.0001$, 0.001, and 0.05 levels, respectively.

The chroma value was inversely proportional to weight loss. As the amount of fruit juice increased, weight loss also increased. The dry matter content and weight loss increased, and as a result, the hue value also increased. SS was inversely proportional to L*, a*, b* values, and particularly to chroma. Titratable acidity was negatively correlated to weight loss (r=-0.63***) and SS (-0.34*). Weight loss was the most correlated value with decay (r=0.66), followed by fruit juice quantity (r=0.53). The increment in decay loss was in line with these two characteristics. FGC was negatively correlated to decay, fruit juice quantity, and especially weight loss, while positively correlated to chroma and TA. VQ score was correlated to acidity, chroma, L, and especially FGC, and was negatively correlated to fruit juice quantity, rotten fruit quantity, and especially weight loss (Figure 1).

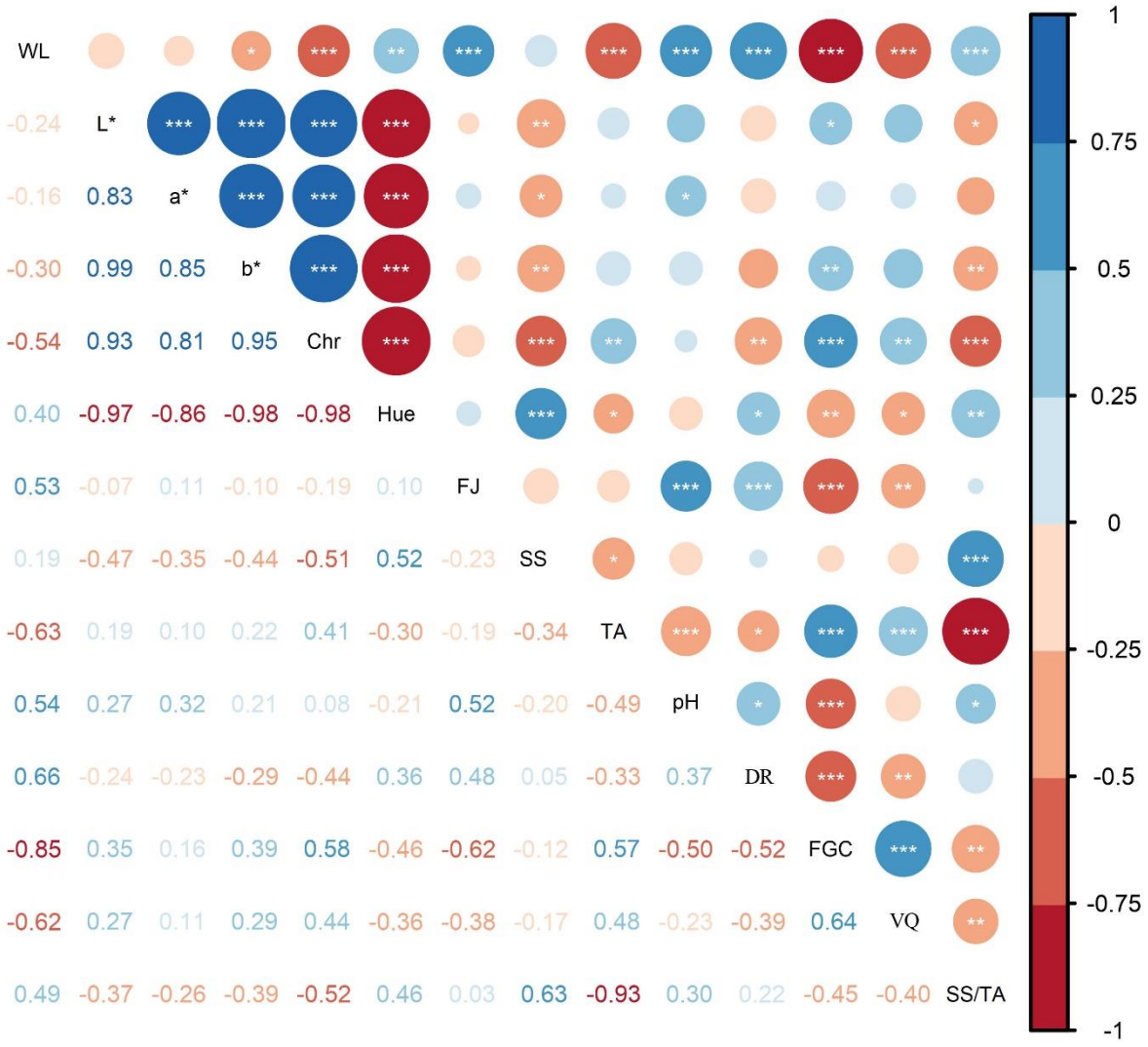
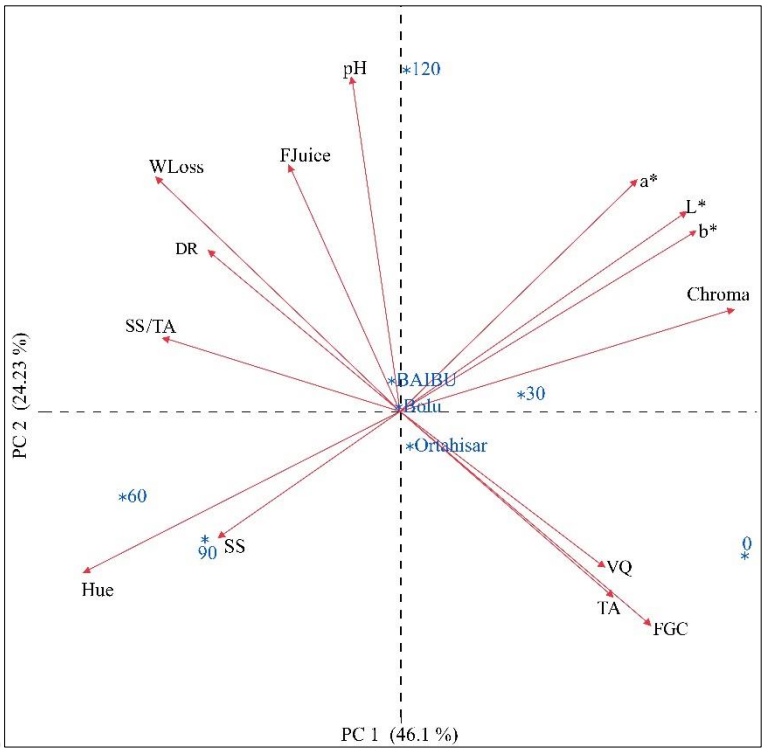


Figure 1. Correlations between measured parameters of Kutdiken lemon in different storages at postharvest.
Şekil 1. Kutdiken limonunun hasat sonrası farklı depolardaki ölçülen parametreler arasındaki korelasyonlar.

Principal Component Analysis (PCA): Similar to Figure 1, in the principal component analysis (Figure 2), some relationships are more clearly observed. PC1 and PC2 explained 65.84% the total relations. The height of acidity and the quantity of green-capped fruits (FGC), which measure consumer preference, are positively correlated with overall appearance (VQ). Overall appearance is inversely correlated with acidity and FGC, as well as with weight loss, fruit juice quantity, rotten fruit quantity, and SS/TA ratio. The L a b chroma values are inversely correlated with dry matter content and inversely correlated with the duration spent in storage. The duration spent in storage is positively correlated with dry matter content. Although

volcanic storage has good properties in the same direction, all storage facilities are at the center of the parameters measured with small differences. There doesn't seem to be a significant difference between valley storages and volcanic storages.

a)



b)

Number	Eigenvalue	Percent	Cum	Prob>ChiSq
1	5.21	40.07	40.07	<.0001
2	3.35	25.77	65.84	<.0001
3	1.62	12.47	78.31	<.0001
4	0.93	7.12	85.43	.0001
5	0.69	5.33	90.76	.0001
6	0.53	4.09	94.85	.0001
7	0.28	2.14	96.99	.0001
8	0.16	1.25	98.24	.0001
9	0.11	0.87	99.11	.0001
10	0.11	0.83	99.94	<.0001
11	0.01	0.05	99.99	<.0001
12	0.00	0.01	100.00	<.0001
13	0.00	0.00	100.00	*

Figure 2. PCA Analysis (a) and eigenvalues (b) of Kutdiken lemon data from different storages and days.
Şekil 2. Farklı depolar ve günlerde alınan Kutdiken limonu verilerinin PCA Analizi (a) ve eigenvalue değerleri (b).

According to Örüng et al., (2016), underground natural cold storage facilities provide significant advantages in the storage of agricultural products, especially in areas predominantly composed of tuff, such as the Cappadocia region. These facilities are particularly concentrated in the towns of Kavak and Ortahisar (Boyraz and Zeren, 2012). The temperature in underground storage facilities is more stable compared to aboveground storage facilities due to the natural rock structure. Throughout the year, even during dry summers or harsh winters, the temperature remains between 8-10°C (Seedoga, 2022).

Reviewing the literature, weight loss in *Citrus* fruits stored in storage facilities increases over time (Karaşahin et al., 2014; Nural, 2019; Özdemir, 2008; Özkaya, 2007; Özdemir et al., 2008). The findings of the study align with existing research in the literature, as the nature of respiration in fruits makes this phenomenon predictable.

Most of the deterioration in *Citrus* fruits occurs in the form of spots and depressions on the peel and stem end (Özdemir, 1999; Strano et al., 2022). In this study, physiological deterioration increased as storage time prolonged, consistent with literature. Factors such as deviations from optimum temperature are important in increasing decay (Borazan, 2019; Canan, 2004; Zan, 2018). As storage time increases and factors such as temperature, humidity fluctuates in the storage facility, and physiological and fungal decay increases (Özdemir et al., 2016; Strano et al., 2022). The construction of isothermal doors in storage facilities, the use of heater rods connected to thermostats, and the implementation of ventilation systems would be appropriate for maintaining temperature and humidity levels (Canan, 2004).

Another storage criterion, the quantity of green-capped fruits (FGC), being high implies a reduction in losses. A significant proportion of the decay in *Citrus* fruits occurs after the capsule turns brown. During storage, all fruits for each application and each replicate were examined, and green-capped, brown, dried, and uncapped fruits were identified, and the rates of green-capped fruits were determined. As the storage

time of *Citrus* fruits prolongs, the capsule turns brown and black and falls off. The fall of the fruit capsule creates an entry environment for the fungal disease Alternaria citri (Strano et al., 2017). Our findings are similar to previous studies on lemons, oranges, and mandarins (Ağar and Kaşka, 1992, 1993; Azak, 1994; Canan, 2004; Didin et al., 2018; Erkan, 1997; Gül, 1996; Karaşahin et al., 2014; Özdemir et al., 2005, 2007, 2008, 2016, 2019; Topçu, 2020; Uzun, 2019; Zan, 2018).

According to Bartholomew and Sinclair (1951), there are increases in fruit juice content along with the storage time (Akpınar, 1990), and these increases are not related to the fruit absorbing moisture from the environment, but rather to the loss of moisture from the fruit peel due to physical and chemical processes. Increases in fruit juice content originate from the structure of the fruit peel and are closely related to water losses (Özdemir et al., 2005). The increase in free water, which is generally observed during the ripening process of the fruit, is thought to result from the increase in water volume due to soluble substances formed as a result of the breakdown of large molecules through respiration. In our experiment, increases in fruit juice content were observed along with the storage time. Similar results to ours were obtained in a study conducted by Canan (2004) on 'Kütdiken' lemon variety fruits stored in natural cooling storage and cold storage.

The TA (titratable acidity) levels of the fruits stored in lemons decreased as the storage time increased. Previous studies on the storage of *Citrus* fruits show similarities (Akpınar, 1990; Canan, 2004; Erkan, 1997; Özdemir, 1999). Anything that slows down metabolism, reduces respiration (low temperature, low oxygen, high carbon dioxide) also reduces acid loss (Karaçalı, 2009).

In the study by Canan (2004), the average maturity index ratio observed in fruit samples was initially 1.37, and it increased continuously as the storage time extended, with the highest increase seen at the 6th month (1.22). When reviewing the literature, it is observed that as the storage time increases, the maturity index also increases in *Citrus* fruits, which is consistent with this study (Borazan, 2019; Canan, 2004; Uzun, 2019).

Bolu province's annual average temperature of 10.5°C is just one aspect of its geographic situation; another important aspect is its geographical features. The consequences of its geographic features make it significant for natural cold storage. Geographically, one of the most important aspects is that Bolu plain is surrounded by high mountains like a deep and wide-mouthed water basin, and the city is located right in the center of this basin. As a result, even the slightest air movement in the vicinity causes the wind to rise as it hits these mountains, constantly forming clouds over the city. Especially due to the humid air currents coming from the Black Sea, the city center remains shaded for a significant part of the day throughout the year. Secondly, since the city center is settled at the bottom of a valley, the sun rises late and sets early. Thirdly, Bolu plain, nestled amidst mountains ranging from 1400 to 1800 meters in height, is a vast frost basin with the lowest point being 750 meters. Moist clouds over the city dissipate with the disappearance of the evening sunlight, condensing heavily on the cooled mountain surfaces, filling the Bolu plain through the Abant-Bolu Mountain, Mudurnu, and Gerede valleys until the first morning sun rises. This cold air mass reaches an altitude of about 200 meters over the plain. Throughout the night, the cold air mass covering the plain from three directions empties out only through the Mengen valley towards the Black Sea via one route, reaching its discharge point around noon at 12:00 PM. Consequently, the weather is cold and foggy for half of the day.

CONCLUSION

This study demonstrated that Kütdiken lemons can be stored in natural valley storage in Bolu, achieving comparable results to those in Ortahisar volcanic warehouse and thermomechanical storage at BAIBU, regarding weight loss, decay, and fruit quality parameters. Bolu's climatic conditions, combined with logistical advantages for markets like Istanbul and Ankara, position it as a viable alternative for lemon storage. Further research and support for establishing natural storage facilities in Bolu are recommended to enhance storage capacity and competitive pricing, potentially transforming Bolu into a significant food storage hub by integrating modern technologies with its natural cold air resource.

CONFLICT OF INTEREST

The author(s) hereby declare that there are no conflicts of interest related to this study. All financial and personal relationships that could influence the research have been disclosed, ensuring the integrity and transparency of the findings.

DECLARATION OF AUTHOR CONTRIBUTION

The authors declare that there are no conflicts of interest related to this study. Each author has made significant contributions to the research and preparation of the manuscript as detailed below, ensuring that all aspects of the work are accurately represented.

YY: Conducted the experiment, performed the laboratory analyses, collected the data, and wrote the thesis.

IC: Planned the experimental design, analyzed the raw data, conceptualized the study, wrote the manuscript, and followed up on the publication process.

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Research Article

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Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Technical and Economic Analysis of Rainwater Harvesting in University Buildings

Üniversite Binalarında Yağmur Suyu Hasadının Teknik ve Ekonomik Analizi

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Abstract: Water is becoming more valuable every day in today's world, where the effects of the growing global population and global warming are increasing, and existing water resources continue to deplete. The inadequacies in water resources are causing problems for the environment and all living beings. Therefore, protecting existing water resources or creating alternative sources has become necessary. Rainwater harvesting is effective method for generating an alternative water source. In this study, the monthly and annual water storage potentials of the buildings in Bursa Uludağ University Faculty of Agriculture were determined by using the rainwater harvesting method, and the rates of meeting the need were calculated in two different scenarios, namely irrigation of the lawn area in the faculty and meeting the amount of water needed in the buildings, and the aim was to determine the amount of economic gain to be obtained. As a result of the study, it was determined that the rainwater harvesting method has an annual water collection potential of 2045.16 m^3. With the installation of the system, it was concluded that an annual economic gain of 76858 TL was achieved in the faculty and that the initial investment costs of the system were amortized over 15.4 years.

Keywords: Rainwater, Rainwater Harvesting, Water, Water management, Sustainability, Water Scarcity

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Öz: Su, dünya nüfusunun ve küresel ısınmanın etkilerinin giderek arttığı ve mevcut su kaynaklarının yok olmaya devam ettiği günümüzde kıymetini her geçen gün arttırmaktadır. Su kaynaklarında yaşanan yetersizlikler çevre ve tüm canlılar için sorunlar ortaya çıkarmaktadır. Bu nedenle mevcut su kaynaklarının korunması veya alternatif kaynaklar yaratılması zorunlu hale gelmiştir. Yağmur suyu hasadı, alternatif bir su kaynağı oluşturmak için etkili bir yöntemdir. Bu çalışmada yağmur suyu hasadı yöntemi ile Bursa Uludağ Üniversitesi Ziraat Fakültesinde bulunan binaların aylık ve yıllık olarak su depolama potansiyelleri belirlenerek, fakültede bulunan çim alanın sulanması ve binalarda ihtiyaç duyulan su miktarının karşılanması olmak üzere iki farklı senaryoda ihtiyacın karşılanma oranları hesaplanmış ve elde edilecek ekonomik kazanç miktarının belirlenmesi amaçlanmıştır. Çalışma sonucunda, yağmur suyu hasadı yöntemi ile 2045.16 m^3'lük yıllık su toplama potansiyeline sahip olduğu belirlenmiştir. Sistemin kurulumu ile birlikte fakültede yıllık olarak 76858 Türk Lirası(TL) ekonomik kazanç elde edildiği ve sistemin ilk yatırım maliyetlerinin 15.4 yıllık bir sürede amorti edildiği sonucuna varılmıştır.

Anahtar Kelimeler: Yağmur Suyu Hasadı, Su, Su Yönetimi, Sürdürülebilirlik, Su Kıtlığı

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INTRODUCTION

Water is one of the basic needs necessary for living beings to sustain their lives. In order to maintain the balance of nature, prevent health problems in living beings, and avoid disruption of the economic order, the efficient use of water has become imperative (Firidin, 2014; Kayaer and Çiftçi, 2018). As the world's population grows each year, the water demand is also increasing accordingly. Due to factors such as global warming, the industrial revolution, and similar causes of environmental pollution and damage, despite the increasing need for water, existing water resources worldwide are being depleted (Doğan and Sever, 2023). In addition to only 3.5% of the total water available worldwide being usable, the losses occurring in existing water resources are causing water problems to increase daily (Aksungur and Firidin, 2008).

Due to the losses in the world's water resources, significant administrative and economic difficulties are being experienced. In countries, if the annual per capita water amount is between 1700 m^3 and 1000 m^3, limited water scarcity occurs, and if it falls below 1000 m^3, water poverty emerges (Evsahibioğlu et al., 2010; Uçar, 2022). Türkiye is losing its water resources day by day and facing increasing water problems due to various reasons such as environmental pollution, inefficient irrigation in agriculture, unsustainable water projects, and climate change. Türkiye while the annual amount of water per capita was 1519 m^3 in 2014, it is expected to decrease to 1120 m^3 in 2030 (Uyduranoğlu Öktem and Aksoy, 2014). While Türkiye is a water-scarce country today, it will become a water-poor country in the coming years. Therefore, some steps must be taken to conserve and create new resources. Rainwater harvesting is an alternative solution to create a new water source and save water.

Rainwater harvesting can be defined as the collection of rainwater, which is then filtered and reused for various purposes. The use of water harvesting, which was first utilized in China 6000 years ago, has continued for thousands of years. This method, which was primarily used in areas where access to water was either non-existent or limited in the past, is now becoming more common in cities due to the increasing pollution and depletion of water resources (Alpaslan, 1992; Örs et al., 2011; Stahn and Tomini, 2016; Börü and Toprak, 2022). The rainwater harvesting system was made mandatory for new buildings on plots of 2,000 square meters and more significant by the Ministry of Environment and Urbanization in 2021 (T.C Resmi Gazete; 2021). As the use of the system becomes increasingly widespread, significant amounts of water and economic gains can be achieved.

This study determined the rainwater harvesting potential of the buildings at the Faculty of Agriculture, Bursa Uludağ University. The rate of meeting the monthly and annual total water requirements for the students, academic, and administrative staff at the faculty, as well as the economic analysis and system designs, were aimed to be established.

MATERIAL AND METHOD

Study Area

This study determined the rainwater storage potential and economic analysis of 6 buildings, namely the Dean's office, lecture hall, and blocks A, B, C, and D, located in the Faculty of Agriculture at Bursa Uludağ University. The buildings where the study was conducted are shown in Figure 1 (Anonymous, 2015). In the study, Equations 1 and 2 were used to determine the rainwater storage potential (m^3) of buildings and the tank volume (m^3) to be used in system designs (DIN, 1989; Yalılı Kılıç et al., 2023; Dağ and Ay, 2024).

Figure 1. Buildings where the study was conducted at the faculty of agriculture, Bursa Uludağ University.
Şekil 1. Bursa Uludağ Üniversitesi Ziraat Fakültesinde çalışmanın yürütüldüğü binalar.

Data Collection and Rainwater Calculation

In the study, Equations 1 and 2 were used to determine the rainwater storage potential (m^3) of buildings and the tank volume (m^3) to be used in system designs (DIN, 1989; Yalılı Kılıç et al., 2023; Dağ and Ay, 2024).

$$\text{Rainwater Storage Potential} = RA \times AOR \times RC \times FAC \quad (1)$$

$$\text{Tank Volume} = HMP \times AOR \times RC \times FAC \quad (2)$$

RA: The roof area (m^2) of the building

AOR: The average rainfall amount (mm) in the region

HMP: The highest rainfall amount (mm) of the year.

RK: The coefficient indicates the amount of precipitation that cannot be collected on the roof. It is expressed as 0.8 in DIN 1989.

FAC: The coefficient expressing the loss of collected rainwater during the first filtration stage. It is expressed as 0.9 in DIN 1989.

Within the scope of the study, the roof areas of all buildings at the Faculty of Agriculture, Bursa Uludağ University, were calculated using a laser meter (Extech DT300, Extech Instruments, USA) to determine their rainwater storage potential. The roof areas of the buildings where the study was conducted are provided in Table 1.

Table 1. Roof areas of the buildings where the study was conducted.
Çizelge 1. Çalışmanın yapıldığı binaların çatı alanları.

Work on completed buildings	Roof areas (m^2)
A and B Blocks	2109.33
C block and Lecture Hall	1630.92
D block	1079.12
Dean's Office	819.04

The average monthly precipitation amount for the Bursa region, where the study was conducted, between 1928-2023 was obtained from the official website of the General Directorate of Meteorology. The monthly average precipitation amount is provided in Table 2 (MGM, 2025).

Table 2. Monthly average rainfall in the Bursa region.
Çizelge 2. Bursa bölgesinde aylık ortalama yağış miktarları.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Avg. of rained day number (day)	14.77	13.43	12.63	11.3	9.02	6.16	3.06	2.91	5.09	8.95	11.11	14.15
Amount of rainfall (mm)	88.5	76	70.3	62.2	50.5	35.5	21.9	18.2	43.2	65.8	77.8	98.9

Calculations were made in two different scenarios regarding the amount of water to be obtained through rainwater harvesting: one for meeting the water needs of the people using the buildings in the faculty and the other for irrigating the 5677 m^2 grass area in the Faculty of Agriculture.

In the first scenario, the potential to meet the needs of the people using the buildings with the amount of water obtained has been determined. While calculating the average water consumption in the buildings, the number of students studying in the Faculty of Agriculture and the number of academic and administrative staff were considered. The average water consumption per student is considered while calculating the water consumption amount for students. In contrast, parameters such as sink usage, general cleaning tasks, and dishwashers are considered for academic and administrative staff. Table 3 shows the average water used for calculating water consumption (Anonymous, 2024).

Table 3. Average water quantities required for calculating water consumption.
Çizelge 3. Su tüketimini hesaplamak için gereken ortalama su miktarları.

Average water consumption areas	Amount of water (liters)	Unit
Student	5	L/day/student
Dishwasher	20	L/day/personnel
Use of the Sink	22,5	L/day/personnel
Cleaning	10	L/day/personnel

Based on the numbers of all administrative and academic staff and students using the buildings in the faculty, as well as the daily average water consumption amounts, the necessary total water consumption amounts have been calculated. Since the buildings are not used on weekends, calculations have been made based on an average of 23 days per month.

In the second scenario, while calculating the annual water requirement for the grass area, the necessary water consumption amounts were calculated by considering the rainfall amounts in May, June, July, August, and September when irrigation will be carried out. When looking at the long-term average in the Bursa region, the total rainfall amount during the months when irrigation will be carried out is 169.3 mm, while a total of 650.07 mm of irrigation should be applied per square meter. Using the obtained data, the annual irrigation water requirement for the grass area has been calculated (Emekli et al. 2007; Yönter et al. 2023).

RESULTS AND DISCUSSION

Rainwater Harvesting Calculations

The amount of water to be collected from the buildings has been calculated using the rainwater harvesting potential formula. Based on the number of students, academic, and administrative staff using the buildings where the study was conducted, and the average per capita water consumption amounts, the total water consumption amounts and the coverage rates of the needs for all buildings have also been determined. The study achieved the highest annual water collection amount in the A and B block buildings with 1076.47 m^3, and 65.93% of the total annual water requirement can be met. The Dean's office, with an annual water volume of 417.99 m^3, is at the lowest level of water harvesting, but due to its low water consumption, it has the highest coverage rate at 72.11%. The average annual water requirement for all the buildings in the faculty is 5248.83 m^3. With the established system, 2045.16 m^3 of water is collected from all buildings, meeting 38.96% of the need. Figure 2 provides the annual water collection and consumption amounts of all the buildings where the study was conducted.

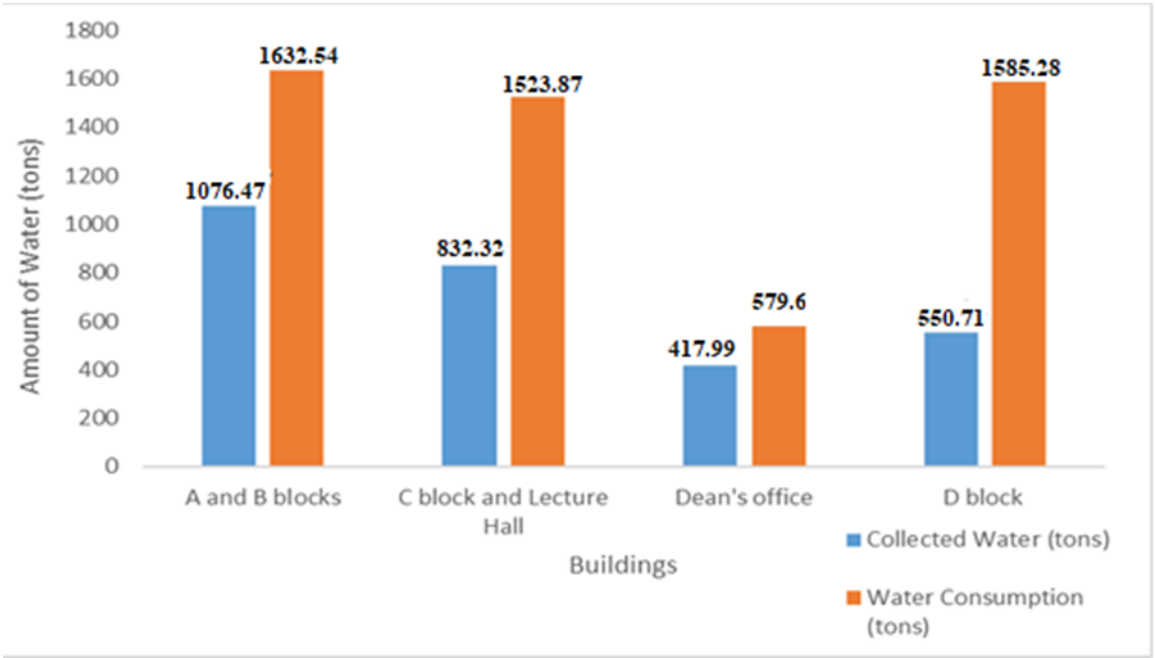

Figure 2. Annual collected and consumed water amount for all buildings.
Şekil 2. Tüm binalar için yıllık toplanan ve tüketilen su miktarı.

In order to prevent declines in the performance of the rainwater harvesting method, various precautions and maintenance should be carried out, taking seasonal realities into account. Excessive snow load, frost, and wind during the winter months can cause the gutters and pipes where water collects from the roofs to break. The leaves that fall from the trees in the spring months clog the gutters, causing a decrease in the

amount of water collected and leading to problems in the system. Due to these effects, there may be a decrease in the amount of water collected, and the existing system components may be damaged, resulting in economic losses. Therefore, the gutters, roofs, and system components need to be regularly inspected and maintained.

Due to the large roof areas of the A and B block buildings, the amount of water collected is high; however, the water consumption is also high because of the large number of students, administrative staff, and academic personnel using the buildings. In the A and B block buildings, 150.20 m^3 of water was collected in December, fully meeting the water demand water needs, while in the other months of the winter season, more than 80% of the total need can be met. In the summer months, due to the decrease in the number of students, the amount of water consumption decreases, and the collected water amount also drops to around 40 m^3, leading to a decrease in the rate of meeting the demand. In August, 25% of the water needed in blocks A and B was supplied, reaching the lowest fulfillment rate of the year.

Academic and administrative staff use the C block building in the faculty, while students use the Amphitheater building. The average water consumption in the C block and lecture hall is high at 132.02 m^3, but the water collected is low due to the smaller roof areas. In the winter months, more than 70% of the total water needs for the C block and lecture hall can be met, while in the summer months, the fulfillment of these needs drops to around 20%. Table 4 provides the monthly collected water, consumption, and the rate of meeting the total need for the A, B, and C blocks and the lecture hall buildings using the rainwater harvesting method.

Table 4. Monthly collected and consumed water amount and saving rate for A, B, C Blocks and Lecture hall buildings. *Çizelge 4. A, B, C Blok ve Derslik binaları için aylık toplanan ve tüketilen su miktarı ve tasarruf oranları.*

Months	A and B blocks			C block and Lecture Hall		
	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)
January	134.41	145.475	92.39	103.92	132.02	78.72
February	115.42	145.475	79.34	89.24	132.02	67.60
March	106.77	145.475	73.39	82.55	132.02	62.53
April	94.46	145.475	64.94	73.04	132.02	55.32
May	76.70	145.475	52.72	59.30	132.02	44.92
June	53.91	107.755	50.03	41.69	111.895	37.25
July	33.26	107.755	30.87	25.72	111.895	22.98
August	27.64	107.755	25.65	21.37	111.895	19.10
September	65.61	145.475	45.10	50.73	132.02	38.42
October	99.93	145.475	68.69	77.27	132.02	58.53
November	118.16	145.475	81.22	91.36	132.02	69.20
December	150.20	145.475	100.00	116.13	132.02	87.97
Total	1076.47	1632.54	65.9	832.31	1523.86	54.6

Students at the faculty use the D block building. There are 23 classrooms in that building. Due to the large number of classrooms in Block D, the monthly water consumption amount is 150.995 m^3, making it the highest of all the buildings. Although the water consumption in Block D is higher than in all other buildings, the roof area is smaller than in the other buildings, resulting in the lowest level of need fulfillment. In the D block building, 50.89% of the water needs were met with 76.84 m^3 of water in December, while in August, 18.74% of the water needs were met with 14.14 m^3 of water. Due to the decrease in the number of students during the summer months, the buildings that are more frequently used by students experience a reduction in water consumption during these months.

In the Dean's office, the amount of water collected is low due to the small roof area; however, since the building is used by administrative staff, the need is met at a high level because the monthly water

consumption is low. In the Dean's office, while the total need can be fully met in December and January, only 92.79% is met in February. Table 5 provides the monthly collected water amount, consumption amount, and the rate of meeting the total need for the D block and Dean's Office buildings using the rainwater harvesting method.

Table 5. Monthly collected and consumed water amount and savings rate for D block and Dean's office.
Çizelge 5. D blok ve dekanlık binası için aylık toplanan ve tüketilen su miktarı ve tasarruf oranları.

Months	D blocks			Dean's Office		
	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)
January	68.76	150.995	45.54	52.19	48.3	100.00
February	59.05	150.995	39.11	44.82	48.3	92.79
March	54.62	150.995	36.17	41.46	48.3	85.83
April	48.33	150.995	32.01	36.68	48.3	75.94
May	39.24	150.995	25.99	29.78	48.3	61.66
June	27.58	75.44	36.56	20.93	48.3	43.34
July	17.02	75.44	22.56	12.91	48.3	26.74
August	14.14	75.44	18.74	10.73	48.3	22.22
September	33.56	150.995	22.23	25.48	48.3	52.74
October	51.12	150.995	33.86	38.80	48.3	80.34
November	60.45	150.995	40.03	45.88	48.3	94.99
December	76.84	150.995	50.89	58.32	48.3	100.00
Total	550.71	1585.27	34.74	417.98	579.6	72.12

The rate at which the irrigation water needs of the grass area in the faculty between May and September have been met has been calculated. The amount of water obtained from all buildings during the irrigation periods meets 18.6% of the required water amount. The amounts of water collected during the months when irrigation is not carried out are planned to be used for the people in the building, as in the other scenario. The potential for meeting the irrigation needs of the grass area using the rainwater method is provided in Table 6.

Table 6. The rate of meeting the need through rainwater harvesting during the irrigation period of grass area
Çizelge 6. Sulama döneminde yağmur suyu hasadı yöntemi ile çim alanın su ihtiyacının karşılanma oranı

Irrigation Season	Collected water (m^3)	Annual required water amount (m^3)	Saving rate (%)
MAY - SEPTEMBER	687.30	3690.472	18.6

In a study conducted similarly to this one, the rainwater harvesting method was used in university buildings, and work was carried out in 24 buildings on the central campus of Ege University in Izmir. Authors aimed to determine the potential amount of water that could be collected from these buildings using rainwater harvesting methods to meet the water needs for irrigating the green areas on the campus. As a result of the study, it was concluded that by installing a rainwater harvesting system in 24 buildings, an annual water harvest of 16.570.30 m^3 could be achieved. The rate of meeting the water requirement for the irrigation of green areas was found to be 11%, similar to this study (Özeren Alkan and Hepcan, 2022).

Yalılı Kılıç et al. (2023) in their study conducted at the Faculty of Theology of Bursa Uludağ University, aimed to determine the potential of the amount of water obtained through the rainwater harvesting method to meet the water needs for irrigating the green areas within the faculty. While determining the amount of water needed for irrigating the green areas on campus as 12.376 m^3 annually, they have also noted that 3.918 m^3 of water can be stored annually through rainwater harvesting methods. As a result of the study, they concluded that 31.7% of the annual water requirement for irrigating green areas could be met.

Design of Rainwater Harvesting System

While designing the rainwater harvesting system to be installed in the A and B block buildings, the slope of the land and the availability of suitable vacant land for the reservoirs were considered, and it was decided to install the system on the north facade of the buildings. In the system to be established, considering the amount of water collected from the A and B block buildings during the year with the highest rainfall, three galvanized modular water tanks with a storage capacity of 50 m^3 each will be used, totaling 150 m^3. Due to the large total roof area of the A and B block buildings, a filter system with a high water filtration rate has been added. Due to the low rainfall, the amount of water collected in the system has decreased, and three-way valves have been added separately for each tank to facilitate tasks such as cleaning. Figure 3 shows the design of the rainwater harvesting system to be installed in the A and B block buildings.

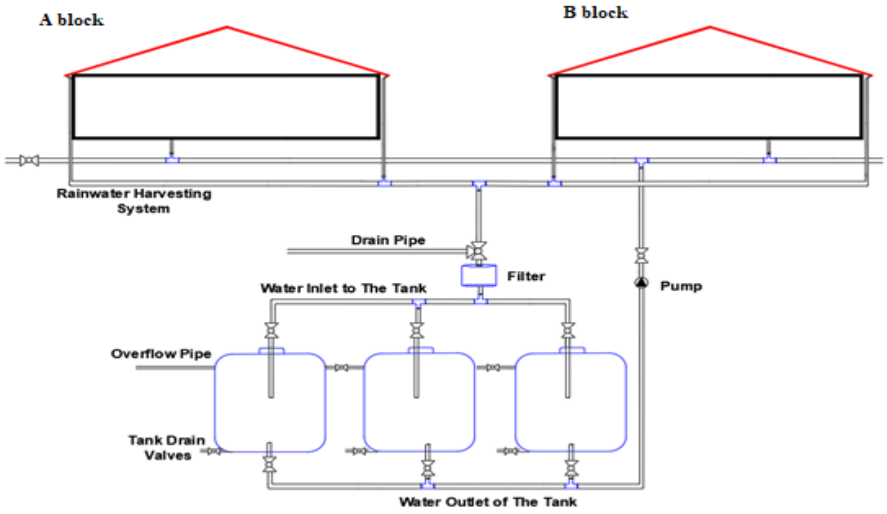

Figure 3. Rainwater harvesting system design for blocks A and B.
Şekil 3. A ve B blokları için yağmur suyu hasadı sistemi tasarımı.

While designing the system for the C block and Dean's office buildings, it was decided to use two 50 m^3 and one 20 m^3 galvanized modular water tank, totaling 120 m^3, considering that December has the highest rainfall, collecting 116.13 m^3. The system is planned to be installed on the eastern facade of the buildings. To facilitate the easy emptying of the tanks in case of malfunction or cleaning, tank drainage valves, and an overflow pipe have been added to the system design. Figure 4 provides the design of the rainwater harvesting system to be installed in the C block and Lecture hall buildings.

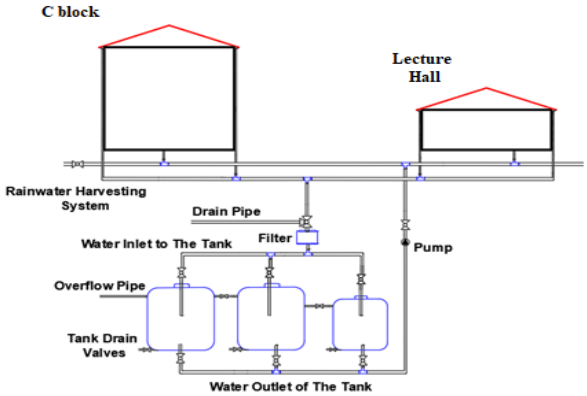

Figure 4. Rainwater harvesting system design for block C and Lecture hall buildings.
Şekil 4. C bloğu ve Derslik binaları için yağmur suyu hasadı sistemi tasarımı.

It is planned to use two tanks with a total water capacity of 60 m^3, one with 50 m^3 and the other with 10 m^3, for the design of the rainwater system of the Dean's office building. Due to the smaller roof area of the Dean's Office building compared to other buildings, a filter with a lower filtration rate was preferred in this design, considering the cost. Figure 5 shows the design of the rainwater harvesting system to be installed in the Dean's office building.

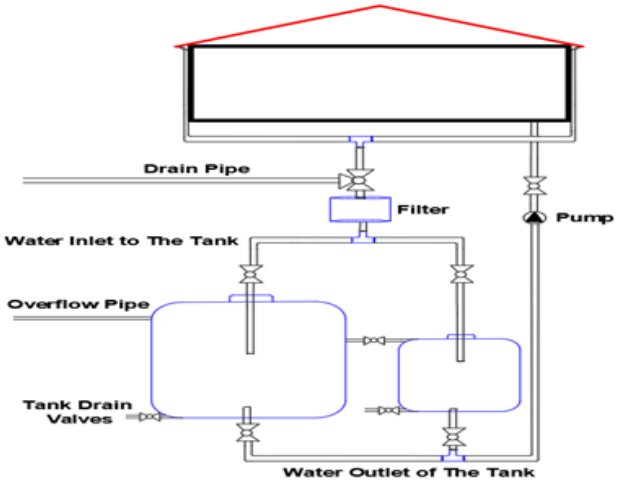

Figure 5. Rainwater harvesting system design for the Dean's building.
Şekil 5. Dekanlık binası için yağmur suyu hasadı sistemi tasarımı.

In the D block building located in the faculty, despite the high usage due to the low amount of water collected, it is planned to use two tanks with a total capacity of 80 m^3, one with a capacity of 50 m^3 and the other with a capacity of 30 m^3. The western facade was preferred for installing the system because the parking lot is the most suitable area around the building. Figure 6 provides the design of the rainwater harvesting system to be installed in Block D.

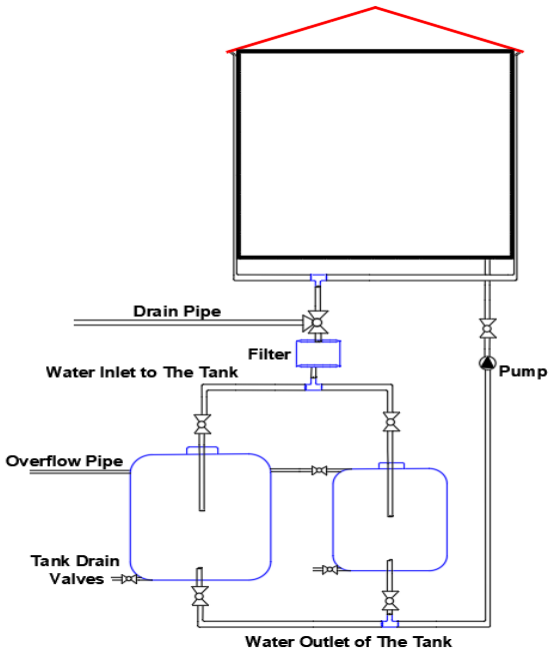

Figure 6. Rainwater harvesting system design for block D building.
Şekil 6. D blok binası için yağmur suyu hasadı sistemi tasarımı.

One of the effects of climate change is excessive rainfall. Especially due to the increase in urbanization, these heavy rains cause floods, high economic damages, and loss of life. (Sılaydın Aydın ve Kahraman, 2022). The rainwater harvesting method also provides benefits as a measure against floods in cases of excessive rainfall.

Economic Analysis of Rainwater Harvesting Method

An economic analysis evaluation was conducted for all buildings where the rainwater harvesting method was applied. Water fee calculations have been carried out considering the pricing implemented by the General Directorate of Bursa Water and Sewerage Administration (BUSKI). As a result of the evaluation, the highest profit from the water fee is achieved from the A and B block buildings, amounting to 28811 TL annually. The study obtained the lowest profit amount in the Dean's building, with an annual profit of 10885 TL. Figure 7 provides the water fees before and after implementing the rainwater harvesting method for all buildings where the study was conducted.

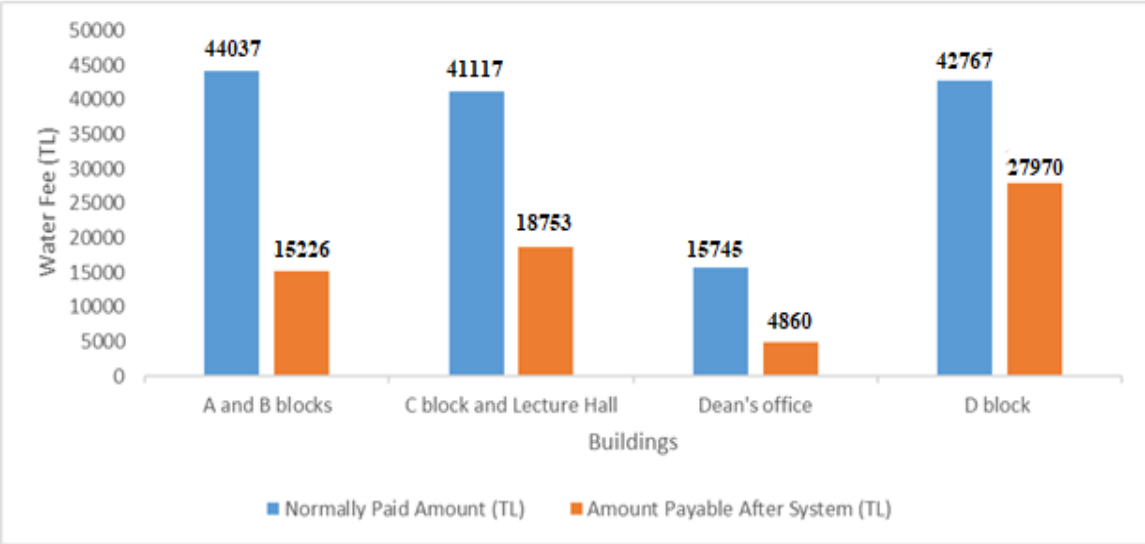

Figure 7. Water costs before and after rainwater harvesting method for all buildings.
Şekil 7. Tüm binalar için yağmur suyu hasadı yöntemi öncesi ve sonrası su maliyetleri.

With the establishment of the rainwater harvesting method in all the buildings where the study is conducted, water conservation is achieved, and significant economic benefits are obtained. The average monthly water fee before the rainwater system was 3669.76 TL in the A and B block buildings. In contrast, after installing the rainwater system in the buildings, the average monthly water fee decreased to 1268.83 TL. In December, when the highest amount of rainfall is collected from these buildings, the entire water need is met, so no water fee is charged.

In the C block and Lecture hall buildings, the water fee to be paid during the Spring, Autumn, and Winter seasons is 3561.61 TL, while due to the decrease in the number of students during the summer months, the water fee is at the level of 3020.87 TL. After installing the system, the average monthly water fee will be 1562.78 TL. Table 7 provides the monthly profit amount to be obtained after installing the rainwater harvesting system in Blocks A, B, C, and the Lecture hall building.

In the D block building, the average water fee paid over the 9 months of the year is 4071.45 TL, while it drops to 2041.35 TL during the summer months. The average monthly water fee paid for Block D is 3563.92 TL. The average water fee to be paid after the system is 2330.83 TL. A monthly average economic gain of 34.6% is achieved from the water bill of the Block D building.

Table 7. Amount of profit obtained from the rainwater system of blocks A, B, C, and the Lecture hall building.
Çizelge 7. A, B, C blokları ve Anfi binasından yağmur suyu sistemi ile elde edilen kar miktarı.

Months	A and B blocks			C block and Lecture Hall		
	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)
January	3923.14	311.74	3611.40	3561.61	769.30	2792.31
February	3923.14	821.83	3101.31	3561.61	1163.70	2397.91
March	3923.14	1054.42	2868.71	3561.61	1343.54	2218.07
April	3923.14	1384.96	2538.18	3561.61	1599.11	1962.50
May	3923.14	1862.40	2060.74	3561.61	1968.26	1593.35
June	2909.63	1460.99	1448.64	3020.87	1900.79	1120.08
July	2909.63	2015.96	893.67	3020.87	2329.89	690.98
August	2909.63	2166.95	742.68	3020.87	2446.63	574.24
September	3923.14	2160.29	1762.85	3561.61	2198.59	1363.02
October	3923.14	1238.05	2685.08	3561.61	1485.52	2076.09
November	3923.14	748.37	3174.76	3561.61	1106.91	2454.71
December	3923.14	0.00	3923.14	3561.61	441.17	3120.44
Total	44037.12	15225.96	28811.16	41117.11	18753.41	22363.69

Due to the low water consumption in the Dean's office building, the water fee is the lowest among all buildings, averaging 1312.12 TL per month. With the rainwater harvesting system, the Dean's Office building achieves an average monthly economic gain of 907.15 TL, resulting in a 69.1% saving. Table 8 shows the monthly profit obtained after installing the rainwater harvesting system in the D Block and Dean's Office buildings.

Table 8. Amount of snow obtained from the rainwater system of block D and the Dean's office buildings.
Çizelge 8. D Blok ve Dekanlık binasından yağmur suyu sistemi ile elde edilen kar miktarı.

Months	Dean's Office			D block		
	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)
January	1312.12	0	1312.12	4071.45	2223.89	1847.57
February	1312.12	107.90	1204.22	4071.45	2484.84	1586.61
March	1312.12	198.22	1113.90	4071.45	2603.84	1467.62
April	1312.12	326.56	985.56	4071.45	2772.94	1298.52
May	1312.12	511.95	800.17	4071.45	3017.19	1054.26
June	1312.12	749.62	562.50	2041.35	1300.24	741.11
July	1312.12	965.12	347.01	2041.35	1584.16	457.19
August	1312.12	1023.74	288.38	2041.35	1661.40	379.95
September	1312.12	627.62	684.50	4071.45	3169.59	901.86
October	1312.12	269.52	1042.60	4071.45	2697.78	1373.67
November	1312.12	79.38	1232.74	4071.45	2447.27	1624.19
December	1312.12	0	1312.12	4071.45	2006.77	2064.68
Total	15745.44	4859.63	10885.82	42767.1	27969.91	14797.23

It has been decided to use galvanized modular water tanks to install rainwater harvesting systems in all buildings of the Faculty of Agriculture. Galvanized modular water tanks have been preferred due to their durability, long lifespan, ease of installation, use, maintenance, and cost-effectiveness (Anonymous, 2025a). Two different rainwater filters have been used in the system, considering the roof sizes of the buildings. Table 9 provides the materials and price list for the rainwater harvesting system to be installed.

Table 9. List of materials and prices used in the rainwater system.
Çizelge 9. Yağmur suyu sisteminde kullanılan malzemelerin listesi ve fiyatları.

Material	Number	Price	References
50-ton galvanized modular water tank	7	868000	Anonymous (2025a)
30-ton galvanized modular water tank	1	84000	
20-ton galvanized modular water tank	1	58500	
10-ton galvanized modular water tank	1	34000	
YFVR-0200 Polyethylene (HDPE) Rainwater Filter	2	36200	Anonymous (2025b)
YFVR-3000 Polyethylene (HDPE) Rainwater Filter	2	77173	
Clean Water Submersible Pump	4	22812	Anonymous (2025c)

The initial investment costs required for installing the rainwater harvesting system in all the buildings where it will be implemented amount to 1180685 TL. With the system installed in all buildings, the annual savings from the water fee amount to 76858 TL. The payback period for the initial cost of the system is 15.4 years. Galvanized modular water tanks have been preferred despite being more durable than polyethylene water tanks because there is not a significant price difference between them. So the galvanized steel modular water tanks used in the study are long-lasting, therefore, in addition to the annual gain of 2877 m^3 of water from the system, economic benefits can also be obtained for many years after the payback period. In both scenarios, there is no change in the amount of economic profitability obtained and the initial costs due to the complete utilization of the annually collected water.

Şimşek and Demir (2023) in their study conducted at On Dokuz Mayıs University, aimed to determine the ratio of the amount of water obtained from the roof of the library on campus through rainwater harvesting to the amount of water needed for irrigation purposes on campus. With the implementation of the rainwater harvesting method on the campus, it has been determined that 33.8% of the annual water requirement for irrigation can be met, and an annual economic gain of 41359.32 TL can be achieved from water fees. As a result of the study, they concluded that the initial investment costs of the system to be installed on the campus could be paid back in 8.7 years.

Dündar et al. (2015) in their study conducted at the Health Campus of Bülent Ecevit University, aimed to determine the potential of the amount of water obtained through rainwater harvesting from the buildings on the campus to meet the water needs for toilets, cleaning, and irrigation of green areas on the campus. In the study, the most economical result with the rainwater harvesting method was found using a reservoir with a capacity of 1200 m^3 to meet 70% of the total water requirement. As a result of the study, it has been determined that 22% of the targeted amount of water to be collected from the buildings on the campus through rainwater harvesting can be met, and a total economic gain of 2933780 TL will be achieved over 50 years. When comparing the cost of the system and the economic benefits obtained, they concluded that the system's payback period is 3 years.

Due to climate change, in addition to losses in existing water resources, there are also reductions in precipitation amounts. This situation is one of the risky aspects of the rainwater harvesting method. Because in the coming years, the significant decrease in rainfall will lead to a decrease in the water level collected, which will cause economic losses to the buildings where the system will be installed.

CONCLUSION

This study was conducted to perform a technical and economic analysis under two different scenarios: one where the amount of water obtained from the installation of a rainwater harvesting system in the buildings of the Faculty of Agriculture at Bursa Uludağ University meets the annual water requirement of the grass area in the faculty, and the other where it meets the water needs of the students, academic, and administrative staff in the faculty. The rainwater harvesting method has determined the average monthly and annual water supply rates for all buildings in the Faculty of Agriculture. The buildings were grouped according to location, and calculations and system designs were carried out.

In the first scenario, calculations were carried out to compare the amount of water obtained through the rainwater method with the consumption amounts of the people using the buildings and to determine the amount of savings.The highest amount of water harvested in the study was 1076.47 m^3 from the A and B block buildings. The amount of water harvested from the A and B block buildings meets 65.93% of the water requirement for these buildings. Among the buildings in the faculty, the building with the lowest water storage was the Dean's Office, with a water volume of 417.99 m^3. When calculating the total water consumption based on the daily average water consumption of students, academic, and administrative staff using all the buildings in the Faculty of Agriculture where the study was conducted, it is determined that an annual amount of 5248.83 m^3 of water is needed. With the installation of the rainwater harvesting method in buildings, an average annual water amount of 2045.16 m^3 can meet 38.96% of the total need.

In the second scenario, calculations were made to determine the amount of irrigation water needed for the 5677 m^2 grass area in the faculty between May and September, which would be met through rainwater harvesting. A total of 687.30 m^3 of water is collected from all the buildings in the faculty between May and September. During this period, 18.6% of the 3690.4 m^3 of water needed for irrigation can be met. In the second scenario, the amounts of water obtained during the periods outside the irrigation season are planned to be used for the consumption water needs of the buildings, just as in the first scenario.

In both scenarios, the economic gain is similar due to the full utilization of the water obtained and the lack of changes in the initial costs. With the established system, an economic gain of 76858 TL is achieved from the annual water fee paid by the faculty. The initial investment cost required for installing the system in all buildings is 1180685 TL. The initial investment cost paid for installing the system is payback over 15.4 years, along with the economic gain from the water fee.

While designing the rainwater harvesting system, it was decided to use galvanized modular steel tanks due to their durability, long lifespan, and low cost. In the designs, two different filters were used, considering the roof sizes of the buildings. Considering the cleaning, maintenance, malfunction, and excess capacity rainfall situations of the tanks, tank drainage valves, overflow, and discharge pipes have been added to the system designs.

As a result of implementing the rainwater harvesting method in the buildings of the Faculty of Agriculture at Bursa Uludağ University, significant water and economic savings are being achieved. Due to the large number of buildings and extensive roof areas on university campuses, rainwater harvesting is a highly profitable method. Due to the high water and economic savings achieved, it has been concluded that this method could be an alternative for use in university buildings for the conservation of existing water resources and the creation of new water resources.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

DECLARATION OF AUTHOR CONTRIBUTION

The authors' contributions to the article are equal.

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Research Article

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Effects of Saline-Alkaline Soils on Forage Quality of Some Quinoa (*Chenopodium quinoa* Willd.) Varieties

Bazı Kinoa (*Chenopodium quinoa* Willd.) Çeşitlerinin Yem Kalitesine Tuzlu-Alkali Toprakların Etkileri

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Abstract: In this research, the forage quality performances of 7 different quinoa varieties in saline-alkaline soils were determined. The study was established using the factorial experimental design in random blocks with 3 replications for 2 years (2021-2022). Sandoval Mix (SM), Red Head (RH), Titicaca (T), Moqu Arrochilla (MA), French Vanilla (FV), Oro de Valle (OV), and Rainbow (R) varieties were used in the experiment. According to the research results, there was only a difference in the crude protein (CP) ratio over the years. Compared to the control soil, saline-alkaline soils had no effect on crude protein content, but caused significant changes in neutral detergent fibre (NDF), acid detergent fibre (ADF), dry matter intake (DMI), dry matter digastiblity (DMD), metabolized energy (ME), relative feed values (RFV) and digestible energy (DE). It was determined that there were significant differences in the forage quality of the quinoa varieties used in the study. According to the research results, Sandoval Mix, Red Head, French Vanilla and Oro de Valle quinoa varieties, which do not show a decrease in crude protein content, should be preferred in quinoa cultivation in saline-alkaline soils. On the other hand, quinoa cultivation should be carried out by taking into account that there will be an increase in NDF content and a decrease in DMI and RFV contents, which are important quality features of quinoa varieties in saline-alkaline soils.

Keywords: Saline, Crude Protein, NDF, ADF, RFV

&

Öz: Bu araştırmada 7 farklı kinoa çeşidinin tuzlu-alkali topraklardaki yem kalite performasnları belirlenmiştir. Çalışma 2 yıl süreyle (2021-2022) tedadüf bloklarında faktöriyel deneme desenine göre 3 tekerrürlü olarak kurulmuştur. Denemede Sandoval Mix (SM), Red Head (RH), Titicaca (T), Moqu Arrochilla (MA), French Vanilla (FV), Oro de Valle (OV) ve Rainbow (R) çeşitleri kullanılmıştır. Araştırma sonuçlarına bakıldığında yıllara göre sadece ham protein (HP) oranında farklılık olmuştur. Kontrol toprağına göre, tuzlu-alkali toprakların ham protein oranı üzerine herhangi bir etkisi olmazken, nötr çözücülerde çözünemeyen lif (NDF), asit çözücülerde çözünmeyen lif (ADF), kuru madde tüketimi (KMT), kuru madde sindirilebilirliği (KMS), sindirilebilir enerji (SE), nispi yem değeri (NYD) ve metabolik enerji (ME) değerlerinde önemli değişimlere neden olmuştur. Araştırmada kullanılan kinoa çeşitlerinin besin değerlerinde önemli farklılıklar olduğu belirlenmiştir. Araştırma sonuçlarına göre, tuzlu-alkali topraklarda kinoa yetiştiriciliğinde ham protein oranında azalma göstermeyen Sandoval Mix, Red Head, French Vanilla ve Oro de Valle kinoa çeşitlerinin tercih edilmesi gerekmektedir. Diğer taraftan tuzlu-alkali topraklarda kinoa çeşitlerinin önemli kalite özelliklerinden NDF içeriğinde artış olacağı ve KMT ve NYD içeriklerinde ise azalış olacağı göz önüne alınarak kinoa yetiştiriciliğinin yapılması gerekmektedir.

Anahtar Kelimeler: Tuzluluk, Ham Protein, NDF, ADF, NYD

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INTRODUCTION

Extreme soil and climate conditions in the world are increasing day by day and limiting the number of products that can be grown in these areas. In addition, extreme climate and soil conditions (salinity, drought, erosion) significantly affect the forage and seed yields per unit area. Approximately 6% of the world's land and 20% of agricultural land are affected by salt (Munns and Tester, 2008). Saline areas are generally found in arid and semiarid areas (Masters et al., 2007). Ions such as Na+, Cl− and SO_4^{2-}, which increase in amount in saline soils, cause a decrease in water potential, ion toxicity in plants as a result of excess ion uptake, decrease in water uptake by plants and therefore slow down plant growth (Munns and Tester, 2008; Golos et al., 2016; Hussain et al., 2018). In saline areas, many crop plants cannot continue to develop and the yield per unit area is limited (Temel et al., 2015; Temel et al., 2016; Aras and Keskin, 2018).

In recent years, research has intensified to find alternative plants for the utilization of saline areas. One of the plants that can be grown in extreme soil conditions is quinoa. Quinoa is a species belonging to the *Chenopodium* genus, which contains approximately 250 species and mostly includes halophyte plants (Kadereit et al., 2005). Some quinoa species can continue their growth at an electrical conductivity salinity level of 600 mM NaCl (50 dS m^{-1}) (Biond et al., 2015). Seed germination in quinoa is not affected much up to 400 mM salinity level and continues to develop without significant yield reduction up to 10-20 dS m^{-1} electrical conductivity level (Pulvento et al., 2012; Jamali and Sharifan., 2018; Rezzouk et al., 2020; Keskin et al., 2023). On the other hand, quinoa is also resistant to adverse climatic conditions such as drought (Fuentes and Bhargava, 2011; Pulvento et al., 2012) and frost (Jacobsen et al., 2007; Rosa et al., 2009).

Quinoa is widely cultivated in South America and temperate regions as human food. Straw remaining during harvest for seed is evaluated as feed for animals (Blanco, 2015; Keskin and Önkür, 2019). Quinoa green parts are made into silage or fed directly to animals (Keskin and Duman, 2024; Keskin and Aksoy, 2024). Additionally, quinoa is rich in carotenoids, ascorbic acid, minerals and protein (Bhargava et al., 2007; Temel and Keskin, 2019a; Temel and Keskin, 2020). Thanks to its genetic diversity, quinoa has varieties that are adapted to different climate and soil conditions and that respond differently to extreme conditions (Morales et al., 2011; Tan and Temel, 2017).

Quinoa hay is used especially in the feeding of ruminant animals. Depending on the quinoa variety, around 4-8 tons ha^{-1} of dry matter can be obtained and 15-17% of the dry matter can consist of protein (Temel and Keskin, 2019a; Temel and Keskin, 2019b; Çağlayan and Kökten, 2021). No significant differences were observed in live weight gains between animals fed alfalfa hay and quinoa hay (Rubio and Rojas Lemus, 2007).

The aim of the present study was to determine some feed quality characteristics of hay belonging to different quinoa varieties grown in saline-alkaline soils and harvested at full bloom, which are important in animal nutrition.

MATERIAL AND METHOD

This research was carried out for 2 years (2021-2022) in the non-salt (control) and saline-alkaline trial areas of Iğdır University Agricultural Application and Research Center. In the research, Sandoval Mix, Red Head, Titicaca, Moqu Arrochilla, French Vanilla, Oro de Valle and Rainbow quinoa varieties with high yield capacity were used (Tan and Temel, 2017; Tan and Temel, 2018; Temel and Keskin, 2020).

The properties of the soils taken from the trial area are given in Table 1 (Richards, 1954; Ülgen and Yurtsever, 1974; FAO, 1990). When Table 1 is examined, it is seen that the pH of saline-alkaline soils is 9.8 and the EC value is 9.69 dS m^{-1}.

Some climate data for the year and long years in which the experiment was conducted are presented in Table 2. During the months of April, May and June when the experiment was conducted, the temperature varied between 17.0 °C and 26.8 °C and the relative humidity varied between 34.4% and 53.9%. The total rainfall for three months was 61 mm in 2021 and 106.6 mm in 2022. According to these data, 2021 was seen to be drier.

Table 1. Some properties of the trial soils.
Çizelge 1. Deneme topraklarının bazı özellikleri.

Analysis Name	Nonsaline soil		Saline soil	
	Value	Classification	Value	Classification
EC (dS m^{-1})	2.05	Nonsaline	9.69	Very saline
pH	8.41	Strong alkaline	9.80	Strong alkaline
Soil texture (Saturation %)	63.16	Clay loam	59.41	Clay loam
Organic Matter %	0.87	Very little	0.93	Very little

Table 2. Some climate data of the experimental area (Anonymous, 2022).
Çizelge 2. Deneysel alanın bazı iklim verileri (Anonim, 2022).

Months	Temperature (°C)		Precipitation (mm)		Relative humidity (%)	
	2021	2022	2021	2022	2021	2022
April	17.4	15.7	18.4	25.8	44.0	43.9
May	21.1	17.0	42.1	54.8	46.7	53.9
June	26.8	24.6	0.7	26.0	34.4	47.6
Ave/Total	21.7	19.1	61.2	106.6	41.7	48.4

In the experiment, seed sowing was done in the first week of April in both years. The trial plots were prepared as 8.75 m^2, 1.75 m wide and 5 m long. Seeds were sown at 35x10 cm intervals. Before planting, 80 kg ha^{-1} phosphorus (42% triple super phosphate) and 80 kg ha^{-1} nitrogen (21% ammonium sulphate) fertilizer was applied and mixed with the soil. Additionally, when the plant height reached 30 cm, an additional 50 kg ha^{-1} nitrogen fertilizer (21% ammonium sulphate) was given to each plot. When the useful water level in the soil reached 50%, irrigation was done with sprinkler irrigation systems. Forage harvests were made in the last week of June when full flowering occurred, leaving a 10 cm stubble height. After the harvested herbs were dried in the shade for a while, they were kept in a drying oven set at 70 °C for 48 hours and then ground with a grinding machine.

Crude protein ratios of ground hay were determined as nitrogen amounts according to the Kjeldahl method, and the crude protein percentage of the grass was determined by multiplying the determined nitrogen amounts by the coefficient of 6.25 (Baur and Ensminger, 1977). NDF and ADF ratios were determined with the Ankom fiber analyzer (Van Soest et al., 1991). DMD [88.9 - (0.779 x ADF)] (Oddy et al., 1983) and DMI (120 / NDF) (Sheaffer et al., 1995) ratios were determined by using NDF and ADF values. The amount of DE [0.27 + 0.0428 x (DMD)] was determined by using the DMD ratio (Fonnesbeck et al., 1984), and the amount of ME (0.821 x DE) was determined by using the DE ratio (Khalil et al., 1986). RFV value was determined by using DMD and DMI ratios (DMD x DMI / 1.29) (Sheaffer et al., 1995).

The data obtained in the experiment were subjected to variance analysis in the JMP 5.0.1 package program and the averages were grouped according to the LSD test.

RESULTS AND DISCUSSION

Some feed values of the harvested at full bloom are given in Table 3 and Table 4.

Crude Protein (CP)

Protein is essential for the growth and health of animals. Protein plays an important role in the formation of animal products (meat, milk). Meeting the energy needs of animals along with protein will contribute significantly to their growth, increased productivity and health (Kutlu et al., 2005; Kutlu and Özen, 2009). The crude protein content of quinoa grass has varied between years. It is estimated that the quinoa plant will grow better in 2022 (Table 2), when rainfall and air humidity are high, causing an increase in the crude protein ratio. Soil properties (control, saline-alkaline) had no effect on the crude protein content of quinoa plants. There were significant differences in crude protein ratios among the quinoa varieties used in the study. Crude protein content of Titicaca, Oro de Valle, Sandoval Mix, Red Head and Moqu Arrochilla quinoa varieties was higher than other varieties. The lowest crude protein content was observed in the French Vanilla variety (Table 3). Changes in crude protein ratios of quinoa varieties according to soil

properties (types) are given in Figure 1. Compared to the control soil, there was an increase in crude protein content in Sandoval Mix, Red Head, French Vanilla and Oro de Valle varieties in saline-alkaline soils, while there was a decrease in crude protein content in Titicaca, Moqu Arrochilla and Rainbow varieties. When plant species and varieties are grown in saline environments, some studies reported a decrease in crude protein ratio (Elfeel and Bakhashwain, 2012; Temel et al., 2015; Kılıç et al., 2015; Hedayati-Fifoozabadi et al., 2020; Waldron et al., 2020; Şen et al., 2021), some studies reported an increase (Fowler et al., 1992; Heidari et al., 2023) and some studies reported no significant change (Suyama et al., 2007; Masters et al., 2010; Temel et al., 2016; Mahmoud and Sallam, 2017). It is thought that the genetic structure of the varieties and their different responses to salinity cause their crude protein contents to differ.

Table 3. CP, NDF, ADF and DMD of quinoa plant grown in saline-alkaline and non-saline soils.
Çizelge 3. Tuzlu-alkali ve tuzsuz topraklarda yetiştirilen kinoa bitkisinin HP, NDF, ADF ve KMS değerleri.

Years (Y)	CP (%)	NDF (%)	ADF (%)	DMD (%)
2021	17.5 b	32.3	19.6	73.7
2022	18.5 a	32.8	19.3	73.8
Soil type (S)				
Control	17.9	30.0 b	18.1 b	74.8 a
Salty-alkaline	18.1	35.1 a	20.8 a	72.7 b
Varieties (V)				
Sandoval Mix	18.2 a-c	35.0 a	20.6 a	72.8 b
Red Head	18.1 ab	32.4 b	19.8 a	73.5 b
Titicaca	19.3 a	30.2 c	16.6 b	76.0 a
Moqu Arrochilla	18.0 ab	32.0 b	19.4 a	73.8 b
French Vanilla	16.6 d	33.4 b	20.3 a	73.1 b
Oro de Valle	18.8 ab	33.3 b	19.6 a	73.6 b
Rainbow	17.0 cd	31.6 bc	19.9 a	73.4 b

The difference between the averages shown with the same letters is not significant.

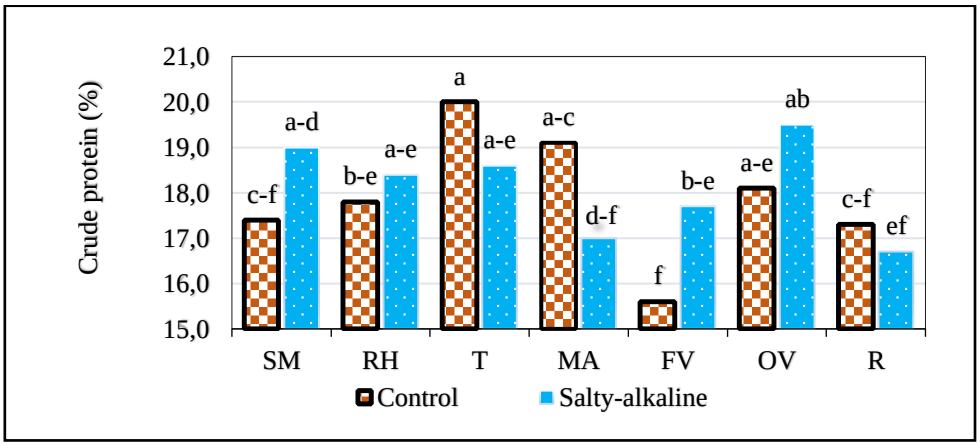

Figure 1. Changes in crude protein content of quinoa varieties according to soil properties.
Şekil 1. Toprak özelliklerine göre kinoa çeşitlerinin ham protein oranlarındaki değişimler.

Neutral Detergent Fibre (NDF)

The total of cellulose, hemicellulose, lignin and silicon contents in the structure of agricultural products is called NDF (Neutral detergent fiber). NDF gives an idea about the feed consumption of animals or the specific gravity of the feed (Kutlu et al., 2005). The NDF content of quinoa grass did not differ among the years. Soil properties (control, saline-alkaline) significantly affected the NDF content of quinoa plants. An increase in NDF ratio was observed in quinoa plants grown in saline-alkaline soils compared to the control soil. There were significant differences between the NDF rates of the quinoa varieties used in the study. While the NDF contents of the Titicaca and Rainbow varieties were lower, the NDF rate of the Sandoval Mix variety was higher than the other varieties (Table 3). Changes in NDF rates of quinoa varieties according to soil types (properties) are given in Figure 2. Compared to the control soil, there was an increase

in NDF rates of all quinoa cultivars in saline-alkaline soils. In studies conducted with different plant species and varieties growing in saline environments, the NDF content of the plant increased in some studies (Masters et al., 2010; Elfeel and Bakhashwain, 2012; Temel et al., 2015; Kılıç et al., 2015; Hedayati-Firoozabadi et al., 2020; Waldron et al., 2020; Heidari et al., 2023), decreased in some studies (Fowler et al., 1992; Temel et al., 2016; Mahmoud and Sallam, 2017; Anderson et al., 2023) and no significant change was reported in some studies (Suyama et al., 2007). Extreme climate and soil conditions (salinity, drought, high temperature, low rainfall) cause an increase in plant cell walls and a decrease in carbohydrate content (Al-Dakheel et al., 2015). As a result, it causes an increase in NDF and ADF rates in the plant and thus a decrease in forage quality. In addition, the decrease in minerals taken by the plant from the soil causes the fiber content to increase (Blanco, 2015).

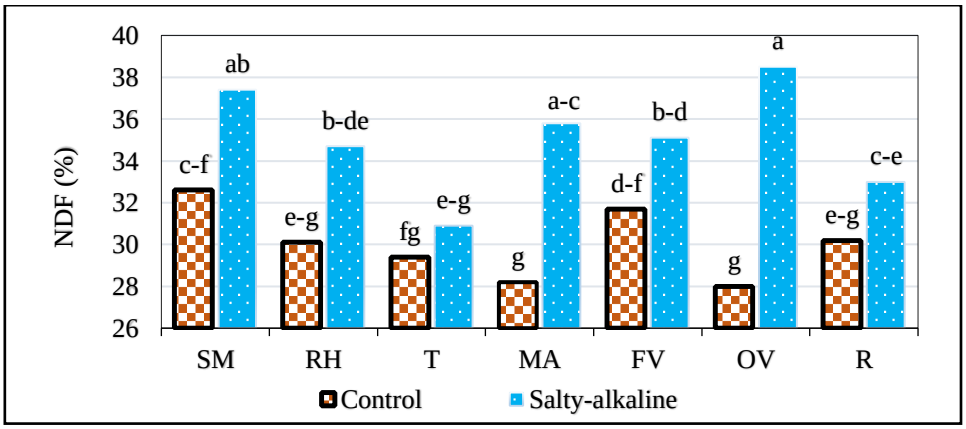

Figure 2. Changes in NDF rates of quinoa varieties according to soil properties.
Şekil 2. Toprak özelliklerine göre kinoa çeşitlerinin NDF oranlarındaki değişimler.

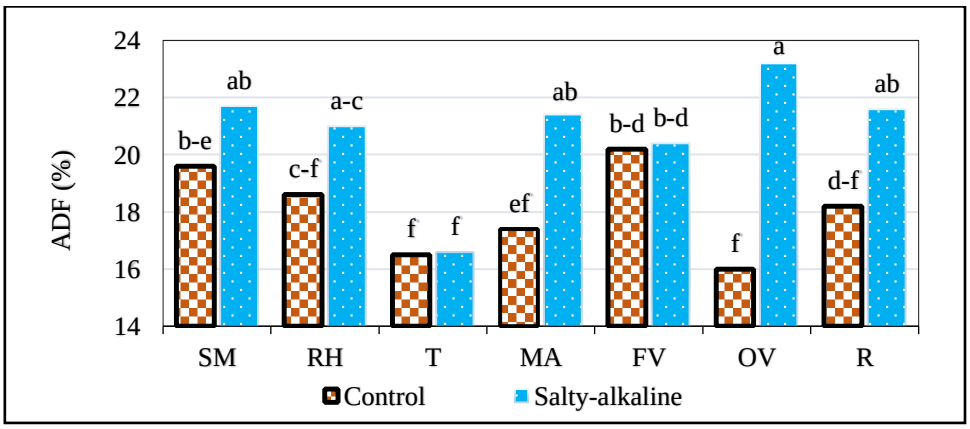

Figure 3. Changes in ADF rates of quinoa varieties according to soil properties.
Şekil 3. Toprak özelliklerine göre kinoa çeşitlerinin ADF oranlarındaki değişimler.

Acid Detergent Fibre (ADF)

The total of cellulose, lignin and silicon contents remaining after hemicellulose is removed from the NDF content in animal feeds is called ADF (Acid detergent fibre). ADF is an indicator of the digestion and energy intake capacities of feeds (Kutlu et al., 2005). The ADF ratio of quinoa grass did not differ between years. Soil properties (control, saline-alkaline) significantly affected the ADF ratio of the obtained hay. There was an increase in ADF rates in the grass of quinoa varieties grown in saline-alkaline soils compared to the control soil. There were significant differences in ADF ratios among the quinoa varieties used in the study. While the ADF rate was lowest in the Titicaca variety, the ADF rates of other quinoa varieties were high (Table 3). ADF rates of quinoa varieties in control and saline-alkaline soil are given in Figure 3. While there was an increase in ADF rates of Sandoval Mix, Moqu Arrochilla, Red Head, Rainbow and Oro de Valle cultivars in saline-alkaline soils compared to the control soil, there was no change in ADF rates of Titicaca

and French Vanilla cultivars. In studies conducted with different plant species and varieties growing in saline environments, the ADF content of the plant has been reported to increase in some studies (Masters et al., 2010; Elfeel and Bakhashwain, 2012; Kılıç et al., 2015; Hedayati-Firoozabadi et al., 2020; Heidari et al., 2023) and to decrease in some studies (Fowler et al., 1992; Mahmoud and Sallam, 2017; Anderson et al., 2023).

Dry Matter Digestibility (DMD)

DMD (Dry matter digestibility) is an indicator of the rate at which feeds are digested by animals (Kutlu et al., 2005; Kutlu and Özen, 2009). The DMD rate of quinoa hay did not differ between years. Soil properties (control, saline-alkaline) significantly affected the DMD rate of quinoa plants. Compared to the control soil, a decrease in DMD rate was observed in the grass of quinoa varieties grown in saline-alkaline soils. There were significant differences in DMD rates among the quinoa varieties used in the study. The DMD rate of Titicaca quinoa variety was higher than other varieties (Table 3). DMD rates of quinoa varieties in control and saline-alkaline soil are given in Figure 4. While there was a decrease in DMD rates of Red Head, Sandoval Mix, Oro de Valle, Moqu Arrochilla and Rainbow cultivars in saline-alkaline soils compared to the control soil, there was no significant change in DMD rates of Titicaca and French Vanilla cultivars. In the research conducted with different plant species and varieties growing in salty environments, a decrease in the DMD content of the plant was reported (Kılıç et al., 2015). It is observed that the increase in ADF rates also causes an increase in DMD rates.

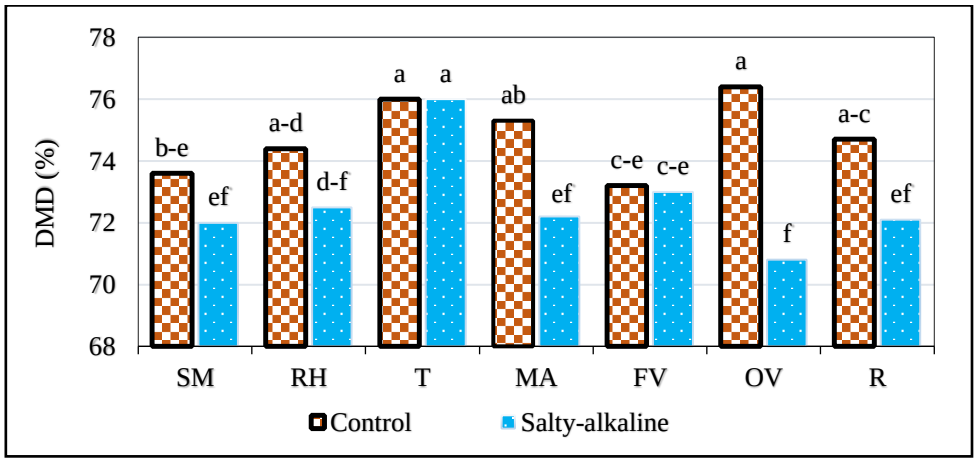

Figure 4. Changes in DMD rates of quinoa varieties according to soil properties.
Şekil 4. Toprak özelliklerine göre kinoa çeşitlerinin KMS oranlarındaki değişimler.

Dry Matter Intake (DMI)

DMI is an indicator of the rate at which animals can consume feed (Kutlu et al., 2005; Kutlu and Özen, 2009). The DMI ratio of quinoa grass did not differ between years. Soil properties (control, saline-alkaline) had a significant effect on the DMI ratio of quinoa plants. The DMI ratio of quinoa grass grown in saline-alkaline soils was lower than that of the control soil. There were significant differences between the DMI rates of the quinoa varieties used in the study. The DMI ratio of Titicaca quinoa variety was higher than other varieties (Table 4). DMI rates of quinoa varieties in control and saline-alkaline soil are given in Figure 5. Compared to the control soil, there was a decrease in DMI rates of all quinoa cultivars in saline-alkaline soils. In the research conducted with different plant species and varieties growing in salty environments, a decrease in the DMI content of the plant was reported (Kılıç et al., 2015). It is seen that the increase in NDF rates also causes an increase in the DMI rate.

Digestible Energy (DE)

Digestible energy is the energy obtained by subtracting the amount of energy excreted in feces from the total energy (Kutlu et al., 2005; Kutlu and Özen, 2009). The amount of DE in quinoa grass did not differ between years. Soil properties (control, saline-alkaline) had a significant effect on the DE content of quinoa plants. There was a decrease in the amount of DE in the grass of quinoa varieties grown in saline-alkaline

soils compared to the control soil. There were significant differences in DE amounts among the quinoa varieties used in the study. The DE amount of Titicaca quinoa variety was higher than other varieties (Table 4). While there was a decrease in DE amounts in Sandoval Mix, Red Head, Oro de Valle, Moqu Arrochilla and Rainbow varieties in saline-alkaline soils compared to the control soil, there was no significant change in DE amounts in Titicaca and French Vanilla varieties (Figure 6).

Table 4. DMI, DE, ME and RFV contents of quinoa plant grown in saline-alkaline and non-saline soils.
Çizelge 4. Tuzlu-alkali ve tuzsuz topraklarda yetiştirilen kinoa bitkisinin DMI, DE, ME ve RFV içerikleri.

Years	DMI (%)	DE (Mcal kg^{-1})	ME (Mcal kg^{-1})	RFV
2021	3.77	3.42	2.81	215.4
2022	3.70	3.43	2.82	212.7
Soil property (S)				
Control	4.02 a	3.47 a	2.85 a	233.6 a
Salty-alkaline	3.45 b	3.38 b	2.78 b	194.5 b
Varieties (A)				
Sandoval Mix	3.44 c	3.38 b	2.78 c	194.8 c
Red Head	3.74 b	3.42 b	2.80 bc	212.9 b
Titicaca	4.00 a	3.52 a	2.88 a	235.7 a
Moqu Arrochilla	3.82 ab	3.43 b	2.83 b	218.8 b
French Vanilla	3.61 bc	3.41 b	2.79 bc	204.9 bc
Oro de Valle	3.72 b	3.42 b	2.82 bc	213.7 b
Rainbow	3.82 ab	3.39 b	2.80 bc	217.6 b

The difference between the averages shown with the same letters is not significant.

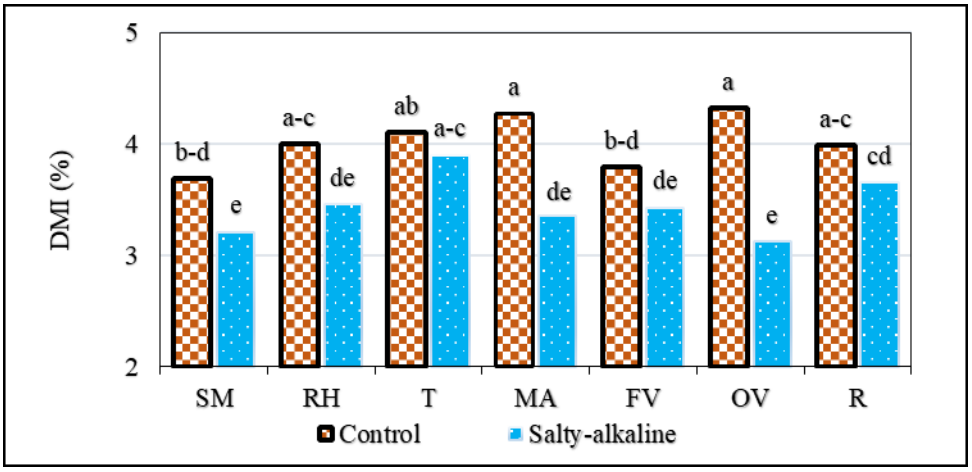

Figure 5. Changes in DMI rates of quinoa varieties according to soil properties.
Şekil 5. Toprak özelliklerine göre kinoa çeşitlerinin KMT oranlarındaki değişimler.

Metabolize Energy (ME)

Metabolic energy refers to the energy remaining after the energy excreted in urine and methane gas is subtracted from digestible energy (Kutlu et al., 2005; Kutlu and Özen, 2009). The amount of ME in quinoa grass did not differ between years. Soil properties (control, saline-alkaline) significantly affected the ME amount of quinoa plants. Compared to the control soil, a decrease in ME content was observed in quinoa varieties grown in saline-alkaline soils. There were significant differences in the ME amounts of the quinoa varieties used in the study. The ME amount of Titicaca quinoa variety was higher than other varieties (Table 4). While there was a decrease in ME amounts of Sandoval Mix, Oro de Valle, Red Head, Moqu Arrochilla and Rainbow varieties in saline-alkaline soils compared to the control soil, there was no significant change in ME amounts of Titicaca and French Vanilla varieties (Figure 7). In studies conducted with different plant species and varieties growing in saline environments, the ME content of the plant was reported to decrease

in some studies (Masters et al., 2010; Waldron et al., 2020) and it did not cause a significant change in some studies (Suyama et al., 2007).

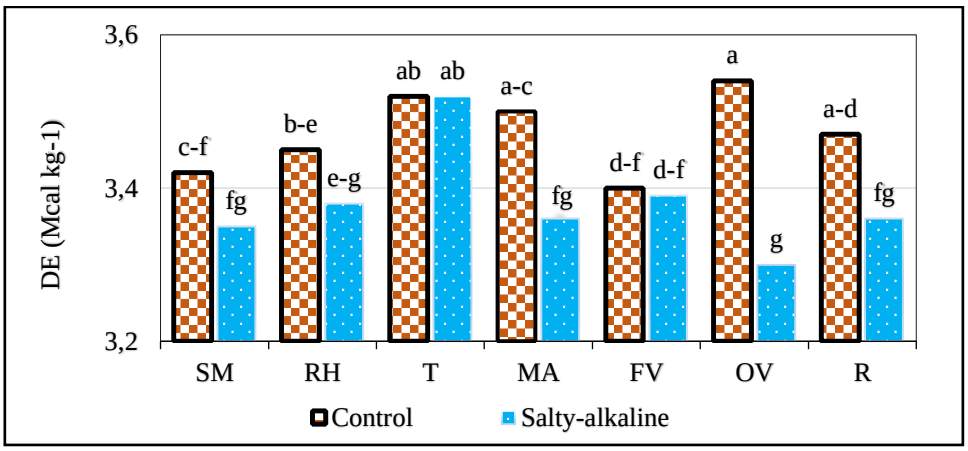

Figure 6. Changes in DE amount rates of quinoa varieties according to soil properties.
Şekil 6. Toprak özelliklerine göre kinoa çeşitlerinin SE miktarlarındaki değişimler.

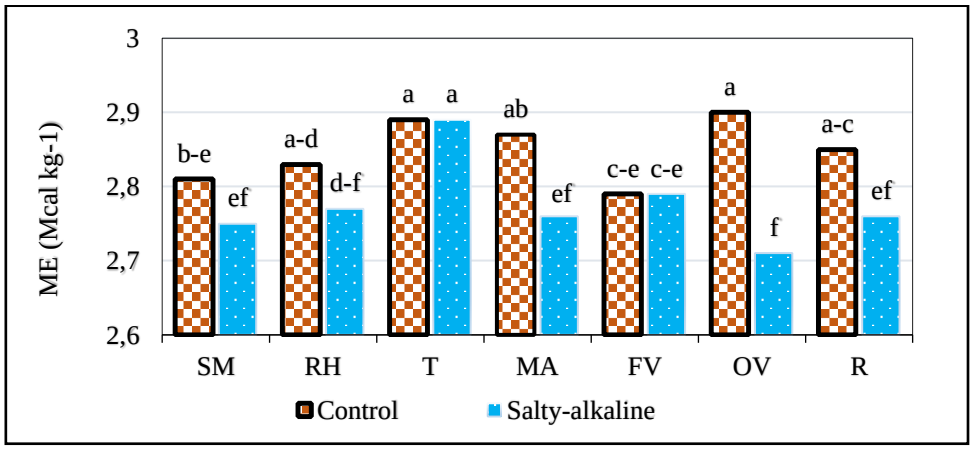

Figure 7. Changes in ME amount rates of quinoa varieties according to soil properties.
Şekil 7. Toprak özelliklerine göre kinoa çeşitlerinin ME miktarlarındaki değişimler.

Relative Feed Values (RFV)

The relative feed value calculated using NDF and ADF ratios is a measure of forage quality accepted as 100 for alfalfa plants (Rohweder et al., 1978; Ball et al., 1996; Morrison, 2003). An RFV value above 150 indicates that the grass is of first quality. If the RFV value is between 125-150, it is considered as the 2nd quality, if it is 103-124, it is considered as the 3rd quality, if it is 87-102, it is considered as the 4th quality, if it is 75-86, it is considered as the 5th quality, and if it is below 75, it is considered as the 6th quality (Rohweder et al., 1978). The RFV value of quinoa grass did not differ between years. Soil properties (control, saline-alkaline) significantly affected the RFV value of quinoa plants. It was observed that quinoa varieties grown in saline-alkaline soils caused a decrease in RFV contents compared to the control soil. There were significant differences between the RFV values of the quinoa varieties used in the study. The RFV value of Titicaca quinoa variety was higher than other varieties (Table 4). RFV rates of quinoa varieties in control and saline-alkaline soil are given in Figure 8.

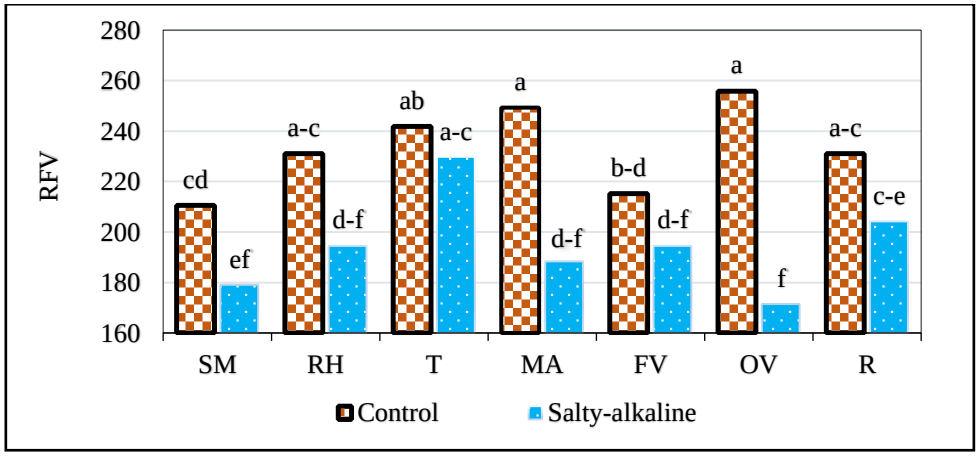

Figure 8. Changes in RFV value rates of quinoa varieties according to soil properties.
Şekil 8. Toprak özelliklerine göre kinoa çeşitlerinin NYD değerindeki değişimler.

Compared to the control soil, there was a decrease in RFV rates of all quinoa cultivars in saline-alkaline soils. In the research conducted with different plant species and varieties growing in saline environments, a decrease in the RFV content of the plant was reported (Kılıç et al., 2015). Quinoa grass has been found to have a Class 1 forage quality because its RFV value is higher than 150.

CONCLUSION

In the two-year study, the crude protein content of quinoa varieties varied from year to year, while there was no change in other feed quality characteristics. According to the average data, there was no significant change in the crude protein ratio of grass grown in saline-alkaline soil compared to the control soil, while other forage quality properties (NDF, ADF, DMD, DMI, DE, ME and RFV) showed significant differences. Accordingly, while there was an increase in the NDF and ADF ratios of the grass obtained in saline-alkaline soil, there was a decrease in the DMD, DMI, DE, ME and RFV contents. On the other hand, the forage quality properties of quinoa varieties CP, ADF, DMD, DE and ME were affected differently in saline-alkaline soils.

In saline-alkaline soils, there was an increase in the crude protein content of Sandoval Mix, Red Head, French Vanilla Oro de Valle varieties, while there was a decrease in the crude protein content of Titicaca, Moqu Arrochilla and Rainbow varieties. While there was an increase in ADF rates of Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow cultivars in saline-alkaline soils, there was no change in ADF rates of Titicaca and French Vanilla cultivars. While there was a decrease in DMD rates of Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow cultivars in saline-alkaline soils, there was no significant change in DMD rates of Titicaca and French Vanilla cultivars. While there was a decrease in DE amounts in Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow varieties in saline-alkaline soils, there was no significant change in DE amounts in Titicaca and French Vanilla varieties. While there was a decrease in ME amounts in Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow varieties in saline-alkaline soils, there was no significant change in ME amounts in Titicaca and French Vanilla varieties.

As a result, Sandoval Mix, Red Head, French Vanilla and Oro de Valle quinoa varieties, which do not show a decrease in crude protein content, should be preferred in quinoa cultivation in saline-alkaline soils. On the other hand, quinoa varieties should be cultivated by taking into account that there will be an increase in NDF content and a decrease in DMI and RFV contents in important quality properties.

CONFLICT OF INTEREST

There is no disagreement between the authors.

DECLARATION OF AUTHOR CONTRIBUTION

The authors contributed equally to each stage of the study.

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Bazı *Crepis* Türlerinin Ot Kalite Özellikleri Açısından Değerlendirilmesi

Evaluation of Some *Crepis* Species in terms of Herbage Quality Characteristics

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Öz: Güneydoğu Anadolu Bölgesinden toplanan *Crepis* türlerinin, hayvan besleme açısından önem arz eden bazı kalite özellikleri ile bu türlerin toplandığı lokasyonların birbirlerine benzerliklerini tespit etmek amacıyla, bu çalışma yürütülmüştür. *Crepis* türleri, Güneydoğu Anadolu Bölgesi'nin mera ve doğal alanlarında yaygın olarak bulunmasından dolayı çalışma konusu olarak ele alınmış ve bölgenin 10 değişik lokasyonundan toplanan *Crepis* türlerine ait bitkiler materyal olarak kullanılmıştır. *Crepis* türlerine ait bitkilerin kuru otlarında ham protein (HP), asit deterjanda çözünmeyen protein (ADP), asit deterjanda çözünmeyen lif (ADF), nötral deterjanda çözünmeyen lif (NDF), sindirilebilir kuru madde (SKM), kuru madde tüketimi (KMT), nispi yem değeri (NYD), kalsiyum (Ca), magnezyum (Mg), fosfor (P) ve potasyum (K) oranları saptanmıştır. İncelenen bu özellikler açısından lokasyonlar arasında önemli istatistiksel farklılıkların olduğu görülmüştür. Araştırmada, *Crepis* türlerinin ADF ve NDF oranlarının düşük, HP, SKM, KMT ve NYD'nin yüksek ve uygun düzeyde olduğu görülmüştür. Ca, P, K, Mg ve K:(Ca+Mg) oranlarının da ideal düzeyde olduğu, ancak Ca:P oranının ise olması gereken sınır değerin (>2) üzerinde olduğu belirlenmiştir. Lokasyonların benzerlik durumlarını ortaya koyma amacıyla kümeleme analizi yapılmıştır. Yapılan kümeleme analizi sonucunda 10 farklı lokasyonun iki ana gruba ayrılacak şekilde varyasyon gösterdiği belirlenmiştir. Bu gruplar arasında *Crepis alpina* türünün alındığı Diyarbakır (1) ve Diyarbakır (2) lokasyonlarının birbirine en yakın, *Crepis alpina* türünün alındığı Diyarbakır (1) ile Adıyaman lokasyonlarının ise birbirine en uzak lokasyonlar olduğu saptanmıştır.

Anahtar Kelimeler: Hindiba, Kalite Özellikleri, Mineraller, Kümeleme Analizi

&

Abstract: This study was carried out to determine some quality characteristics of *Crepis* species collected from the Southeastern Anatolia Region, which are important for animal nutrition, and the similarities among the locations where these species were collected. *Crepis* species were considered as the subject of the study because of their widespread occurrence in pastures and natural areas of Southeastern Anatolia Region and plants belonging to *Crepis* species collected from 10 different locations of the region were used as material. Crude protein (HP), acid detergent crude protein (ADP), acid detergent fiber (ADF), neutral detergent fiber (NDF), digestible dry matter (DMD), dry matter itnake (DMI), relative feed value (RFV), calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K) ratios were determined in the hay of *Crepis* species. It was observed that there were significant statistical differences among the locations analyzed in terms of these traits. In the study, it was observed that the ADF and NDF ratios of *Crepis* species were low, while HP, DDM,DMI and RFV were high and at ideal levels. The ratios of Ca, P, K, Mg and K:(Ca+Mg) were also found to be at ideal levels, but the Ca:P ratio was above the limit value (>2). Cluster analysis was performed in order to reveal the similarity of the locations. As a result of the cluster analysis, it was determined that 10 different locations showed variation to be divided into two main groups. Among these groups, Diyarbakır (1) and Diyarbakır (2) locations, where *Crepis alpina* species were taken, were the closest to each other, while Diyarbakır (1) and Adıyaman locations, where *Crepis alpina* species were taken, were the most distant locations.

Keywords: Chicory, Quality Characteristics, Minerals, Clustering Analysis

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GİRİŞ

Asteraceae (Papatyagiller) familyasının bir cinsi olan *Crepis* cinsi, Kuzey Yarımküre ve Afrika'da dağılım göstermekte ve 200'den fazla türü içerisinde barındırmaktadır (Bremer, 1994; Enke, 2009). Bu cins Türkiye'de 9'u endemik olmak üzere 41 takson ile temsil edilmektedir (Yıldırımlı, 2021). *Crepis* türleri, dağlık bölgeler, bataklıklar, çayır alanları, ormanlar ve sahil kenarlarına kadar değişik habitatlarda yaşama şansı bulabilmektedir. Boyları birkaç santimetreden (Örneğin *Crepis pygmaea*) iki metreye (Örneğin *Crepis sibirica*) kadar değişebilmektedir (Enke, 2008).

Crepis türlerinden farklı şekillerde faydalanılmaktadır. Badalamenti (2022), *Crepis* türlerinin kökleri ve toprak üstü kısımlarından elde edilen ekstraktlar ve izole edilmiş bileşiklerin antiviral, antimikrobiyal, antiülser, antioksidan ve besleme açısından test edilerek değerlendirildiğini ve *Crepis* türleri birkaç yüzyıldır tıbbi bitki olarak halk hekimliğinde ve gıda olarak kullanıldığını bildirmiştir. Ülkemizde *Crepis* türleri genellikle Akdeniz ikliminin hakim olduğu bölgelerde büyük ilgi görmüş ve eski çağlardan beri tarım ve gıda alanında kullanılmıştır. Örneğin, *Crepis reuterana* subsp. *reuterana* türü Karaman bölgesinde keklik otu olarak bilinmekte ve yapraklarından salata yapılmaktadır (Koçak ve Özhatay, 2013). Mayasıl otu olarak bilinen *Crepis zacintha* türü, Türkiye'de hemoroide karşı geleneksel tedavide kullanılan bir bitkidir (Erbay ve Sarı, 2018). *Crepis foetida* subsp. *rhoeadifolia* türü, Kahramanmaraş bölgesinde damar açıcı özelliği nedeniyle tıbbi bitki olarak kullanılmaktadır (Kocabaş vd., 2017). Aynı bitki Doğu Anadolu Bölgesinde yürek otu olarak bilinmekte ve otu kaynatılarak kalp ve damar hastalıklarında yine tıbbi bitki olarak kullanılmaktadır (Çakılcıoğlu vd., 2010; Altundag ve Ozturk, 2011). Van bölgesinde endemik *Crepis hakkarica* türünün yerel isminin Tahliş olduğu, yaprak ve çiçeklerinin kaynatılarak diyabet hastalığına karşı kullanıldığı bildirilmiştir (Dalar, 2018). Manisa bölgesinde *Crepis sancta* türünün yerel isminin düğmelik olduğu ve köklerinin kaynatılarak sindirim düzenleyici olarak kullanıldığı bildirilmiştir (Akyol ve Altan, 2013). Yine *Crepis foetida* subsp. *rhoeadifolia* türünün geleneksel tıpta bitkisel çay ve gıda takviyesi olarak kullanılabileceğini rapor edilmiştir (Zengin vd., 2015). Ankara bölgesinde *Crepis foetida* türünün soğuk algınlığı, nezle ve öksürüğe karşı kullanıldığı bildirilmiştir (Deliorman Orhan vd., 2012). Bu araştırmacılara ilaveten Akan vd. (2008) Şanlıurfa florasında *Crepis foetida* subsp. *rhoeadifolia* türünün Şirok ismi ile bilindiğini ancak etnobotanik açıdan hangi amaçlarla kullanıldığının saptanamadığını bildirmişlerdir.

Crepis türleri ülkemiz doğal alanlarında bulunduğu birçok flora çalışması ile ortaya konulmuştur. Örneğin; Atamov vd. (2014) Ilısu (Hasankeyf) bölgesindeki en zengin familyanın *Asteraceae* ve en zengin cinsin de *Trifolium* ve *Centaurea*'dan sonra 9 adet taksonla *Crepis* olduğunu bildirmişlerdir. Demirkuş vd. (2018), Van gölü havzasında endemik *Crepis gemicii* ile birlikte başka *Crepis* türlerinin olduğunu bildirmişlerdir. Mutlu ve Karakuş (2015) Malatya bölgesi florasında *Crepis* türlerinin bulunduğunu ve bunların çöl kıskısı (*Crepis syriaca*), kohum (*Crepis foetida* subsp. *foetida*) ve sakarkanat (*Crepis foetida* subps. *rhoeadifolia*) gibi isimlerle anıldığını bildirmişlerdir. Polat vd. (2020) Bingöl ili florasında yer alan *Crepis sancta* subsp. *obovata* türünün sahip olduğu polen ve nektardan dolayı arıcılık açısından önemli bir potansiyele sahip olduğunu bildirmişlerdir.

Ülkemizde yapılan birçok mera çalışmasında da *Crepis* türlerinin tespit edildiği bildirilmiştir. Örneğin; Özaslan Parlak vd. (2018) Akdeniz meralarında bu cinse ait türlerin bulunduğunu, Şahin vd. (2015) Çankırı meralarında *Crepis alpina*, *Crepis sancta* ve *Crepis foetida* türlerinin bulunduğunu ve bu türlerin istilacı nitelikte olduğunu, Cengiz (2013) tarafından Erzurum doğal meralarında bulunan *Crepis* sp. türünün ballı bitkiler içerisinde yer aldığını, Özaslan Parlak vd. (2015), bazı *Crepis* türlerinin (*C. foetida, C. pulchra, C. zacintha*) Çanakkale meralarında botanik kompozisyonu oluşturan türler olduğunu, Aydın vd. (2014), Mardin meralarında *Crepis* türlerinin bulunduğunu ve bu türlerin tek yıllık ve istilacı nitelikte olduğunu, Çaçan ve Başbağ (2017) tarafından Bingöl meralarında tek yıllık ve çok yıllık *Crepis* türlerini tespit ettiklerini ve bunların meralarda bulunan istilacı bitkiler grubunda olduğunu, Alay vd. (2016) Sinop meralarında en yaygın karşılaşılan istilacı bitki türleri arasında *Crepis armena* türünün olduğunu rapor etmişlerdir. *Crepis* türlerinin tespit edildiği bu mera çalışmalarında, genel olarak türlerin sadece var olup olmadıkları üzerinde durulmuş ve bazı çalışmalarda da bu türlerin, istilacı türler oldukları ifade edilmiştir. İstilacı türler, otlatmaya direnç gösteren, hızlı gelişebilen ve yayılabilen, floristik kompozisyonun değişimine sebep olan ve neticede çayır ve meraların kalitesinin düşmesine neden olabilen türlerdir

(Sürmen vd., 2015). Çayır ve meralarda bitki kompozisyonu belirlenirken türlerin yem üretme değeri, üreme ve çoğalma yeteneklerine göre istilacı, azalıcı ve çoğalıcı şeklinde sınıflandırılmaktadır. İstilacı türler, genel olarak o bölgenin vejetasyonunu oluşturan yerli türlerdir ve vejetasyonun floristik yapısıyla denge halindedirler (Sürmen vd., 2013). Ancak aşırı ve bilinçsiz otlatma gibi insan kaynaklı veya kuraklık gibi çevre faktörlerinden dolayı, istilacı türlerin olumsuz etkileri görülebilmektedir. Normal koşullar altında o bölgenin floristik yapısını oluşturan türlerdir ve hayvan besleme açısından değerlendirilmeleri gerekmektedir. Örneğin *Avena sativa* çayır ve mera alanlarında varlık gösteren istilacı bir tür olmasına rağmen, hem insan beslenmesinde hem de hayvan yemi olarak kullanılan çok önemli bir tahıldır (Sürmen vd., 2013).

Yukarıda ifade edilen çalışmalara ilaveten bazı *Crepis* türlerinin hayvanlar üzerinde zararlı etkileri olabileceğini bildiren çalışmalar da mevcuttur. Örneğin Russo vd. (2018), güney İtalya çiftçilerinin *Crepis lacera* bitkisinin küçükbaş hayvanlar için ölümcül olabildiğine inandıklarını belirtmişlerdir. Bu nedenle bu bitkinin küçükbaş hayvanlar üzerindeki toksik etkisini inceledikleri çalışmalarında; bu bitkinin küçükbaş hayvanlar tarafından fazla tüketilmesi durumunda tehlikeli olabileceğini doğruladıklarını bildirmişlerdir. *Crepis lacera* türü küçükbaş hayvanlar için tehlike oluşturabilmektedir ancak diğer *Crepis* türleri hayvanlar üzerinde farklı aktiviteler sergilemektedir. *Crepis* türlerinin, hayvan sağlığı üzerinde etkileri türden türe değişiklik göstermekte ve dolayısıyla bu konuda daha fazla araştırma yapılması gerektirmektedir.

Bu bilgilere ilaveten *Crepis* türlerinin sahip olduğu ve hayvancılık açısından önem arz eden kalite özelliklerine ait çalışmaların oldukça yetersiz olduğu görülmüştür. Bu nedenle bu çalışma, Güneydoğu Anadolu Bölgesinin farklı lokasyonlarından toplanan *Crepis* türlerinin hayvanlar açısından besleme derecesini ortaya koymak ve türlerin toplandığı lokasyonlar arasındaki benzerlik ve farklılıkları incelemek amacıyla yürütülmüştür.

MATERYAL VE METOT

Güneydoğu Anadolu Bölgesi'nin 10 farklı lokasyonundan toplanan *Crepis* türlerine ait bitki örnekleri, araştırmanın materyalini oluşturmaktadır. *Crepis* türlerinin toplandığı lokasyonlara ait bazı bilgiler (enlem, boylam, yükseklik ve tarih) Çizelge 1'de verilmiştir. Çizelge 1'de görüldüğü üzere *Crepis alpina*, *Crepis foetida* ve *Crepis sancta* olmak üzere üç farklı *Crepis* türü toplanmıştır. Bu türler genel olarak hindiba olarak bilinmekte, tek yıllık ve istilacı grupta yer almaktadırlar (Serin vd., 2008; Anonim, 2024).

Çizelge 1. *Crepis* türlerinin toplandığı lokasyonlar, toplanma tarihleri ve bu lokasyonların coğrafi konumları.
Table 1. Locations where Crepis species were collected, collection dates and geographical locations.

Türler	Lokasyon	Tarih	Yükseklik (m)	Enlem (N)	Boylam (E)
1.*Crepis alpina* L.	Adıyaman	06.05.2023	736	37.878105°	38.903748°
2.*Crepis alpina* L.	Diyarbakır (1)	13.05.2023	813	38.37804°	40.246895°
3.*Crepis alpina* L.	Diyarbakır (2)	15.05.2023	652	37.914333°	40.27253°
4.*Crepis foetida* L.	Diyarbakır	10.05.2023	887	38.369648°	40.55304°
5.*Crepis foetida* L.	Şırnak	07.05.2023	891	37.290447°	41.633801°
6.*Crepis foetida* L.	Kilis	06.05.2023	624	36.777069°	37.277817°
7.*Crepis foetida* subsp. *rhoeadifolia* (M. Bieb) Celak.	Mardin	07.05.2023	1002	37.443211°	40.638088°
8.*Crepis sancta* (L.) Bornm.	Diyarbakır (1)	10.05.2023	887	38.369648°	40.55304°
9.*Crepis sancta* (L.) Bornm.	Diyarbakır (2)	10.05.2023	763	38.298576°	39.961922°
10.*Crepis sancta* subsp. *nemausensis* (P. Fourn.) Babc.	Karacadağ	21.05.2023	1469	37.775105°	39.783733°

Crepis türleri, Çizelge 1'de verilen lokasyonlardan çiçeklenme döneminde toplanmış ve toplanan *Crepis* türlerine ait bazı fotoğraflar Şekil 1'de verilmiştir. Toplanan bitki örneklerinin teşhisi Dicle Üniversitesi Fen Fakültesi Biyoloji Bölümü öğretim üyelerinden Prof. Dr. A. Selçuk ERTEKİN tarafından yapılmıştır.

Çizelge 1'de belirtilen lokasyonlarda ve belirtilen tarihlerde *Crepis* türlerine ait bitki örnekleri, tesadüfi ve üç tekerrürlü olacak şekilde yaklaşık 200 g alınmıştır. Bitki örnekleri 65 °C'de 48 saat kurutulduktan sonra el değirmeni yardımıyla öğütülmüştür. Öğütülen örnekler 1 mm elekte elendikten sonra analize gönderilmiştir. *Crepis* türlerinin HP, ADP, ADF, NDF, Ca, Mg, P ve K analizleri NIRS (Near Infrared Spectroscopy, Foss Model 6500) cihazı ile yapılmıştır. Analizde baklagil yem bitkilerine ait kalibrasyon seti kullanılmıştır (Başaran vd., 2011; Başbağ vd., 2011; Çınar, 2012; Başbağ vd., 2018). Tespit edilen ADF ve NDF değerlerinden hareketle SKM, KMT ve NYD hesaplanmıştır (SKM=88.9-(0.779 x %ADF), KMT= (120/NDF), NYD= (SKM x KMT) / 1.29) (Morrison, 2003).

Şekil 1. *Crepis* türlerine ait fotoğraflar (*Crepis sancta* ve *Crepis foetida*).

Figure 1. The Photos of Crepis species (*Crepis sancta* and *Crepis foetida*).

Araştırma verileri, tesadüf blokları deneme deseninde üç tekerrürlü olacak şekilde JMP programı vasıtasıyla varyans analizine tabi tutulmuştur. Ortalamalar arasındaki benzerlikler ve farklılıklar Tukey (%5) testi ile karşılaştırılmıştır. Araştırmada türler bir faktör olarak ele alınmış olup, lokasyonların birbirine olan yakınlık ve uzaklıklarını belirlemek için de kümeleme analizi (cluster) yapılmıştır (JMP, 2018).

BULGULAR VE TARTIŞMA

Farklı lokasyonlarından toplanan *Crepis* türlerinin HP, ADP, ADF ve NDF içerikleri Çizelge 2'de sunulmuştur. Çizelge 2'deki verilere göre, incelenen tüm parametreler açısından *Crepis* türleri arasında istatistiksel olarak anlamlı farklılıklar tespit edilmiştir ($P<0.01$, $P<0.05$).

Crepis türlerinin HP oranları %14.5 ile %18.6 arasında değişim göstermiştir. En yüksek HP oranı *Crepis alpina*'nın Diyarbakır (2) lokasyonundan elde edilmiştir. *Crepis alpina*'nın temin edildiği Diyarbakır (1) ve Adıyaman lokasyonları ile *Crepis foetida*'nın Diyarbakır lokasyonu da istatistiksel olarak aynı gurupta yer almıştır. En düşük HP oranı ise Mardin lokasyonundan alınan *Crepis foetida* subsp. *rhoeadifolia* türünde saptanmıştır. ADP oranı %0.32 ile %0.80 arasında değişim göstermiştir. En düşük ADP oranı *Crepis foetida*'nın Kilis lokasyonundan alınmıştır. *Crepis foetida*'nın Şırnak ve *Crepis alpina*'nın Adıyaman lokasyonları da istatistiksel olarak en düşük değeri veren grup içerisinde yer almıştır. En yüksek ADP oranları ise geriye kalan diğer tüm lokasyonlarda tespit edilmiştir. ADF oranı %22.1 ile %31.1, NDF oranı ise %31.3 ile %39.4 arasında değişmiştir. Her iki özellik açısından da en yüksek değerler Mardin lokasyonundan alınan *Crepis foetida* subsp. *rhoeadifolia* türünde, en düşük değerler ise Karacadağ lokasyonundan alınan *Crepis sancta* subsp. *nemausensis* türünde saptanmıştır.

Jayanegara vd. (2011), *Crepis aurea* türünün ham protein oranını %13.6-14.1, NDF oranını %31.9-32.4 ve ADF oranını %23.5-25.3 olarak tespit etmişlerdir. Hosseinkhani vd. (2018), *Crepis sancta* türünün yonca tarlalarında görülen bir tür olduğunu ve kuru madde oranını %87.71, ham protein oranını %6.9, ADF oranını %28.83 ve NDF oranını %45.09 olarak tespit etmişlerdir. Pedreiro vd. (2021), *Crepis vesicaria* subsp. *taraxacifolia* türünün gıda ve geleneksel tıpta kullanıldığını ve nem içeriğinin %85.5, protein içeriğinin %7.18, ADF oranının %21.6 ve hemiselüloz içeriğinin %4.27 olduğunu bildirmişlerdir. Basbag ve Sayar (2023) *Crepis sancta* türünün ham protein oranını %15.54, ADF oranını %25.55 ve NDF oranını %29.92 olarak

tespit etmişlerdir. Çalışma konusu olan bitkiler doğadan ve farklı lokasyonlardan toplandıkları için elde edilen sonuçlar ile daha önce yapılan çalışmalar arasında farklılıkların olması muhtemeldir.

Çizelge 2. *Crepis* türlerine ait HP, ADP, ADF ve NDF içerikleri.
Table 2. CP, ADP, ADF and NDF contents of Crepis species.

Türler	Lokasyon	HP (%)	ADP (%)	ADF (%)	NDF (%)
Crepis alpina	Adıyaman	17.6 a	0.46 b	26.9 bc	31.6 d
Crepis alpina	Diyarbakır (1)	18.5 a	0.72 a	24.2 bcd	33.4 bcd
Crepis alpina	Diyarbakır (2)	18.6 a	0.77 a	23.2 cd	31.3 d
Crepis foetida	Diyarbakır	18.4 a	0.70 a	23.3 cd	38.0 ab
Crepis foetida	Şırnak	15.1 bcd	0.48 b	27.7 ab	36.8 abc
Crepis foetida	Kilis	15.5 bcd	0.32 b	24.5 bcd	32.6 cd
Crepis foetida subsp. *rhoeadifolia*	Mardin	14.5 d	0.77 a	31.1 a	39.4 a
Crepis sancta	Diyarbakır (1)	15.8 bc	0.79 a	23.1 cd	32.0 cd
Crepis sancta	Diyarbakır (2)	14.9 cd	0.80 a	25.3 bcd	34.1 bcd
Crepis sancta subsp. *nemausensis*	Karacadağ	16.2 b	0.75 a	22.1 d	31.6 d
	Ortalama	**16.5**	**0.66**	**25.1**	**34.1**
	CV (%)	**2.56****	**8.48****	**5.57****	**8.33***

*: P<0.05, **: P<0.01 düzeyinde önemli ve tabloda aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark önemsizdir.

ADF oranı %31, NDF oranı %40'dan düşük olması durumunda yem bitkilerinin kalite standardı en iyi kalite olan prime, ham protein oranı ise %19'dan büyük olunca prime, %17-19 arasında birinci kalite, %14-16 arasında ikinci kalite grubunda yer almaktadır (Lacefield, 1988). ADF açısından Mardin dışındaki tüm lokasyonların, NDF açısından tüm lokasyonların prime grubunda olduğu görülmektedir. Ham protein açısından ise ilk dört lokasyonun birinci, geriye kalan altı lokasyonun ise ikinci kalite grubunda yer aldığı görülmektedir.

Farklı lokasyonlarından toplanan *Crepis* türlerine ait SKM, KMT ve NYD Çizelge 3'te yer almaktadır. Çizelge 3 incelendiğinde, tüm özellikler açısından lokasyonlar arasında istatistiksel olarak anlamlı farklılıklar bulunduğu belirlenmiştir (P<0.01, P<0.05).

Çizelge 3. *Crepis* türlerine ait SKM ve KMT oranları ile NYD.
Table 3. DDM, DMI and RFV of Crepis species.

Türler	Lokasyon	SKM (%)	KMT (%)	NYD
Crepis alpina	Adıyaman	68.0 bc	3.80 ab	200 ab
Crepis alpina	Diyarbakır (1)	70.0 abc	3.59 abc	195 ab
Crepis alpina	Diyarbakır (2)	70.8 ab	3.83 ab	210 ab
Crepis foetida	Diyarbakır	70.8 ab	3.16 c	173 ab
Crepis foetida	Şırnak	67.4 cd	3.26 bc	170 ab
Crepis foetida	Kilis	69.8 abc	3.97 a	217 a
Crepis foetida subsp. *rhoeadifolia*	Mardin	64.6 d	3.04 c	152 b
Crepis sancta	Diyarbakır (1)	70.9 ab	3.75 ab	206 ab
Crepis sancta	Diyarbakır (2)	69.2 abc	3.52 abc	189 ab
Crepis sancta subsp. *nemausensis*	Karacadağ	71.7 a	3.80 ab	211 ab
	Ortalama	69.3	3.57	192
	CV (%)	1.57**	9.61*	11.35*

*: P<0.05, **: P<0.01 düzeyinde önemli ve tabloda aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark önemsizdir.

SKM oranı %64.6-71.7, KMT oranı %3.16-3.97 ve NYD 152-217 arasında değişim göstermiştir. Ortalama SKM oranı %69.3, KMT oranı %3.57 ve NYD ise 192 olarak belirlenmiştir. En yüksek SKM oranı, Karacadağ

lokasyonundan alınan *Crepis sancta* türünde tespit edilmiştir. Diyarbakır (1) ve Diyarbakır (2) lokasyonlarından alınan *Crepis alpina*, Diyarbakır ve Kilis lokasyonlarından alınan *Crepis foetida* ile Diyarbakır (1) ve Diyarbakır (2) lokasyonlarından alınan *Crepis sancta* türleri de istatistiksel olarak aynı gurupta yer almıştır. En düşük SKM oranı Mardin lokasyonundaki *Crepis foetida* türünden alınmıştır. En yüksek KMT oranı, Kilis lokasyonundaki *Crepis foetida* türünden alınırken, Adıyaman, Diyarbakır (1) ve Diyarbakır (2) lokasyonlarından alınan *Crepis alpina*, Diyarbakır (1), Diyarbakır (2) ve Karacadağ lokayonlarından alınan *Crepis sancta* türleri de istatistiksel olarak aynı gurupta yer almıştır. En düşük KMT oranı, Mardin lokasyonundaki *Crepis foetida* türünden alınmıştır. En düşük NYD ise Mardin lokasyonundaki *Crepis foetida* türünden alınırken, en yüksek NYD ise geriye kalan diğer tüm türlerden alınmıştır.

Jayanegara vd. (2011), *Crepis aurea* türünün in vitro organik madde sindirilebilirliğini %74.1-74.8 olarak tespit etmişlerdir. Hosseinkhani vd. (2018), *Crepis sancta* türünün kuru madde tüketimi oranının %2.6, sindirilebilir kuru madde oranının %66.43 ve yonca otunun göreceli lezzetliliği %100 olarak alındığında *Crepis sancta* türünün göreceli lezzetlilik oranının %82.33 olduğunu bildirmişlerdir. Basbag ve Sayar (2023) *Crepis sancta* türünün SKM oranını %68.99, KMT oranını %4.04 ve NYD'yi 216 olarak tespit ettiklerini ve *Crepis sancta* türüne ait otun prime (en iyi kalite) grubunda olduğunu bildirmişlerdir. Daha önce yürütülen bu çalışmalar ile elde edilen sonuçlar benzerlikler göstermektedir.

Lacefield (1988), SKM oranı %65, KMT oranı %3.0 ve NYD 151'den büyük olan kaba yemlerde kalitenin en iyi (prime) olduğunu bildirmiştir. Bu açıdan bakıldığında, KMT ve NYD açısından tüm lokasyonların, SKM açısından ise Mardin lokasyonu dışında kalan diğer tüm lokasyonların en iyi grupta yer aldığı görülmüştür.

Crepis türlerinin Ca, P, Ca:P, K, Mg ve K:(Ca+Mg) değerleri Çizelge 4'te sunulmuştur. Bu özellikler açısından türler arasındaki farklılıklar, istatistiksel olarak önemli bulunmuştur (P<0.01).

Çizelge 4. *Crepis* türlerine ait Ca, P, Ca:P, K, Mg ve K:(Ca+Mg) değerleri.
Table 4. Ca, P, Ca:P, Mg and K:(Ca+Mg) values of Crepis species.

Türler	Lokasyon	Ca (%)	P (%)	Ca:P	K (%)	Mg (%)	K:(Ca+Mg)
Crepis alpina	Adıyaman	1.81 a	0.26 e	6.83 a	2.25 d	0.44 a	1.00 f
Crepis alpina	Diyarbakır (1)	1.43 cde	0.40 a	3.58 cd	4.17 a	0.42 abc	2.26 abc
Crepis alpina	Diyarbakır (2)	1.56 bc	0.36 b	4.30 c	3.65 ab	0.40 bcd	1.87 cde
Crepis foetida	Diyarbakır	1.26 e	0.40 a	3.13 d	4.12 ab	0.28 f	2.67 a
Crepis foetida	Şırnak	1.40 cde	0.37 b	3.81 cd	2.90 c	0.38 cd	1.62 de
Crepis foetida	Kilis	1.70 ab	0.31 d	5.52 b	2.84 c	0.32 ef	1.47 e
Crepis foetida subsp. *rhoeadifolia*	Mardin	1.53 bcd	0.35 bc	4.39 c	3.85 ab	0.40 bcd	2.00 bcd
Crepis sancta	Diyarbakır (1)	1.53 bcd	0.29 d	5.32 b	3.60 b	0.38 d	1.89 cde
Crepis sancta	Diyarbakır (2)	1.40 cde	0.36 b	3.85 cd	4.08 ab	0.33 e	2.36 ab
Crepis sancta subsp. *nemausensis*	Karacadağ	1.30 de	0.34 c	3.87 cd	2.71 cd	0.43 ab	1.56 de
	Ortalama	1.49	0.34	4.46	3.42	0.38	1.87
	CV (%)	5.55**	2.32**	6.44**	5.22**	3.89**	8.25**

**: P<0.01 düzeyinde önemli ve tabloda aynı sütunda aynı harfle gösterilen ortalamalar arasındaki fark önemsizdir.

Lokasyonların kalsiyum oranları %1.26-1.81, fosfor oranları %0.26-0.40, Ca:P oranları 3.13-6.83, potasyum oranları %2.25-4.17, magnezyum oranları %0.28-0.44 ve K:(Ca+Mg) değeri ise 1.00 ile 2.67 arasında değişim göstermiştir. Genel bir değerlendirme yapıldığında; en yüksek kalsiyum oranının alındığı Adıyaman lokasyonundaki *Crepis alpina* türünden, aynı zamanda en düşük fosfor, en yüksek Ca:P, en düşük potasyum, en yüksek magnezyum ve en düşük K:(Ca+Mg) oranlarının alındığı saptanmıştır. En düşük kalsiyum oranının alındığı Diyarbakır lokasyonundaki *Crepis foetida* türünden ise en yüksek fosfor, en düşük Ca:P, en düşük magnezyum ve en yüksek K:(Ca+Mg) oranlarının alındığı görülmüştür.

Bitkilerde kalsiyumun %0.10-1.00, fosforun %0.20-0.50, potasyumun %1.00-5.00 ve magnezyumun %0.10-0.40 arasında olması yeterli kabul edilmektedir (Motsara ve Roy, 2008). Çizelge 4'e göre P ve K oranlarının tüm lokasyonlarda, Mg oranlarının iki lokasyon dışında (Adıyaman ve Diyarbakır (1) lokasyonlarındaki *Crepis alpina*), geriye kalan lokasyonlarda istenilen değerlerde olduğu görülmektedir. Ancak tüm lokasyonlarda Ca oranlarının olması gereken değerin (%1.00) üzerinde olduğu görülmektedir. Bu durum Ca:P oranının da yüksek olmasına sebebiyet vermektedir. Ca:P oranının 2.0'den fazla olması, hayvanlarda zehirlenmelere yol açabilmektedir (Ayan vd., 2010). Çizelge 4'te belirtilen Ca:P dengesizliğin temel nedeninin fosfor eksikliği değil, lokasyonlardan alınan ottaki kalsiyum fazlalığından kaynaklandığı ön görülmektedir.

K:(Ca+Mg) oranının da 2.2'in üzerinde olması, hayvanlarda tetani hastalığı riskini artırmaktadır (Aydın ve Uzun, 2002). K:(Ca+Mg) değerinin Diyarbakır (1) lokasyonundaki *Crepis alpina*, Diyarbakır lokasyonundaki *Crepis foetida* ve Diyarbakır (2) lokasyonundaki *Crepis sancta* türleri dışında diğer tüm lokasyonlarda istenilen sınır değerleri içerisinde olduğu, bu lokasyonlar için böyle bir riskin olmadığı anlaşılmaktadır.

Pedreiro vd. (2021), *Crepis vesicaria* subsp. *taraxacifolia* türünün gıda ve geleneksel tıpta kullanıldığını ve türün kuru maddede Ca içeriğinin %2.14, P içeriğinin %4.12, K içeriğinin %4.09 ve Mg içeriğinin %3.14 olarak tespit ettiklerini bildirmişlerdir. Basbag ve Sayar (2023) *Crepis sancta* türünde P oranını %0.30, K oranını %3.19, Ca oranını %1.38, Mg oranını %0.39, Ca/P oranını %4.62 ve K:(Ca+Mg) oranını da 1.80 olarak tespit etmişlerdir.

Farklı lokasyonlardan toplanan *Crepis* türlerinin kümeleme (cluster) analizi sonuçları Şekil 2'de sunulmuştur. Bu analiz, lokasyonlardan elde edilen türlerin benzerlik düzeylerini değerlendirmek amacıyla gerçekleştirilmiştir.

Şekil 2. *Crepis* türlerinin toplandığı lokasyonların kümeleme analizi.
Figure 2. Clustering analysis of Crepis species collected locations.

Şekil 2'de sunulduğu üzere kümeleme analizi neticesinde 2 farklı kümenin oluştuğu ve birinci kümede *Crepis alpina* türünün alındığı Adıyaman ve *Crepis foetida* türünün alındığı Kilis lokasyonlarının, ikinci kümede ise geriye kalan diğer tüm lokasyonların olduğu görülmektedir. Kümelerin benzerlik durumlarına göre birinci kümede *Crepis alpina* türünün alındığı Adıyaman ve *Crepis foetida* türünün alındığı Kilis lokasyonlarının, ikinci kümede *Crepis alpina* türünün alındığı Diyarbakır (1) ve Diyarbakır (2) lokasyonlarının, *Crepis sancta* türünün alındığı Diyarbakır (1) ve *Crepis sancta* subsp. *nemausensis* türünün alındığı Karacadağ lokasyonlarının, *Crepis foetida* türünün alındığı Şırnak ve *Crepis foetida* subsp. *rhoeadifolia* türünün alındığı Mardin lokasyonlarının benzerlik bakımından birbirlerine en yakın ve benzer lokasyonlar olduğu görülmektedir. İncelenen özellikler bakımından *Crepis alpina* türünün alındığı Diyarbakır (1) ve Diyarbakır (2) lokasyonlarının birbirine en yakın, *Crepis alpina* türünün alındığı Diyarbakır (1) ve *Crepis alpina* türünün alındığı Adıyaman lokasyonlarının ise birbirine en uzak olan lokasyonlar olduğu sonucuna varılmıştır.

Bu kümeleme analizinde, aynı coğrafyada yaşayan farklı türlerin aynı kümede ancak farklı coğrafyalarda bulunan aynı türlerin ise farklı bir kümede yer aldığı görülmektedir. Bu durum, bitkilerin yetişmiş oldukları alanın iklim ve toprak yapısından beslenmelerinden ileri gelmektedir. Yani türler farklı olsa bile

benzer lokasyonlarda, ortaya koydukları benzer adaptasyon yeteneklerinden dolayı birbirlerine daha yakın sonuçlar verebilmektedirler.

Kümeleme analizi, lokasyon veya genotiplerin birbirleriyle yakınlıklarını ve uzaklıklarını belirlemek maksadıyla kullanılan analiz yöntemlerinden bir tanesidir. Öten ve Albayrak (2016) Batı Akdeniz bölgesinden toplanan yonca popülasyonları arasındaki varyasyon seviyesini belirlemek için kümeleme analizini kullanmışlardır. Yaptıkları kümeleme analizi sonucunda yonca genotiplerinin iki ana ve dört alt gruba ayrıldığını ve birinci grubun %60, ikinci grubun %65 oranında alt gruba ayrıldığını bildirmişlerdir. Yine Öten ve Albayrak (2018) 26 yonca popülasyonunun 21 farklı özelliği arasındaki ilişkiyi kümeleme analizi ile incelemişlerdir. Kümeleme analizi neticesinde yonca hatlarının %50 ile %98 arasında benzerlik gösterdiğini ve hatların esasında iki ana gurup altında beş farklı alt guruba ayrıldıklarını tespit etmişlerdir. Akçelik (2018), yonca popülasyonlarının benzerliklerini tespit etmek için kümeleme analizini kullanmıştır. Analiz sonucunda popülasyonlar arasında %80 oranında benzerlik olduğu ve popülasyonların altı gruba ayrılarak geniş bir varyasyon gösterdiğini bildirmiştir. Başbağ vd. (2019) Güneydoğu Anadolu Bölgesi'nin değişik lokasyonlarından topladıkları *Astragalus hamosus* türünün lokasyonlar arası benzerliklerini tespit etmek için kümeleme analizini kullanmışlardır. Kümeleme analizi sonucunda 20 farklı lokasyonunun dört grup olacak şekilde varyasyon gösterdiğini bildirmişlerdir.

SONUÇ

Güneydoğu Anadolu Bölgesinin 10 farklı lokasyonundan toplanan *Crepis* türlerinin kalite özellikleri ile bu türlerin toplandığı lokasyonların benzerliklerini belirlemek amacıyla yürütülen bu çalışmada; *Crepis* türlerinin ADF ve NDF içeriklerinin düşük, HP, SKM, KMT ve NYD'nin ise yüksek ve ideal düzeyde olduğu belirlenmiştir. Ca, P, K, Mg ve K:(Ca+Mg) oranlarının da istenilen seviyede, ancak Ca:P değerinin maksimum seviyenin (>2) üzerinde olduğu görülmüştür. Bu sonuç, *Crepis* türlerinden elde edilen otun Ca ve P içerikleri arasında bir dengesizlik olduğunu ve bu dengesizliğin de hayvanlarda zehirlenmelere yol açabileceği anlamını taşımaktadır. Bu şekilde ortaya çıkabilecek olumsuz bir durum, bu türden elde edilen otun ya kurutularak ya da başka otlarla birlikte karıştırılarak hayvanlara yedirilmesi ile engellenebilir. Doğal alanlarda veya meralarda otlayan hayvanlar, karışık beslendikleri için bu şekilde ortaya çıkabilecek bir zehirlenme riski zaten düşük olmaktadır. Yapılan kümeleme analizi neticesinde 10 farklı lokasyonun esasında iki gruba ayrılacak şekilde varyasyon gösterdiği görülmüştür. İncelenen özellikler açısından *Crepis alpina* türünün alındığı Diyarbakır (1) ve Diyarbakır (2) lokasyonlarının birbirine en yakın, *Crepis alpina* türünün alındığı Diyarbakır (1) ve Diyarbakır (2) lokasyonlarının Adıyaman lokasyonuna en uzak lokasyonlar olduğu görülmüştür.

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Research Article

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Effect of Iron and Boron Interaction on Yield and Nutrient Contents of Chickpea (*Cicer arietinum* L.)*

Demir ve Bor İnteraksiyonunun Nohutun (*Cicer arietinum* L.) Verim ve Besin Elementi İçerikleri Üzerine Etkisi

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Abstract: Iron and boron are essential elements in plant development. The effect of both elements on plant growth and nutrient content were tried to be determined by field study. The study was carried out with three replications according to factorial experiment design in randomized blocks in the research area of Van Yüzüncü Yıl University, Department of Field Crops. At the end of the study, changes in yield and yield criteria and grain macro and micronutrient content were examined. Iron applications only affect the biological yield of the yield criteria, whereas the chickpea straw N, P, K, Mg, Fe, Mn, Zn, Cu and grain P, Mg, Fe, Zn and B contents were affected. The effect of boron application on second branch count, number of pods and fertile number of pods, while straw nutrient content P, Mg, Zn, B and grain nutrient elements P, K, Ca, Mg, Fe, Mn, Zn, B were found to be affected. It was determined that the boron and iron doses to be applied to nutrient contents and yield were 0.25 kg B da^{-1} and 10 kg Fe da^{-1}.

Keywords: Soil, Chickpea, Yield, Fertilizer, Iron, Boron

&

Öz: Demir ve bor bitki gelişiminde önemli elementlerdir. Her iki elementinde bitki büyümesine ve bitki besin elementi içeriğine etkisi arazi çalışmasıyla belirlenmeye çalışılmıştır. Araştırma Van Yüzüncü Yıl Üniversitesi Tarla Bitkileri Bölümü araştırma alanında faktöriyel deneme desenine göre tesadüf bloklarında üç tekerrürlü olarak yürütülmüştür. Çalışma sonunda verim ve verim kriterlerindeki değişimler ile tane makro ve mikro besin içerikleri incelenmiştir. Demir uygulamaları verim kriterlerinden sadece biyolojik verimi etkilerken, nohut sapının N, P, K, Mg, Fe, Mn, Zn, Cu ve tane P, Mg, Fe, Zn ve B içerikleri etkilenmiştir. Bor uygulamasının ikinci dal sayısı, bakla sayısı ve fertil bakla sayısı üzerine etkisi önemli olarak belirlenirken, nohut sapının besin elementi içeriğinde P, Mg, Zn, B ile tane besin elementlerinden P, K, Ca, Mg, Fe, Mn, Zn ve B içerikleri üzerine öenmli etkisi belirlenmiştir. Besin elementi içeriği ve bitki verimi açısından uygulanacak uygun bor ve demir dozlarının 0.25 kg B da^{-1} ve 10 kg Fe da^{-1} olduğu belirlenmiştir.

Anahtar Kelimeler: Toprak, Nohut, Verim, Gübreleme, Demir, Bor

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INTRODUCTION

Nutrition of humans depends on plant and animal foods, so the nutrient content of these foods is of great importance. Micronutrient elements stand out for ideal life and physiological functions. Widespread global micronutrient deficiencies (MNDs) are a major risk, especially for pregnant women and young children. It causes weak growth, mental disorders, perinatal complications and an increase in mortality because of the diseases (Bailey et al., 2015). The main causes of hidden hunger, which affects more than 2 billion people worldwide and is characterized by micronutrient deficiencies, are iron, vitamin A and iodine deficiencies (Yılmaz and Yılmaz, 2025). The fact that 2/3 of the world's population is confronted with one or more nutrient deficiencies has brought about the widespread research for solving these problems in human nutrition by performing biofortification of the plants used in agricultural production agronomically and genetically with chemical or organic fertilizers (Orman and Kaplan, 2017). Soils used for agricultural activities around the world prevent the desired levels of plant yields from growing for one or more reasons, the same negative effect is also seen on desired levels of nutrient contents. The world population is expected to be 7.5 billion for now and 9.2 billion in 2050 (Anonymous, 2019a). On the other hand, world agricultural areas are expected to be 443 million hectares (Anonymous, 2019b) and this population increase is expected to increase the agricultural need by 40-70%. As a result, we are facing food safety as an important problem (Anonymous, 2019a). The biofortification technique that introduces a new approach in fertilization, reveals a situation different from the known agricultural production methodology (Orman and Ok, 2016). The most common micronutrient deficiency is observed especially in iron and zinc elements. Biofortification is aimed at increasing the content of micronutrient elements that can be used biologically in edible parts of agricultural products and to reduce malnutrition and hidden hunger (Singh et al., 2016). It is estimated that more than 60% of the world's population suffers from iron deficiency, more than 30% from zinc deficiency, more than 30% from iodine deficiency and more than 15% from selenium deficiency (White and Broedley, 2009). Iron deficiency causes anemia in particular and causes deterioration of the functions of the endocrine and immune systems (de Benoist et al., 2008; Bailey et al., 2015). The incidents such as climate change, erosion, urbanization, industrialization, chemical pollution, salinity, acidification that agricultural areas are exposed to and the insufficiency of agricultural areas in feeding the population, make it necessary to make more efficient use of existing areas (Anonymous, 2019c). All these factors negatively affect the biofortification of the plants grown. Biofortification studies are mostly focused on Fe and Zn (Singh et al., 2016). Although the total iron content of agricultural soils is between 20-40 g kg^{-1} (Cornell and Schwertmann, 2003), the iron content that can be taken is 10^{-20}-10^{-6} mg L^{-1} in mineral soils, and 10^{-4}-10^{-3} mg L^{-1} in organic soils (Kacar and Katkat, 1998). Soil properties that determine the behavior of iron in the soil are generally pH with redox potential (Colombo et al., 2014). The lower the pH of the soil solution, the higher the amount of soluble iron (Robin et al., 2008). In contrast, the higher the pH of the soil solution, the lower the soluble iron content will be. Therefore, iron deficiency is an important problem in calcareous soils (Mengel et al. 2001; Güneş et al., 2013). Increased yield and nutrient content have been reported with iron fertilizer applications both from leaf and soil against iron deficiency (Çimrin et al., 2000; Gökmen Yılmaz et al., 2012; Akgül et al., 2013).

Boron, first reported in 1923 as essential for the cell structure of plants (Warington, 1923), is a non-metallic micro element. The metabolic activities of boron in plants serve as a part of sugar transport, cell wall synthesis, lignification, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism and cell membranes (Welch, 1995; Ahmad et al., 2009; Güneş et al., 2013). In humans, it affects the skeletal and immune system and energy metabolism (Velioğlu and Şimşek, 2003). Factors affecting the roots and boron uptake of plants are soil texture, alkalinity/calcification, pH, clay minerals, organic matter content, amount of other nutrients, irrigation type, soil water content, boron content of soil solution and plant variety. In addition, boron uptake is a non-metabolic event (Welch et al., 1991; Brown and Hu, 1998; Ahmad et al., 2012). Critical value of boron content of soils is 1.0 mg kg^{-1} (Reisenaur et al., 1973) for normal growth of plants, whereas this value is 0.5 mg kg^{-1} (Keren and Bingham, 1985) in cereals. Significant increases in yield (Kausar et al., 1988; Seth and Singh, 1985; Zada and Afzal, 1997; Soylu et al., 2005) and content of some nutrients (Lopez-Lefebre et al., 2002; Shaaban et al., 2004; Ahmed et al., 2011; Aref, 2012; Ekinci et al., 2015) are reported due

to boron applications. It has been reported by studies that zinc and potassium, when applied more than necessary in the environment, increase boron intake (Smithson and Herthcote, 1976; Woodruff et al., 1987) while zinc decreases it (Pilbeam and Kirkby, 1983). In a study conducted by Atsak and Çirka (2024) on bean plants, the effect of boron on heavy metals was investigated and it was determined that increasing doses of boron applications increased iron uptake in the plant. In another study conducted on black-eyed peas, the plant's iron uptake varied because of the interaction between increasing doses of boron and heavy metals (Çirka, 2023).

It was determined by Zada and Afzal (1997) that iron and boron applications did not show positive effect on yield and yield criteria when applied together and boron applications were more effective alone. On the other hand, it has been reported that the highest values have been reached in case of application of foliar boron and iron together (Rawashdeh and Sala, 2013; Gürel and Başar, 2016). In another study, it was reported that the application of iron and boron together with the seed caused a decrease in germination but increased the yield (Mirshekari, 2012).

In this study, the effects of the application of iron and boron applications to soil separately or together on the yield and yield criteria of chickpea and the biofortification of stem and grain samples were investigated.

MATERIAL AND METHOD

Materials

This study was carried out in the trial areas of the Faculty of Agriculture in the campus area of Van Yüzüncü Yıl University in the summer of 2015. Inoculant (*Rhizobium ciceri*) obtained from Ankara Soil, Fertilizer and Water Research Institute was applied to South Yellow chickpea seeds used in the experiment. South Yellow (ILC-482) chickpea cultivar used in the experiment was improved in 1983 by GAP International Agricultural Research and Training Center and registered in 1986. Plant height is 40-45 cm, height of first pod is 20-26 cm, number of pods per plant is 17-27, number of pods is 1-1,5 and the 100-grain weight is 28-31 g. Its plant growth is semi-horizontal, grain color is cream, grain type is ram and it is a winter and drought resistant early variety.

Climate Characteristics of The Research Site

The trial location is the area of the Faculty of Agriculture in the campus of Van Yüzüncü Yıl University. The study was conducted in the summer of 2015. Long-term average and climatic data of the months covering the periods in which the study was conducted are given in Table 1. The annual rainfall of the region in which the research is conducted is 297.2 mm and the average temperature is 16.6 ^{0}C and the average relative humidity is 49.98%. The rainfall in 2015 growing season is 116.5 mm. The average temperature is 16.6 ^{0}C, the average relative humidity is 58.28% (Anonymous, 2015).

Table 1. Monthly and long-term average values of some climatic characteristics of Van Province in 2015 during the growing period of Chickpea.
Çizelge 1. 2015 yılına ait Van ili nohut yetiştirme periyodunda bazı iklim özelliklerinin aylık ve uzun dönem ortalama değerleri.

Months	Rainfall (mm)	Avr.Years	Temperature (C^0)	Avr.Years	Relative humidity (%)	Avr.Years
April	66.9	165.7	8.9	8.8	49.4	68.5
May	21.1	99.9	13.7	13.0	42.6	62.7
June	23.4	25.3	19.8	18.9	35.7	53.1
July	5.1	6.3	24.0	22.7	72.2	48.8
Total	116.5	297.2	66.4	63.4	199.9	233.1
Average	29.13	74.3	16.6	15.85	49.98	58.28

Soil Characteristics of The Research Site

Some physical and chemical analysis results of soil samples taken from 0-30 cm depth in the research area are given in Table 2. When the soil analysis results are examined, it is observed that the soil of the trial area has loamy structure, it is not salty, has a slightly alkaline reaction, it is very lime in terms of lime content,

it has too little organic material content, its nitrogen content is insufficient, phosphorus content is high, potassium and copper contents are sufficient, iron and zinc content is deficient (Düzgüneş et al. 1987). The boron content of the trial site was reported to range from 1.0 to 2.0 mg kg^{-1}. This information is specified in the "Turkey Boron Map" provided by the National Boron Research Institute (BOREN).

Table 2. Some physical and chemical soil analysis results of field trials.
Çizelge2. Deneme toprağının bazı fiziksel ve kimyasal analiz sonuçları.

Depth	Texture		pH	Lime	O.M.	N	P	K	Fe	Cu	Zn
		%					mg kg^{-1}				
0-30 cm	Loamy	0.033	7.80	19.59	0.69	0.034	17.90	459	0.2	0.92	0.68

Methods

The experiment was established as a field study in the trial area of the Department of Field Crops in Van Yüzüncü Yıl University. The experiment was conducted according to the factorial experiment design in randomized blocks with three replications. South Yellow variety was used as the material. Planting frequency was 60 seeds per m^2 (Toğay et al., 2005).

During the planting, urea (46% N) and DAP (18% N, 46% P_2O_5) were spread to the soil by hand as nitrogen 4 kg da^{-1} and 6 kg P_2O_5 da^{-1} and rake was used to mix it in the soil. In the experiment, seed planting was carried out by hand with 30 cm and 4-5 cm above the row. The parcel size was 1.5 m x 4 m = 6 m^2. The experiment consisted of a total of 27 parcels. There is a 1-meter gap between the parcels and a 2-meter gap between the blocks. Iron sulphate ($FeSO_4.7H_2O$) was used as the applied iron doses of Fe_0;0, Fe_1;5, Fe_2;10 kg Fe da^{-1} and boric acid (H_3BO_3) was used as applied boron doses of B_0;0, B_1;0.25, B_2;0.50 kg B da^{-1}. Both iron and boron doses were carefully spread on the plot surfaces before seed sowing and then mixed with a rake. The trial area was periodically observed. As weeds emerged in the field, weed control was carried out mechanically by plucking out the weeds on the rows by hand and grubbing up the weeds between the rows. At the time of the harvest, 0.5-meter areas were removed from parcel heads and one row from each side is deducted. Then the assessments were made on an area of 1.2 m x 3m = 3.6 m^2. The experiment was carried out under dry farming conditions. Sowing was carried out in the third week of April (20.04.2015), and the crop was harvested in full maturity in the last week of July (24.07.2015).

Nutrient Analysis in Plant Samples

At the end of the experiment, plant samples taken from each parcel were brought to the laboratory and separated into stems and grains. The separated stem and grain samples were dried in the oven at 70 ^{0}C until they reach constant weight. The dried samples were milled with a plant grinding mill and made ready for analysis according to Kacar and Inal (2008). The obtained extracts were read in the Van Yüzüncü Yıl University Central Research Laboratory using Atomic Absorption Spectrophotometer for K, Ca, Mg, Fe, Mn, Zn and Cu elements and ICP-OES instrument for boron. Nitrogen analysis was determined by micro-Kjeldahl method and phosphorous extracts were determined spectrophotometrically according to yellow color method (Kacar ve Inal, 2008).

Yield and Yield Criteria's

The yield components of 10 plants taken from each plot representing that plot were determined according to Tosun and Eser (1975). Biological and grain yields were calculated as yield per decare by harvesting the plants in the middle and weighing them carefully in the laboratory after removing lots from each side and reducing 50 cm from each head of the parcel. Harvest index was determined by ratio of grain yield to biological yield.

Chemical Analysis of Soil Sample

The soil sample taken according to Jackson (1958) from the trial area was placed in a plastic bag and brought to the laboratory. After drying under appropriate conditions in the laboratory, it was hammered with a wooden mallet and passed through a 2 mm sieve and stored in plastic boxes with lids during the analysis. In soil samples, the analyses of structure, pH, salt, lime, organic matter and N, P, K, Fe, Mn, Zn and Cu elements were made according to the methods specified by Kacar (1994). Total nitrogen analysis in soil

samples was determined by micro kjehldahl method, and available phosphorus analysis was determined by spectrophotometer. Exchangeable K and available Fe, Mn and Zn elements were determined with the ICP-OES instrument.

Statistical Analysis

Whether the effects of iron and boron applications on yield and nutrient content were significant was determined by two-way analysis of variance with the help of CoStat statistical package program. The parameters found to be significant in the analysis of variance were subjected to Student-t (LSD) test and the minimum significant difference between the applications was determined (Düzgüneş et al., 1987).

RESULTS AND DISCUSSION

Effect of Iron and Boron Applications on Yield and Yield Criteria

The results of variance analysis of the effects of iron and boron applications on chickpea yield and yield criteria are given in Table 3. The averages of the effects of applications on yield and yield criteria are given in Tables 4. The BxFe interaction, which has an important effect on number of pods and number of fertile pods, is given in Figures 1 and 2.

Table 3. Results of variance analysis of the effects of boron and iron applications on chickpea yield and yield criteria.
Çizelge 3. Bor ve demir uygulamalarının nohut verimi ve verim kriterleri üzerindeki etkilerine ilişkin varyans analizi sonuçları.

Yield criterias	V.S.	D.F.	M.O.	F value
Plant height	Iron (Fe)	2	0.67	0.44 ns
	Boron (B)	2	1.81	1.22 ns
	BxFe	4	1.49	1.01 ns
First pod height	Iron (Fe)	2	2.735	2.81 ns
	Boron (B)	2	0.577	0.59 ns
	BxFe	4	0.648	0.67 ns
First branch number	Iron (Fe)	2	0.335	1.32 ns
	Boron (B)	2	0.087	0.34 ns
	BxFe	4	0.294	1.15 ns
Second branch number	Iron (Fe)	2	0.049	0.12 ns
	Boron (B)	2	2.020	4.84*
	BxFe	4	0.464	1.11 ns
Pods number	Iron (Fe)	2	3.766	1.55 ns
	Boron (B)	2	37.254	15.29 **
	BxFe	4	7.340	3.01 *
Fertile pods number	Iron (Fe)	2	2.170	0.99 ns
	Boron (B)	2	34.854	15.99**
	BxFe	4	7.484	3.43*
Biological yield	Iron (Fe)	2	481.34	3.87*
	Boron (B)	2	3.957	0.03 ns
	BxFe	4	148.14	1.19 ns
Grain yield	Iron (Fe)	2	143.72	3.08 ns
	Boron (B)	2	4.21	0.04 ns
	BxFe	4	20.09	0.81 ns
Harvest index	Iron (Fe)	2	0.425	0.14 ns
	Boron (B)	2	0.633	0.21 ns
	BxFe	4	2.002	0.66 ns

*, %5; **, %1; ns, non significant.

As can be seen in Table 3, the number of branches ($p \leq 0.05$), number of pods ($p \leq 0.01$) and fertile number of pods ($p \leq 0.01$) were affected by boron applications, while iron applications only had an effect on biological yields ($p \leq 0.05$). The effect of the interaction was determined only on the number of fertile pods. The effect of applications on other yield criteria was not determined (Tab. 3).

It has been found that boron and iron applications cause decreases in plant height compared to control, but these changes do not have a statistically significant effect. Plant height, which was 23.25 cm in control

plants, increased to 24.11 cm in B_1 (0.50 kg B da^{-1}) application. The lowest plant height was obtained in B_0 (0 kg B da^{-1}) application as 23.25 cm (Table 4).

Compared to control plants, iron applications had a positive effect on first pod height, while boron applications had a negative effect. The first pod height was increased to 14.07 cm in Fe_2 (10 kg Fe da^{-1}) application and was measured as 12.97 cm in Fe_0 (0 kg Fe da^{-1}) (Table 4).

It has been found that boron and iron applications cause decreases in plant height compared to control, but these changes do not have a statistically significant effect. Plant height, which was 24.65 cm in control plants, decreased to 23.26 cm in B_1 (0.50 kg B da^{-1}) application and 23.35 cm in Fe_2 (10 kg Fe da^{-1}) application. The lowest plant height was obtained with B_1xFe_1 (0.25 kg B da^{-1}x5 kg Fe da^{-1}) interaction as 22.92 cm. Compared to control plants, iron applications had a positive effect on first pod height, while boron applications had a negative effect. The first pod height was increased to 14.73 cm in 10 kg Fe da^{-1} application and was measured as 13.24 cm in control. The most significant first pod height in boron x iron applications was measured with B_2xFe_2 (0.50 kg B da^{-1}x10 kg Fe da^{-1}) application as 14.15 cm (Fig. 1). The number of first branches decreased with iron applications compared to control. The number of first branches, which was 4.01 number $plant^{-1}$ at the control, decreased to 3.88 number $plant^{-1}$ and 3.33 number $plant^{-1}$ with 5 kg Fe da^{-1} and 10 kg Fe da^{-1} applications, respectively. This was a decrease of 22.8%. It was determined that there was an increase and then a decrease with boron applications. The first branch number increased to 3.94 number $plant^{-1}$ with 0.25 kg B da^{-1} boron application and decreased to 3.77 number $plant^{-1}$ with 0.50 kg B da^{-1} application (Table 4).

Table 4 Effects of iron and boron applications on average yield and yield criteria of chickpea.
Çizelge 4. Demir ve bor uygulamalarının nohutta ortalama verim ve verim kriterleri üzerine etkileri.

Treatments	PH	FPH	FBN	SBN	PN	FPN	BY	GY	HI
	cm		Number				Kg da^{-1}		%
Iron, kg da^{-1}									
0	23.74	12.97 b	4.01	3.58	15.22	14.71	95.3 b	47.3 b	49.6
5	23.30	13.54 ab	3.83	3.72	15.71	14.63	101.7 ab	50.7 ab	49.7
10	23.79	14.07 a	3.63	3.68	16.65	15.50	109.9 a	54.1 a	49.3
LSD(<0.05)	1.21	0.98	0.50	0.79	1.60	1.48	10.5	6.7	2.7
Boron, kg da^{-1}									
0.00	23.25	13.82	3.77	3.15 b	13.61 b	12.70 b	101.9	50.3	49.3
0.25	24.11	13.36	3.94	3.74 ab	16.73 a	15.82 a	103.1	51.1	49.4
0.50	23.46	13.40	3.77	4.09 a	17.23 a	16.32 a	102.0	50.8	49.8
LSD(<0.05)	1.21	0.98	0.50	0.79	1.60	1.48	10.5	6.7	2.73

a, b, c; Values followed by the different letters are significantly different, PH, Plant Height; FPH, First Pod Height; FBN, First Branch Number; SBN, Second Branch Number; PN, Pods Number; FPN, Fertile Pods Number; BY, Biological Yield; GY, Grain Yield; HI, Harvested Index.

The second branch number increased with both boron applications compared to control plants and had statistically significant effect. The number of second branches which was 3.15 number $plant^{-1}$ in control plants are respectively determined as 3.74 number $plant^{-1}$, and 4.09 number $plant^{-1}$ with 0.25 kg B da^{-1} and 0.50 kg B da^{-1} applications. These increases were 18.7%, and 29.8% respectively (Table 4).

Both the number of pods and the number of fertile pods increased with iron and boron applications compared to control. It was found that boron and boron x iron had statistically significant effects in these applications. The number of pods and fertile pods that were 13.61 No. $plant^{-1}$ and 12.70 No. $plant^{-1}$ in control plants respectively are detected as 17.23 No. $plant^{-1}$ and 16.32 No. $plant^{-1}$ respectively with 0.50 kg B da^{-1} applications. Compared to control plants, these increases were realized as 26.6% and 28.5% in boron applications respectively (Table 4).

Although iron, boron and boron x iron applications affect the biological yield and grain yield, only iron applications were found to be statistically significant. The biological yield which was 95.30 kg da^{-1} in control, raised to 101.7 kg da^{-1}, 109.9 kg da^{-1} with 5 and 10 kg Fe da^{-1} applications, and 47.3 kg da^{-1} in control,

raised to 50.7 kg da^{-1}, and 54.1 kg da^{-1}, respectively with 0.25 kg B da^{-1} and 0.50 kg B da^{-1} applications. These increases were realized as 6.7%, 15.3%, 7.2% and 14.4% respectively (Table 4).

Although boron, iron and boron x iron applications have effects on harvest index, these changes are not found to be statistically significant. Even though the harvest index was 49.6% in control plants, it was detected as 49.7%, 49.3% respectively with 5 kg Fe da^{-1} and 10 kg Fe da^{-1}, and 49.3% in control plants, 49.4% and 49.8 % respectively with 0.25 kg B da^{-1} and 0.50 kg B da^{-1} applications (Table 4).

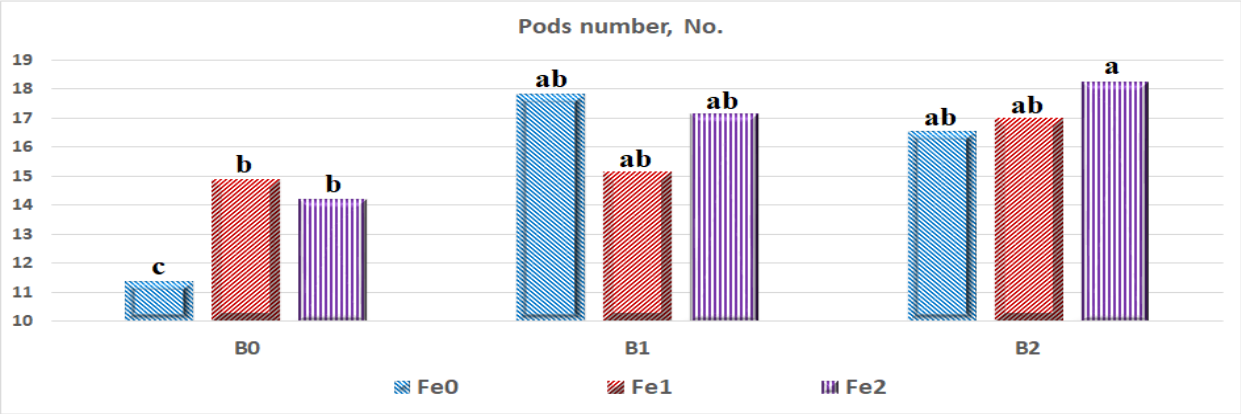

Figure 1. Effects of BxFe interactions on number of pods, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 2.89.
Şekil 1. BxFe interaksiyonunun bakla sayısı üzerine etkisi.

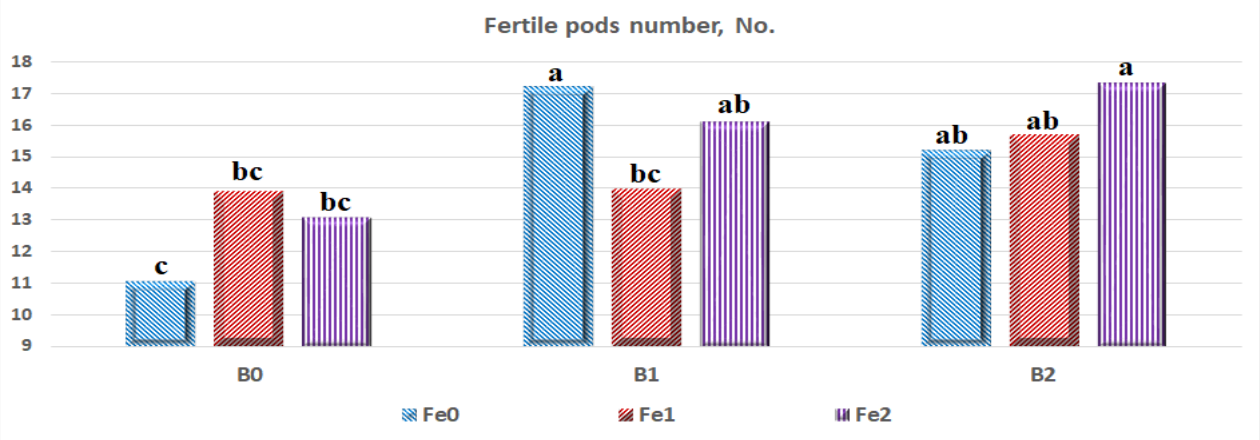

Figure 2. Effects of BxFe interactions on fertile pods number, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05):2.62.
Şekil 2. BxFe interaksiyonunun fertile bakla sayısı üzerine etkisi.

The highest value in boron x iron interaction both number of pods and number of fertile pods were obtained with 18.25 and 17.33 No. plant^{-1} in B_2xFe_2 (0.50 kg B da^{-1}x10 kg Fe da^{-1}) application. An increase of 60.2/56.3% was observed in comparison to control treatments (B_0xFe_0) (Figure 1, 2).

Effect of B and Fe Applications on Chickpea Straw and Grain Nutrient Contents

The results of variance analysis of the effects of iron and boron applications on chickpea straw and grain nutrients are given in Tables 5 and 6. The effects of applications on nutrient contents of chickpea straw and grain are given in Tables 7. and 8. The BxFe interactions, which have an important effect on the straw and grain nutrient contents, are given in Figures 3, 4, 5, 6, 7 and 8.

While iron (FE) application had an effect at $P \leq 0.01$ level on chickpea stem N, P, K and B contents and effect at $P \leq 0.05$ level on Mg, Fe, Mn and Zn contents, boron (B) application had an effect at $P \leq 0.01$ level on P, Mg, Zn and B contents. It was detected that iron application on chickpea grain P, Mg, Fe, Zn and B contents had

a significant effect at $P \leq 0.01$ level, while boron application had a significant effect on P, K, Ca, Mg, Fe, Mn, Zn, Cu and B contents at $P \leq 0.01$ level. Boron x iron (BxFe) interaction was found to have effects on stem P ($p \leq 0.01$), grain Ca ($p \leq 0.05$), grain Mg ($p \leq 0.01$), stem Fe ($p \leq 0.05$), grain Zn ($p \leq 0.05$) and stem Cu ($p \leq 0.01$) contents (Tab. 4, 5).

Table 5. The results of variance analysis of the effects of boron and iron applications on the straw and grain macro element contents of chickpea.
Çizelge 5. Nohutun sap ve tane makro element içerikleri üzerine bor ve demir uygulamalarının etkilerine ait varyans analizi sonuçları.

Elements	Organs	V.S.	D.F.	M.O	F value
N	Straw	Iron (Fe)	2	0.106	7.45 **
		Boron (B)	2	0.012	0.87 ns
		BxFe	4	0.005	0.33 ns
	Grain	Iron (Fe)	2	0.0112	0.74 ns
		Boron (B)	2	0.0035	0.23 ns
		BxFe	4	0.0067	0.44 ns
P	Straw	Iron (Fe)	2	129016	12.66**
		Boron (B)	2	516100	28.76**
		BxFe	4	99499	10.36**
	Grain	Iron (Fe)	2	1223377	13.69 **
		Boron (B)	2	2959572	26.62 **
		BxFe	4	98251	0.84 ns
K	Straw	Iron (Fe)	2	22701744	7.15 **
		Boron (B)	2	3672597	1.16 ns
		BxFe	4	1507395	0.48 ns
	Grain	Iron (Fe)	2	1088233	1.22 ns
		Boron (B)	2	5535958	6.23 **
		BxFe	4	593876	0.67 ns
Ca	Straw	Iron (Fe)	2	2195184	1.02 ns
		Boron (B)	2	5529074	2.56 ns
		BxFe	4	2011710	0.93 ns
	Grain	Iron (Fe)	2	51974	1.49 ns
		Boron (B)	2	334902	9.58 **
		BxFe	4	111864	3.20 *
Mg	Straw	Iron (Fe)	2	371063	3.76 *
		Boron (B)	2	1956428	19.83 **
		BxFe	4	174058	1.76 ns
	Grain	Iron (Fe)	2	2343292	55.02 **
		Boron (B)	2	336545	7.90 **
		BxFe	4	427561	10.04 **

*, %5; **, %1; ns, non significant.

As can be seen in Table 7, both iron and boron applications caused a decrease in the nitrogen content of chickpea straw compared to control. Nitrogen content, which was 1.696% in control plants was detected as 1.481% representing a lowest value in Fe_1 applications. It was found that there was a decrease of 14.5% compared to control.

Straw potassium content increased with iron applications compared to control, whereas in boron applications, it decreased. Straw K content which was 1.989% in control increased to 2.289% with Fe_2 application. These changes were detected as 15.1%. While straw Ca content increased with boron and iron applications. The effect of iron and boron applications on straw calcium content was not statistically significant (Table 7).

Table 6. The results of variance analysis of the effects of boron and iron applications on the straw and grain micro element contents of chickpea.

Çizelge 6. Nohutun sap ve tane mikro element içerikleri üzerine bor ve demir uygulamalarının etkilerine ait varyans analizi sonuçları.

Elements	Organs	V.S.	D.F.	M.O	F value
Fe	Straw	Iron (Fe)	2	28139	12.19 **
		Boron (B)	2	4702	2.03 ns
		BxFe	4	8074	3.50 *
	Grain	Iron (Fe)	2	5770	54.66 **
		Boron (B)	2	3323	31.49 **
		BxFe	4	298	2.83 ns
Mn	Straw	Iron (Fe)	2	23.895	4.20 *
		Boron (B)	2	6.004	1.05 ns
		BxFe	4	13.689	2.40 ns
	Grain	Iron (Fe)	2	9.245	1.16 ns
		Boron (B)	2	65.130	8.18 **
		BxFe	4	19.767	2.48 ns
Zn	Straw	Iron (Fe)	2	25.055	4.42 *
		Boron (B)	2	102.105	18.05 **
		BxFe	4	10.750	1.90 ns
	Grain	Iron (Fe)	2	228.647	13.12 **
		Boron (B)	2	328.005	18.82 **
		BxFe	4	61.759	3.54 *
Cu	Straw	Iron (Fe)	2	0.064	0.03 ns
		Boron (B)	2	1.166	0.53 ns
		BxFe	4	23.648	10.69 **
	Grain	Iron (Fe)	2	11.234	3.05 ns
		Boron (B)	2	32.028	8.70 **
		BxFe	4	10.455	2.81 ns
B	Straw	Iron (Fe)	2	18.481	8.08 **
		Boron (B)	2	350.259	153.15 **
		BxFe	4	0.477	0.48 ns
	Grain	Iron (Fe)	2	814.78	11.75 **
		Boron (B)	2	514.11	7.42 **
		BxFe	4	25.06	0.36 ns

*, %5; **, %1; ns, non significant.

Table 7. Effects of iron and boron applications on average macro nutrients of chickpea.

Çizelge 7. Nohutun ortalama makro besin elementleri üzerine demir ve bor uygulamalarının etkileri.

Treatments	Nitrogen		Phosphorous		Potassium		Calcium		Magnesium	
	%		mg kg^{-1}		%		%		mg kg^{-1}	
	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
Iron, kg da^{-1}										
0	1.696 a	4.695	578 b	3589 b	1.989 b	0.899	0.863	0.173	2748 b	1279 b
5	1.481 b	4.647	585 b	4092 a	2.048 b	0.969	0.874	0.179	2912 ab	1698 a
10	1.559 b	4.716	901 a	4403 a	2.289 a	0.929	0.954	0.188	3152 a	682 c
LSD(<0.05)	0.119	0.123	156	333	0.178	0.094	0.147	0.019	314	207
Boron, kg da^{-1}										
0.00	1.621	4.663	374 a	3366 b	2.124	0.847 b	0.809	0.158 b	2411 b	1393 a
0.25	1.552	4.697	785 a	4377 a	2.165	0.949 a	0.960	0.190 a	3102 a	1255 a
0.50	1.562	4.698	905 a	4340 a	2.039	1.001 a	0.921	0.192 a	3299 a	1011 b
LSD(<0.05)	0.119	0.123	156	333	0.178	0.094	0.147	0.019	314	207

a, b, c; Values followed by the different letters are significantly different.

It was determined that straw phosphorus content increased in boron, iron and boron x iron applications compared to control. Straw P content that was 578 mg kg^{-1} in control, raised to 901 mg kg^{-1} in Fe_2 application. This increase was 55.9%. Straw phosphorus content increased with boron applications. While it was 374 mg kg 1 in control, it increased by 785 mg kg 1 and 905 mg kg 1 with B_1 and B_2 applications, respectively. These increases were 109.8% and 141.9% (Table 7). The lowest value in boron x iron interaction was determined as 300 mg kg^{-1} in B_0xFe_0 application, while the highest straw phosphorus content was determined as 1155 mg kg^{-1} in B_2xFe_2 application. This increase was realized as 285.0% (Figure 3).

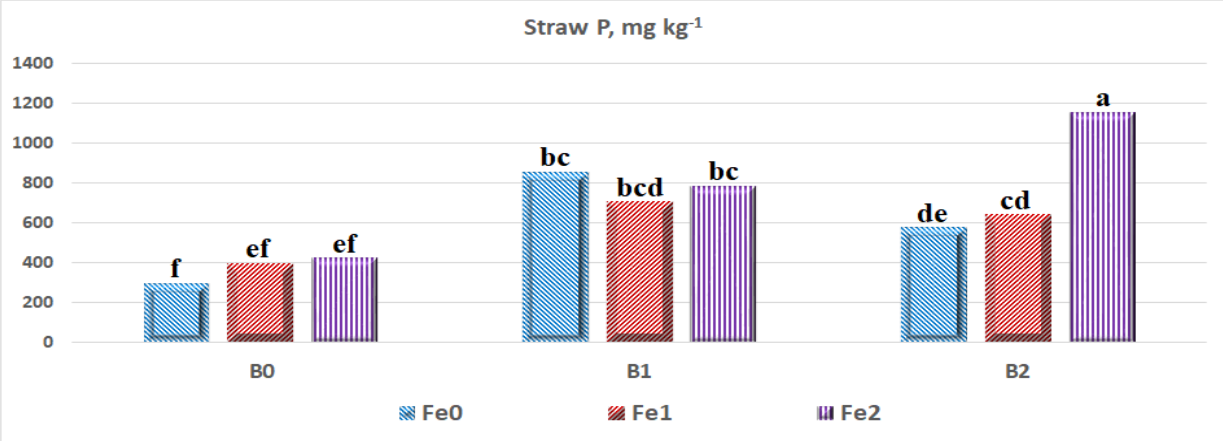

Figure 3 Effects of BxFe interactions on straw phosphorous content, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 270.
Şekil 3. BxFe interaksiyonunun sap fosfor içeriği üzerine etkisi.

Straw Mg content of boron and iron applications were found to increase compared to control. Straw Mg content, which was 2748 mg kg^{-1} in the control, increased to 2921 mg kg^{-1}, and 3152 mg kg^{-1} in Fe_1, and Fe_2 applications, respectively. These increases were realized as 6.0% and 14.7% respectively. Straw magnesium content increased with boron applications. While 2411 mg kg^{-1} in control, 3102 mg kg^{-1} and 3299 mg kg^{-1} increased with B_1 and B_2 administration. These increases were realized as 28.6% and 36.8%, respectively (Table 7).

Table 8 Effects of iron and boron applications on average micronutrients of chickpea.
Çizelge 8. Nohutun mikro besin elementleri üzerine demir ve bor uygulamalarının etkileri.

Treatments	Iron		Manganese		Zinc		Copper		Boron	
	mg kg^{-1}									
	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
Iron, kg da^{-1}										
0	500 b	89.1 c	21.9 a	23.0	26.9 b	46.9 b	16.5	17.8 b	8.33 b	58.3 b
5	574 a	121.6 b	19.1 b	24.1	29.0 ab	53.8 a	16.3	19.3 ab	10.33 a	65.8 b
10	610 a	138.9 a	19.1 b	25.0	30.2 a	56.7 a	16.5	19.9 a	11.11 a	77.2 a
LSD(<0.05)	48	10.3	2.4	2.9	2.4	4.2	1.5	1.9	1.5	8.3
Boron, kg da^{-1}										
0.00	542	97.4 c	20.0	21.6 b	26.2 b	45.6 b	16.8	16.8 b	3.44 c	59.7 b
0.25	556	116.4 b	20.9	27.0 a	27.4 b	57.1 a	16.2	19.9 a	10.44 b	66.9 ab
0.50	587	135.9 a	19.2	23.6 b	32.5 a	54.7 a	16.2	20.3 a	15.89 a	74.8 a
LSD(<0.05)	48	10.3	2.4	2.9	2.4	4.2	1.5	1.9	1.5	8.3

a, b, c; Values followed by the different letters are significantly different.

It was determined that iron application had significant effect on chickpea straw Fe content. The iron content, which was 500 mg kg^{-1} in the control, increased to 610 mg kg^{-1} with Fe_2 application and this amounted to 22.0% (Table 8). Boron x iron application also increased straw iron content. In the boron x iron interaction, the lowest straw iron value was determined as 436 mg kg^{-1} in B_1xFe_0 application, while the

highest straw iron content was determined as 622 mg kg^{-1} in B_2xFe_2 application. This increase was 61.4% (Figure 4).

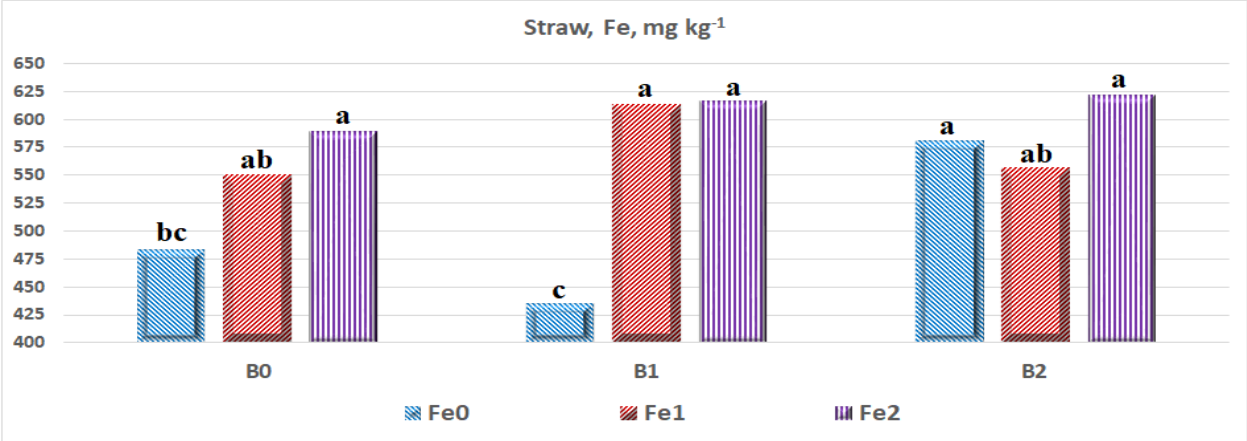

Figure 4. Effects of BxFe interactions on straw iron content, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 83.
Şekil 4. BxFe interaksiyonunun sap demir içeriği üzerine etkisi.

Straw Mn content decreased with iron application compared to control. Mn content of chickpea straw which was 21.9 mg kg^{-1} in the control decreased to 19.1 mg kg^{-1} with Fe_2 application and this decrease was 14.7% (Table 8).

Straw Zn content increased with boron, iron and boron x iron applications compared to control. Straw zinc content increased with iron applications. While it was 26.9 mg kg^{-1} in the control, 29.0 mg kg^{-1} and 30.2 mg kg^{-1} increased with Fe_1 and Fe_2 applications. These increases were 7.8% and 12.3%, respectively. Straw zinc content increased with boron applications. While it was 26.2 mg kg^{-1} in the control, 27.4 mg kg^{-1} and 32.5 mg kg^{-1} increased with B_1 and B_2 applications. These increases were 4.6% and 24.0%, respectively (Table 8).

Chickpea straw B content increased with boron and iron applications. Straw boron content, which was 8.33 mg kg^{-1} in in the control, increased by 10.33 mg kg^{-1} and 11.11 mg kg^{-1} with Fe_1 and Fe_2 applications. These increases were 24.0% and 33.4%, respectively. Straw boron content, which was 3.44 mg kg^{-1} in in the control, increased by 10.44 mg kg^{-1} and 15.89 mg kg^{-1} with B_1 and B_2 applications. These increases were 203.5% and 361.9%, respectively (Table 8).

The effects of iron applications on chickpea's grain nitrogen, potassium and calcium contents were not found to be significant. Boron applications, on the other hand, had a significant effect on phosphorus, potassium, calcium and magnesium contents, except nitrogen (Table 5). Grain phosphorus content increased from 3589 mg kg^{-1} (Fe_0) to 4403 mg kg^{-1} (Fe_2) with increasing iron applications. This increase was 22.7%. Similarly, the grain phosphorus content increased with boron applications, from 3366 mg kg^{-1} in B_0 application to 4340 mg kg^{-1} in B_2 application. This increase was realized as 28.9% (Table 7).

A statistically significant increase in grain potassium and calcium contents were determined only with boron application. While grain K and Ca contents were 0.847% and 0.158%, respectively, in B_0 application, it increased to 1.001% and 0.192%, respectively, with B_2 application. These increases were 18.2% and 21.5% (Table 6). Boron x iron interaction had a statistically significant effect on grain calcium content (Table 4).

Although the effect of iron and boron applications on the copper content of chickpea straws was statistically insignificant, the BxFe interaction had a significant effect (Table 6). While the lowest straw copper value in the boron x iron interaction was determined as 14.3 mg kg^{-1} in B_2xFe_0 application, the highest straw copper content was determined as 20.6 mg kg^{-1} in B_0xFe_0 application. This difference was 44% (Figure 5).

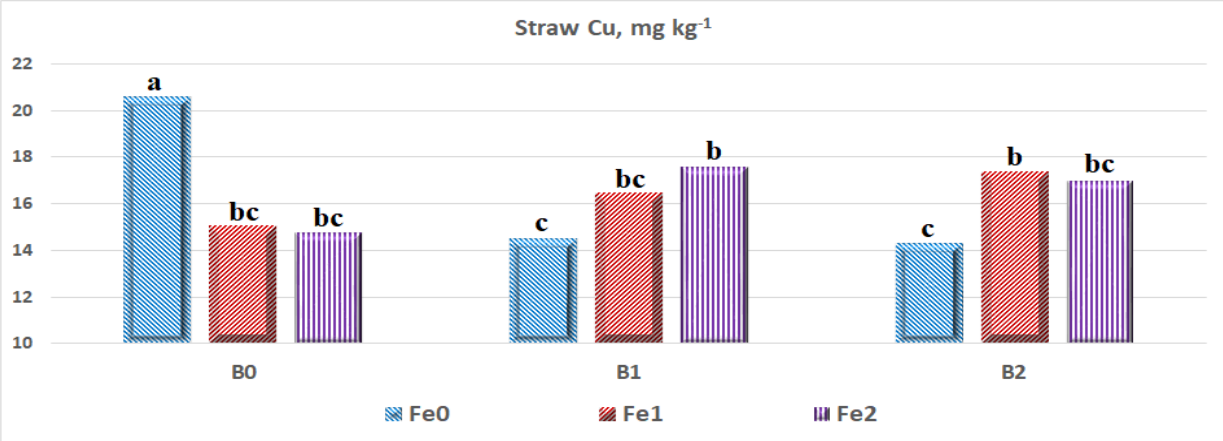

Figure 5. Effects of BxFe interactions on straw copper content, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 2.57.
Şekil 5. BxFe interaksiyonunun sap bakır içeriği üzerine etkisi.

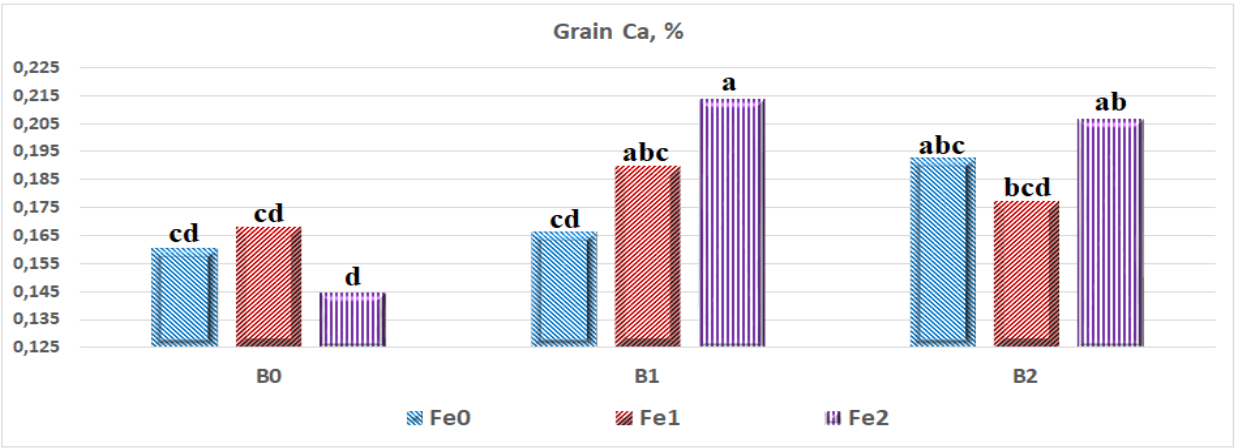

Figure 6. Effects of BxFe interactions on grain calcium content, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 323.
Şekil 6. BxFe interaksiyonunun tane kalsiyum içeriği üzerine etkisi.

The lowest grain calcium content was determined as 1445 mg kg^{-1} in B_0xFe_2 application, while the highest grain calcium content was determined with 2138 mg kg^{-1} in B_1xFe_2 application. There was a difference of 47.9% between these two applications (Figure 6).

A statistically significant decrease was determined in grain magnesium content with both iron and boron applications. While grain Mg content was 1279 mg kg^{-1} in Fe_0 application, it decreased to 682 mg kg^{-1} with Fe_2 application. This decrease was 87.5%. Grain magnesium content was determined as 1393 mg kg^{-1} in B_0 application, while it was determined as 1011 mg kg^{-1} in B_2 application. This decrease was 37.8% (Table 7). Grain magnesium content was affected by boron x iron interaction (Table 4). The lowest grain magnesium content was 747 mg kg^{-1} in B_2xFe_0 interaction, the highest grain magnesium content was determined with 2092 mg kg^{-1} in B_0xFe_1 interaction. 180.0% difference was determined between these two (Figure 7).

While the grain iron, zinc, and boron contents of chickpeas were statistically significantly affected by both iron and boron applications, the grain manganese and grain copper content were statistically significantly affected only by boron application. Boron x iron interaction had a statistically significant effect only on grain zinc (Table 7).

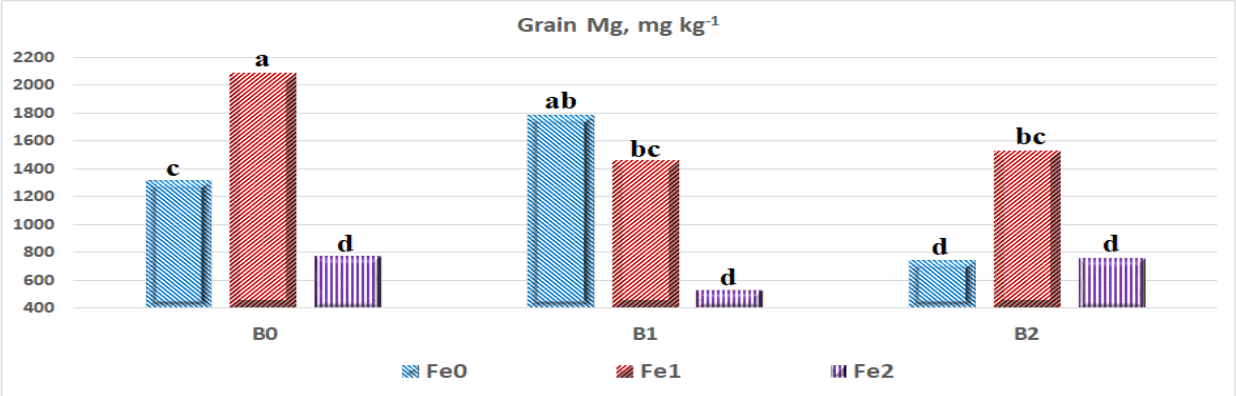

Figure 7. Effects of BxFe interactions on grain magnesium content, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 357.
Şekil 7. BxFe interaksiyonunun tane magnezyum içeriği üzerine etkisi.

Grain iron content increased with increasing iron applications. The grain iron content, which was 89.1 mg kg^{-1} in Fe_0 treatment, was determined as 138.9 mg kg^{-1} with Fe_2 treatment. An increase of about 55.9% was achieved here. A similar situation was obtained in the boron application. The grain iron content, which was 97.4 mg kg^{-1} in B_o application, increased to 135.9 mg kg^{-1} with B_2 application and this increase occurred at the level of 39.5% (Table 8).

Grain manganese content increased only with increasing boron applications. The grain manganese content, which was 21.6 mg kg^{-1} in B_0 application, was determined as 27.0 mg kg^{-1} with B_1 application and 23.6 mg kg^{-1} in B_2 treatment. There was a difference of 25.0% between B_o and B_1 applications (Table 8).

Zinc content of chickpea grain increased with iron and boron applications. While grain zinc content was determined as 46.9 mg kg^{-1} and 45.6 mg k^{-1} in Fe_0 and B_0 applications, respectively, it reached the highest value in Fe_2 and B_1 applications, respectively, as 56.7 mg kg^{-1} and 57.1 mg kg^{-1} (Table 8). When the effect of boron x iron interaction was examined, the lowest grain zinc content was found as 39.8 mg kg^{-1} in B_0xFe_0 interaction, and the highest grain zinc content was 66.8 mg kg^{-1} in B_1xFe_2 interaction. There was a difference of 67.8% between these two values (Figure 8).

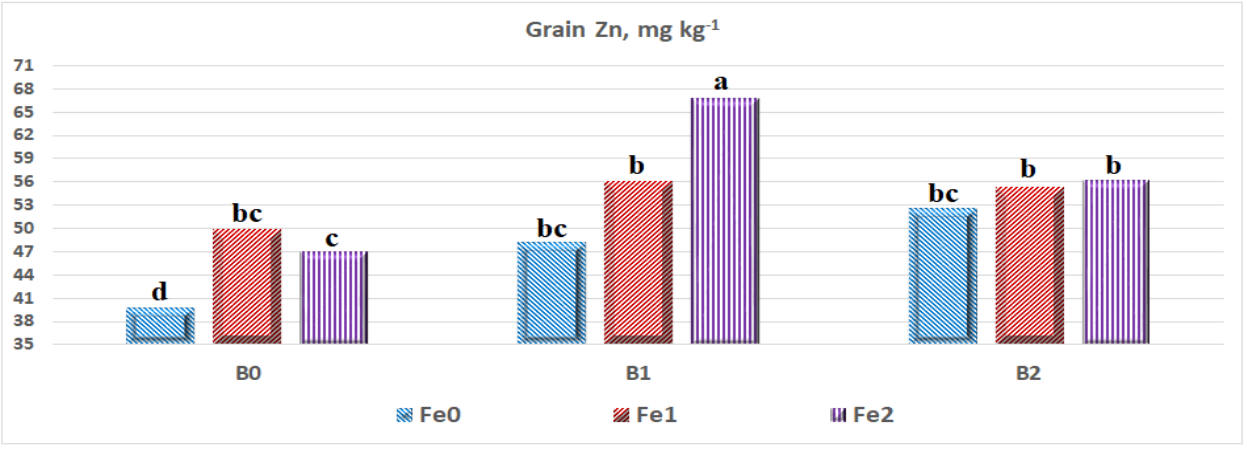

Figure 8. Effects of BxFe interactions on grain zinc content, B_0;0 kg B da^{-1}, B_1;0.25 kg B da^{-1}, B_2;0.50 kg B da^{-1}, Fe0; 0 kg Fe da^{-1}, Fe_1; 5 kg Fe da^{-1}, Fe_2;10 kg Fe da^{-1}, LSD (<0.05): 7.23.
Şekil 8. BxFe interaksiyonunun tane çinko içeriği üzerine etkisi.

Copper content of chickpea grain increased with iron and boron applications. While grain Cu content was determined as 17.8 mg kg^{-1} and 16.8 mg k^{-1} in Fe_0 and B_0 applications, respectively, it reached the highest value in Fe_2 and B_2 applications, respectively, as 19.9 mg kg^{-1} and 20.3 mg kg^{-1} (Table 8).

Chickpea grain boron content increased with both iron and boron applications. While grain boron content was determined as 58.3 mg kg^{-1} in Fe_0 application, it was determined as 77.2 mg kg^{-1} in Fe_2 application. 32.4% increase was achieved here. The grain boron content increased with increasing boron doses, the lowest grain boron content was 59.7 mg kg^{-1} in B_0 application, and the highest grain boron content was 74.8 mg kg^{-1} in B_2 application. Between these two values was determined a difference of 25.3% (Table 8).

DISCUSSION

As a result of the study, which investigated the effect of iron and boron applications on the biofortification of chickpea stem and grain organs, it was determined that application of iron and boron applications separately or together was effective on second branch number, number of pods, fertile pod number and biological yield. This may be due to the genetic characteristics of the plant, or the positive or negative factors brought about by the synergistic or antagonistic relationships between the nutrients. As a matter of fact, in similar studies, it was reported that the effects of iron or boron applications on the yield and yield components differed in applications where they were applied separately or together (Bayrak et al., 2005; Gülümser et al., 2005; Yıldırım, 2016; Erdemci et. al., 2017; Janmohammadı et al., 2017; Kuldeep et al., 2018). Factors such as low relative humidity, low precipitation and high temperature due to unfavorable environmental conditions between March and June, affect the yield; and water is of great importance in the uptake of nutrients by plant roots (Çetin et al., 1999).

When the effects of iron applications on the nutrient contents of chickpea were examined, it was determined that P, K, Mg, Fe, Zn and B contents increased and N, Ca, Mn and Cu contents decreased compared to control plants. When the effects of iron applications on grain nutrient contents were examined, it was determined that N, P, Mg, Fe, Zn and B contents increased and K, Ca, Mn and Cu contents decreased compared to control plants (Figure 4, 5, 6, 7). The pH value in 81.2% of the soils in Turkey is above 7 (Ülgen and Yurtsever, 1995). This limits the intake of other micronutrient elements as well as the iron intake of the plants. The deficiency of micro nutrients, especially iron and zinc, is a global problem (Monreal et al. 2016). Some cultivated plants have special mechanisms to increase the uptake of nutrients such as iron in situations like this (Kacar and Katkat, 1998; Keuskamp et al. 2015). However, this situation causes a decrease in the yields of plants and biofortification does not reach the desired levels. In this context, it is reported that ferrous fertilizer applications cause increases and decreases in nutrient content of cultivated plants (Ghasemi-Fasaei and Ronaghi, 2008; Habib, 2009; Morovat et al., 2019). This is undoubtedly due to antagonistic relations between iron and some elements.

It was determined that boron applications caused an increase in chickpea stem P, Ca, Mg, Fe, Zn and B contents and decrease in its N, K, Mn and Cu contents. Boron applications caused an increase in P, K, Ca, Mg, Fe, Zn and B contents and decrease in N, Mn and Cu contents in BxFe interaction. Boron and boron x iron (BxFe) applications, except for grain magnesium content, were found to cause an increase in N, P, Ca, Mg, Fe, Mn, Zn, Cu and B contents (Figure 4, 5, 6, 7). It is reported in the studies of Ahmed et al. (2011) that boron applications increase N, P, K, Cu, Zn and Fe content. It was reported that the increase in the dry matter of the plant with boron application encourages the intake of more nutrients (Qiong et al., 2002). Similarly, Nasar et al. (2018) reported that boron and molybdenum applications increased yield and nutrient content of peanuts. Boron may have contributed to the increase in yield and nutrient content by taking part in the protein and fat synthesis in the plant (Devi et al. 2012). In the study where boron, zinc, sulfur and phosphorus applications were performed separately or together, it was reported by Tripath et al. (2020) that there is an increase in yield and nutrients of chickpea.

CONCLUSION

As a result, it was determined that both iron and boron applications had positive effects on the stem and grain biofortifications of chickpea. According to the results of soil analysis in terms of yield and yield criteria of chickpea, it is predicted that iron and boron applications will be beneficial when applied together. As a result of our study, the most suitable dose in terms of biological yield, grain yield and biofortification was determined as 0.25 kg B da^{-1} and 10 kg Fe da^{-1} (B_1xFe_2).

CONFLICT OF INTEREST

There is no disagreement between the authors.

DECLARATION OF AUTHOR CONTRIBUTION

MHÖ: Gathered the information, analyzed the data the manuscript. FS: conceptualized and designed the study, wrote and checked the final draft

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Investigation of the Soil Properties in the Habitat of the Local Endemic Taxon *Verbascum yurtcuranianum*

Lokal Endemik *Verbascum yurtkuranianum* Taksonunun Yetiştiği Alandaki Toprak Özelliklerinin İncelenmesi

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Abstract: *Verbascum yurtkuranianum* is a locally endemic species distributed in Ericek province of Gürsu District of Bursa Province. In research, the element contents and soil properties of soil samples from 5 different locations where the *V. yurtkuranianum* taxon naturally spread were analyzed and they were correlated with the number of individuals in the locations. The soil properties in locations were determined to be clayey, low-medium calcareous, and moderately rich in organic matter. In this study dated 2023, it was determined that the total number of individuals with flowers or rosette leaves in 5 populations of *V. yurtkuranianum* naturally spread in Ericek location was 235, 216 of them had rosette leaves and 19 of them had flowers. The highest number of individuals with rosette leaves was found in location V, and the highest number of individuals with flowers was found in location I. At the same time, it was observed that the total number of individuals was highest in the region between the road and the shore of the pond located on the southeastern shore of Ericek province, which is the location V. considering that *V. yurtkuranianum*, a locally endemic species, is at risk due to human activities, we believe that the results obtained will provide important findings for the conservation studies of the species.

Keywords: Biological Diversity, Bursa, Local Endemic, Soil Properties, *Verbascum yurtkuranianum*

&

Öz: *Verbascum yurtkuranianum* Bursa İli, Gürsu İlçesi, Ericek köyü'nde bulunan lokal endemik bir türdür. Araştırmada, *V. yurtkuranianum* taksonunun doğal yayılış gösterdiği Ericek köyü mevkiinde 5 farklı lokasyona ait toprak örneklerinin element içerikleri ve toprak özellikleri analiz edilmiş olup lokasyonlarda bulunan birey sayılarıyla da ilişkilendirilmiştir. Lokasyonlardaki toprak özelliklerinin; killi, az-orta kireçli, organik madde açısından ise orta-zengin özellikte olduğu belirlenmiştir. 2023 yılına ait bu çalışmada *V. yurtkuranianum*'un Ericek mevkinde doğal yayılış gösterdiği 5 popülasyonundaki çiçekli veya rozet yapraklı birey sayılarının 235 olduğu, bunlardan 216 tanesinin rozet yapraklı, 19 tanesinin ise çiçekli bireyler olduğu tespit edilmiştir. Rozet yapraklara sahip bireylerin V. lokasyonda en yüksek sayıda, çiçekli bireylerin ise I. lokasyonda en yüksek sayıda bulunmuştur. Aynı zamanda toplam birey sayısının V. lokasyon olan Ericek Göleti'nin güneydoğu kıyısında yer alan Gölet kıyısı ile yol arasındaki bölgede en yüksek sayıda olduğu gözlenmiştir. Lokal endemik bir tür olan *V.m yurtkuranianum*'un insan faaliyetleri nedeniyle risk altında olduğu düşünüldüğünde, elde edilen sonuçların, türün koruma çalışmaları için önemli bulgular sağlayacağı kanısındayız.

Anahtar Kelimeler: Biyolojik Çeşitlilik, Bursa, Lokal Endemik, Soil Properties, *Verbascum yurtkuranianum*

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INTRODUCTION

The main problem underlying biodiversity conservation is the extinction of species due to anthropogenic factors (Collen et al., 2013; Erken et al., 2022; Rice, 2012). The loss of plant biodiversity, in particular, has become a global concern and an important issue today (Le Roux et al., 2019; Knapp et al., 2020). It is estimated that more than 40% of the world's plant species are currently threatened with extinction (Nic Lughadha et al., 2020).

In Anatolia, the genus *Verbascum* L., also known as "Sığırkuyruğu," is represented by 360 taxa worldwide, including 256 species and 129 hybrids in Türkiye, 198 of which are endemic (Aytaç and Duman, 2012; Bani et al., 2010; Çıngay and Karavelioğulları, 2016; Duman et al., 2017; Fırat, 2017a, 2017b; Karavelioğulları et al., 2014; Ulukuş et al., 2020). The *Verbascum* genus is widely distributed in the temperate regions of the Northern Hemisphere, particularly in the eastern parts of Eurasia, and Anatolia is predominantly within the Irano-Turanian phytogeographic region (Dong et al., 2022; Fırat, 2022; Karavelioğulları, 2012). Within the geographical confines of the Bursa Province and its immediate environs, a total of 22 plant species belonging to the *Verbascum* genus have been documented. The flowers of *Verbascum* species are generally yellow, and the flowers of twoof the species found in Türkiye are pink-purple. *Verbascum yurtkuranianum*, otherwise known as Gök Sığırkuyruğu, is a species that has been documented as being endemic to a specific area within the boundaries of Bursa Province. The literature has recorded it as the third purple-flowered taxon distributed within Türkiye (Anonim, 2016).

Gök Sığırkuyruğu (*V. yurtkuranianum*) is a locally endemic species belonging to the *Verbascum* genus of the Scrophulariaceae family, introduced to the scientific world in 2006. Gök Sığırkuyruğu (*V. yurtkuranianum*) is found in small groups within a very narrow range of 2 km² in the Ericek area of Gürsu district, Bursa Province (Anonim, 2016). The area where the plant was identified is located in the Euro-Siberian Phytogeographic Region and corresponds to the A2 square according to the Flora of Türkiye (Erdoğan et al., 2011). Like other *Verbascum* species, *V. yurtkuranianum* is found in habitats dominated by ruderal conditions, such as roadsides, highway drainage channels, picnic areas, and locations near rural settlements. Its preference for these challenging ruderal habitats as its living environment has restricted the species' distribution and placed it in the critically endangered (CR) category according to IUCN criteria, making it part of the highly at-risk group of endemic plants (Erdoğan et al., 2011). Due to various anthropogenic effects and their presence in synanthropic (urban) habitats with altered living conditions, it is suggested that the species may lose more than 50% of its individuals within the next 10 years.

In recent years, considerable endeavours have been made to conserve biodiversity; nevertheless, biodiversity currently faces significant challenges due to human-induced factors (Le Roux et al., 2019; Soysal, 2012). Of particular note is that limited geographic distribution is a significant indicator of the extinction risk of terrestrial plants (Knapp et al., 2020). Despite the implementation of various social initiatives by public institutions aimed at safeguarding the habitats of *V. yurtkuranianum*, which is limited to a few populations within a confined area, it is evident that there is a lack of data concerning soil properties, cultivation requirements, the plant's metabolic processes, and the identification of its active compounds. Concurrently, this species, which possesses the potential to be utilized as an ornamental plant due to its distinctive characteristics, including bright green, hairless basal leaves, purple petals, and a prolonged flower lifespan, is in urgent need of scientific research to facilitate a more comprehensive understanding of its properties (Erken, 2021).

Leaves are the place where the plant best reflects important physiological events such as respiration, photosynthesis, transpiration and nutrition. Therefore, the nutrient concentration in the leaves is very important in evaluating the nutrient content of the plant. Soil is an important environmental factor that drives plant ecology (Laliberte et al., 2014). The uptake of nutrient elements absorbed inorganically from the soil varies depending on the pH, temperature, amount of light and structure of the soil. Endemic plants are species with limited geographic distribution and settlement, and it is expected that the soil characteristics of the populations where these species are found will meet the specific requirements of the plant species (Muller, 2015). Due to the narrow distribution areas, in order to ensure the continuation of

the generation of the *Verbascum* species, examining the soil structure of the area where the plant is distributed and determining its characteristics will be very important in terms of the sustainability of biodiversity.

Therefore, in this study, soil samples were collected from five different locations in Ericek, a neighborhood in the Gürsu district of Bursa Province, where the locally endemic species *V. yurtkuranianum* naturally occurs. The samples were analyzed for their elemental content and soil properties to better understand the species' distribution area. Additionally, the number of individuals present at these natural locations was determined and correlated with the soil analyses. This study aims to contribute to efforts for the *ex situ* conservation and sustainability of this locally endemic species.

MATERIAL AND METHOD

In 2023, soil sampleswith five replicates were taken and and analyzed from five different locations in a 2 km² area in the Ericek region of Gürsu district, Bursa Province, where the plant naturally spreads. The location details of the natural distribution of *V. yurtkuranianum* populations are provided in Table 1. Although the 2016 Action Plan by the Nature Conservation and National Parks II Regional Directorate – Bursa Branch indicated nine locations where *V. yurtkuranianum* populations were found, only five locations were identified during our 2023 fieldwork.

Table 1. Localities where *Verbascum yurtkuranianum* species were found from which soil samples were taken.
Çizelge 1. Toprak örneği alınan Verbascum yurtkuranianum türünün bulunduğu lokaliteler.

Stations	Altitude	X, Y Coordinate	Habitat
I	670 m	691965.13 D, 4465260.18 K	Roadside
II	694 m	692681.57 D, 4465387.58 K	Fieldside
III	695 m	693092.00 D, 4465080.00 K	Fieldside
IV	689 m	693054.00 D, 4465055.00 K	Meadow area
V	744 m	694641.29 D, 4464523.37 K	Between pond shore and road

In the study, soil samples taken from a depth of 0-20 cm following the principle of efficiency were analyzed for clay, silt, and sand fractions according to the "hydrometer method" and their texture classes were determined according to the "Soil Survey Manual" (Bouyoucos,1962).

The pH values of the soil samples were determined using an Orion 720A model pH/ion meter after diluting the samples with pure water at a 1:1 ratio. The EC values of the samples were measured using a WTW LF 92 model EC meter after diluting the samples with pure water at a 1:1 ratio (Rhoades,1996). The lime contents were measured using the "Scheibler calcimeter," and the results were expressed as % $CaCO_3$ (Allison and Moode, 1965). The organic matter content of the soil samples was determined using the "modified Walkley-Black" method (Nelson and Sommer, 1982). The nitrogen (N) content of the samples was determined using the "Kjeldahl method" (Bremner, 1965). The samples were combusted in a Buchi K-437 digestion block and distilled using a Buchi K-350 steam distillation unit. The plant-available phosphorus (P) content of the soils was determined in the filtrate obtained by extracting with "0.5 M sodium bicarbonate ($NaHCO_3$, pH 8.5)" using the "ascorbic acid method"(Watanabe and Olsen, 1965). The extractable copper (Cu), zinc (Zn), manganese (Mn), and iron (Fe) contents of the soils in the area where the plant is located were determined using a Perkin Elmer OPTIMA 2100DV model ICP in the filtrate obtained after extraction with DTPA +TEA+$CaCI_2$ solution (pH: 7.3) (Lindsay and Norvell, 1978). The obtained results were compared with the threshold values reported by Motsara and Roy (2008). Critical limits for DTPA-extractable micronutrients are given in Table 2.

Table 2. Microelement limit values in the soils sampled in the study.
Çizelge 2. Çalışmada örneklenen topraklardaki mikroelement sınır değerleri.

Availability	Micronutrients (mg kg^{-1})			
	Zn	Cu	Fe	Mn
Very low	<0.5	<0.1	<2.0	<0.5
Low	0.5-1.0	0.1-0.3	2.0-4.0	0.5-1.2
Medium	1.0-3.0	0.3-0.8	4.0-6.0	1.2-3.5
High	3.0-5.0	0.8-3.0	6.0-10.0	3.5-6.0
Very high	>5.0	>3.0	>10.0	>6.0

Statistical Analysis

The data were statistically evaluated using the JMP 7.0 (SAS Company, US) program. A completely randomized design was used in the evaluation. The comparison was made with five replications. The LSD test was employed to determine the statistically significant differences among the mean values.

RESULTS AND DISCUSSION

In this study conducted in 2023, the soil samples taken from five populations of the locally endemic species *V. yurtkuranianum*, naturally distributed in the Ericek area, were analyzed for sand, silt, clay, texture, pH, EC, lime, organic matter, N, P, Cu, Zn, Mn, and Fe contents. The analysis results are presented in Table 3. The soil texture classes of the study area were evaluated as "loam," "silty clay," and "clay (Pansu and Gautheyrou, 2006). Accordingly, it was determined that the clay content of the soils ranged from 33.50% to 54.20%, the silt content ranged from 20.15% to 41.20%, and the sand content ranged from 17.60% to 42.5%.

The soil pH values ranged between 7.00 and 7.54. Based on these values, the soils of the study area were evaluated as having a 'neutral' reaction (Richards, 1954). The soil EC values ranged from 218 to 748 µS cm^{-1}. According to these results, the soils were classified as 'non-saline' (Richards, 1954). Compared to other *Verbascum* species, Cabi et al. (2022) noted that *Verbascum bugulifolium* (Riva Sığırkuyruğu), which is also one of the rare plant species of our country and found in various flower colors such as blue, green, and brown, also grows in non-saline soils but is found in acidic soils in terms of pH values.

Table 3. Mean statistics results of soil samples taken from localities where *Verbascum yurtkuranianum* species are found.
Çizelge 3. Verbascum yurtkuranianum türünün bulunduğu lokalitelerden alınan toprak örneklerinde yapılan ortalama istatistik sonuçları.

	Locations					
Properties	**I**	**II**	**III**	**IV**	**V**	**LSD**
Sand %**	19.28	25.65	18.80	17.60	42.50 *	3.82
Silt %**	33.07	20.15	41.20 *	29.90	24.00	3.75
Clay %**	47.65	54.20 *	40.00	52.50	33.50	5.17
Texture	Clay	Clay	Silty Clay	Clay	Loam	
pH*	7.00 b	7.38 ab	7.54 a*	7.08 b	7.21 b	0.27
EC, µS cm^{-1}**	270 cd	279 c	748 a*	218 d	444 b	53.29
Lime ($CaCO_3$), %**	2.54 b	0.53 c	0.66 c	0.53 c	7.89 a*	0.19
Organic matter, %**	3.42 c	3.96 b	2.79 d	3.38 c	5.69 a*	0.36
N content %*	0.213 b	0.323 a*	0.175 b	0.197 b	0.316 a	0.08
Available P, mg kg^{-1}**	0.90 c	0.65 c	1.51 b	2.18 a*	2.09 a	0.39
DTPA eks Cu, mg kg^{-1}**	0.60 c	1.42 b	2.38 a*	1.58 b	0.80 c	0.23
DTPA eks Zn, mg kg^{-1}**	1.82 b	1.08 d	1.92ab	1.34 c	2.15 a*	2.05
DTPA eks Mn, mg kg^{-1}**	16.26 b	4.06 d	13.14 c	12.78 c	24.74 a*	2.05
DTPA eks Fe, mg kg^{-1}**	13.22 a*	3.70 c	7.86 b	10.32 b	4.80 c	2.37

**p<0.01, *p<0.05 Lower case letters indicate the difference between means.
* It represents the highest value among the locations.

The soil samples collected from five different locations showed statistically significant differences. In terms of soil pH values, the highest value was observed at location III, with the ranking as follows: III (7.54) > II (7.38) > V (7.21) > IV (7.08) > I (7.00). The highest salinity value was also determined at location III, ranked as follows: III (748) > V (444) > II (279) > I (270) > IV (218). The total $CaCO_3$ content of the soil samples collected from the natural distribution areas of *V. yurtkuranium* ranged between 0.53% and 7.89% (Table 3). For lime ($CaCO_3$) content, location V recorded the highest value (7.89%), followed by location I (2.54%) and location III (0.66%). Locations II (0.53%) and IV (0.53%) had the same lime values. Based on these values, the soils were classified as 'non-calcareous' to 'moderately calcareous' (Allison and Moode, 1965). The organic matter content of the soils varied between 2.79% and 5.69%. According to these values, the soils were observed to range from 'moderate' to 'high' and 'very high' in terms of organic matter content. Similarly, it has been demonstrated by Cabi et al. (2022) that *Verbascum bugulifolium* (Riva Sığırkuyruğu) also thrives in soils with good levels of organic matter content. In parallel with these findings, the nitrogen (N) content of the soil samples collected from the natural distribution areas of *V. yurtkuranium* ranged between 0.175% and 0.323%. When evaluated in terms of nitrogen (N) content, the highest N content was found at location II (0.323%). The ranking of nitrogen contents was as follows: II (0.323%) > V (0.316%) > I (0.213%) > IV (0.197%) > III (0.175%). Based on these results, the soil samples were classified as 'moderate' to 'high' in terms of nitrogen content.

It has been determined by Hilooğlu and Sözen (2017) that *Verbascum alyssifolium* Boiss, an endemic plant species with a narrow distribution range in Erzincan province, is similarly found in soils that are slightly to moderately calcareous, have low salinity levels, and contain moderate to rich levels of organic matter. Likewise, Hilooğlu et al. (2017) identified that *Teucrium leucophyllum*, another endemic plant species in the Erzincan region, grows in nitrogen-rich and highly organic matter-rich soils in its distribution areas. Özbucak et al. (2022) studied *Alchemilla orduensis* B. Pawl, a locally endemic species found in the Perşembe plateau in the Aybastı district of Ordu province, and revealed that the soil in the area where the plant occurs is rich in organic matter (6.40%-6.86%).

As indicated in Table 3, the highest available P content (2.18 mg kg^{-1}) was detected at location IV, while the lowest value (0.65 mg kg^{-1}) was observed at location II. The soils where *V. yurtkuranium* naturally occurs were classified as 'very low' in terms of available P content. Accordingly, it was determined that the *V. yurtkuranium* species prefers soils with low P content. Similarly, soil analysis of *Verbascum bugulifolium* (Riva Sığırkuyruğu), a rare plant species in the genus *Verbascum* with flower colors differing from the typical yellow, also revealed that it grows in soils with low P content (Cabi et al., 2022).

For DTPA-extractable Cu, the highest value was at location III (2.38 mg kg^{-1}), and the lowest was at location I (0.6 mg kg^{-1}). Regarding DTPA-extractable Zn and Mn contents, the highest values were obtained from soils at location V (2.15-24.74 mg kg^{-1}), whereas the lowest values were found in soil samples from location II (1.08-4.06 mg kg^{-1}). The DTPA-extractable Fe content of the soils was ranked as follows: I (13.22 mg kg^{-1}) > IV (10.32 mg kg^{-1}) > III (7.86 mg kg^{-1}) > V (4.80 mg kg^{-1}) > II (3.7 mg kg^{-1}). The soils were classified as 'low' to 'moderate' in Fe, 'low' to 'high' in Cu, 'low' in Zn, and 'very low' to 'moderate' in Mn content. Accordingly, it was determined that the endemic *V. yurtkuranium* species prefers soils with low to moderate levels of Fe, Zn, Mn, and Cu. Compared to other *Verbascum* species, it was observed that the soil requirements of *Verbascum olympicum*, an Uludağ endemic from Bursa province, differ significantly from those of *V. yurtkuranium*. *Verbascum olympicum* develops in soils rich in metals such as Cu, Fe, Zn, and Mn, and accumulates these metals in plant tissues (Akpınar, 2017). When compared to the elemental content of soils where *Verbascum alyssifolium* Boiss is found, it was determined that *V. yurtkuranium* grows in soils with higher Cu and Mn content, while both species occur in soils with similar Zn and Fe levels (Hilooğlu and Sözen, 2017).

The total number of *V. yurtkuranium* individuals was determined to be 235 (Table 3). Of these, 216 were identified as rosette-leaved individuals, while 19 were flowering individuals. It has been noted by Anonim 2016 that *V. yurtkuranium*, a biennial plant, has rosette leaves in its first year and blue-purple flowers in its second year. Accordingly, it was observed that among the populations of *V. yurtkuranium* in its natural

distribution at the Ericek site, the highest number of rosette-leaved individuals was found at location V. flowering individuals were most numerous at location I, with 8 flowering individuals. Additionally, the total number of individuals was highest in the area between the Ericek Pond's southeastern shore and the road, located at location V.

Table 4. Number of individuals with flowers or rosette leaves in *V. yurtkuranium* populations from which soil samples were taken.
Çizelge 4. Toprak örneği alınan V. yurtkuranium popülasyonlarındaki çiçekli veya rozet yapraklı birey sayıları.

Location	2023	
	Flowering	Rosette Leaf
I	8	15
II	2	26
III	4	12
IV	4	12
V	1	151
Total	19	216
Total Number of Individuals	235	

CONCLUSION

Soil conditions can limit the formation and distribution of plant species. The soil characteristics of the populations of *V. yurtkuranium* (Gök Sığırkuyruğu), a locally endemic species with a natural distribution in the Ericek area of Gürsu district, Bursa province, have been investigated for the first time in this study. The soil characteristics of the five different populations where the species occurs naturally were presented, correlating with the number of *V. yurtkuranium* individuals found at these locations. It was observed that the dominant soil characteristics at the locations are clayey, slightly to moderately calcareous, low salinity, and of medium to rich organic matter content.

When the soil samples were evaluated in terms of element contents such as Fe, Mn, Zn, and Cu, it was found that they were at low to moderate levels. Compared to the number of individuals at the locations, the highest number of individuals was observed at location V. The highest number of flowering individuals was found at location I. Based on the findings, it was determined that *V. yurtkuranium* grows in soils with different characteristics. The results of this study are expected to provide significant data for the development of conservation strategies for the locally endemic *V. yurtkuranium* populations in the Ericek area of Gürsu district, Bursa province, which are at risk due to human activities.

CONFLICT OF INTEREST

The authors of the articles declare that they have no conflict of interest.

DECLARATION OF AUTHOR CONTRIBUTION

Ferrin Ferda AŞIK and Ayşegül AKPINAR carried out the fieldwork together. The results were obtained by Ferrin Ferda AŞIK , and the writing of the article was done by Ayşegül AKPINAR.

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Research Article

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New Locality Record for Indian Crested Porcupine *Hystrix indica* Kerr, 1792 in Afyonkarahisar Province, Türkiye

Hint Oklu Kirpisinin *Hystrix indica* Kerr, 1792 Afyonkarahisar ilinde Yeni Lokalite kaydı, Türkiye

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Abstract: The Indian crested porcupine (*Hystrix indica,* Kerr, 1792) is a large rodent species that is listed as Least Concern (LC) on the IUCN Red List at the international level and is listed as Endangered category (EN) in Türkiye. The presence of the Indian crested porcupine was determined in Sandıklı region of Afyonkarahisar province and the first locality record was given in this study for this province. The study was carried out using direct and indirect observation techniques. In addition, information about the habitat characteristics and conservation measures of the Indian crested porcupine in the region was given in this study.

Keywords: *Hystrix indica,* Ecology; Habitat, Conservation, Camera Trapping

&

Öz: Hint oklu kirpisi (*Hystrix indica*, Kerr, 1792), uluslararası düzeyde IUCN Kırmızı Listesi'nde En Az Endişe Verici (LC) olarak listelenen ve Türkiye'de Tehlike Altında (EN) kategorisinde yer alan büyük bir kemirgen türüdür. Afyonkarahisar ili Sandıklı ilçesinde Hint oklu kirpisinin varlığı tespit edilmiş ve bu il için ilk lokalite kaydı bu çalışmada verilmiştir. Çalışma doğrudan ve dolaylı gözlem teknikleri kullanılarak gerçekleştirilmiştir. Ayrıca bu çalışmada Hint oklu kirpisinin bölgedeki habitat özellikleri ve koruma önlemleri hakkında bilgi verilmiştir.

Anahtar Kelimeler: *Hystrix indica,* Ekoloji; Habitat, Koruma, Fotokapan

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INTRODUCTION

Porcupines belong to the family Hystricidae of the order Rodentia. The Old-World porcupines (Hystricidae) distributed in the southern Asia, Mediterranean Europe and throughout Africa (Kahraman et al., 2022; Siler, 2023; Yürümez and Ulutürk, 2016). The Indian crested porcupine (*Hystrix indica* Kerr, 1792) is the exclusive representative of its family found in Türkiye, as documented by Yürümez and Ulutürk (2016), Kahraman et al., (2022), and Siler (2023). The first description of the Indian crested porcupine in Türkiye was made by Yılmaz et al., in 1998, who classified it as *H. cristata.* It was later confirmed by several authors, including Kumerloeve (1975) as *H. indica*, the largest rodent in Türkiye, distributed in the Aegean, Mediterranean, south-eastern Anatolia, Bitlis and Siirt. (Arslan, 2008; Fattorini and Pokheral, 2012). Presence of porcupines has been reported to date in Adana, Adıyaman, Antalya, Aydın, Balıkesir, Bursa, İskenderun, İzmir, Kahramanmaraş, Kocaeli, Kütahya Mersin and Muğla (İnaç et al., 2011), Batman (Yürümez and Ulutürk, 2016), Hatay (Hassa, Reyhanlı districts) (Çoğal et al., 2016), Adıyaman, Adana and İçel (Arslan, 2006), Gaziantep (Arslan, 2008), Manisa (İlemin, 2022). İskenderun, Mersin, Muğla, Aydın (Söke, Koçarlı, Karpuzlu, Yenipazar, Çine districts), İzmir, Balıkesir (Kahraman et al., 2022). According to Kumerloeve (1975), with reference to Corbet and Morris (1967), a record of the species was also given in Finike.

The Indian crested porcupine is classified as a species of "least concern" on the IUCN Red List; however, it is considered a endangered rodent species in Türkiye (Kahraman et al., 2022; Siler, 2023). Although they are called "hedgehogs" because of the quill which are hollow and hardened bristles, that start from the shoulder part of their body to the tail, they are not related to porcupines.

There is an ongoing requirement for research on porcupines in Türkiye (Yürümez and Ulutürk, 2016). Crested porcupines are known for their monogamous nature and generally prefer a solitary existence, only coming together for mating or the nurturing of their young (Coppola and Felicioli, 2021; Gurung and Singh, 1996; Kleiman, 1977; Lovari et al., 2013; Mori et al., 2017). It accompanies a mate during the mating season, followed by the offspring for a period of up to one year (Fattorini and Pokheral, 2012; Mori et al., 2017). This animal is primarily active during the night and rests in a burrow or a small cave throughout the day. (Amr et al., 2004; Gurung and Singh, 1996; Siler, 2023).

In environments characterized by aridity or semi-aridity, the availability of wild fruits is limited throughout the year, compelling porcupines to traverse extensive distances, occasionally up to 3.5 km from their dens, in search of sustenance (Lovari et al., 2013; Mori et al., 2017). Underground storage organs of plants and agricultural products enable porcupines to survive without the need for drinking water, which is a crucial adaptation in a semi-arid climate (Alkon and Saltz, 1988; İnaç et al., 2011; Mori et al., 2017).

It is known that they live on deserted slopes, away from human influence and where the Mediterranean climate prevails (Siler, 2023). They prefer grassy and wetland areas with vegetation such as oaks and shrubs. They live close to wetlands, they get water from the food they eat but need to drink it and they are good swimmers (İnaç et al., 2011; Yürümez and Ulutürk, 2016).

Average lifespan of porcupines is 15-20 years (İnaç et al., 2011). These wild animal species mate in April. Data collected from captured wild Indian crested porcupines indicates that their reproductive activity is ongoing, particularly from April to September (Coppola and Felicioli, 2021). Male and female stay together during the mating and offspring time. After a pregnancy lasting 60-70 days (nine weeks), the female gives birth to 2-4 cubs with open eyes and soft spines in her own nest (İnaç et al., 2011). Certain studies (Amr et al., 2004; Gurung and Singh, 1996), it is noteworthy information attracts attention that the mother brings water to the young animals with her hollow terminal spines. The duration of inbreeding of the Indian crested porcupine from birth to dispersal varies from 1 to 2 years, depending on when subadults reach sexual maturity (Coppola and Felicioli, 2021; İnaç et al., 2011).

The main food source of the species is vegetal matter such as cultivated crops, grains, fruits, roots, bulbs and tubers (Bruno and Riccardi, 1995). It has been reported that it causes damage to agricultural areas such as grapes, vineyards and orchards, and therefore is caught by farmers in traps (İnaç et al., 2011; Khan et al.,

2022). Currently, *H. indica* faces significant threats primarily due to habitat destruction, the use of pesticides, and hunting for their meat by non-Turkish nomads in certain areas, resulting in a decline in the porcupine population in Anatolia (Amr et al., 2004; Çoğal et al., 2016; İlemin, 2022; İnaç et al., 2011; Yürümez and Ulutürk, 2016). According to Turkish law, hunting is prohibited (İnaç et al., 2011; Yürümez and Ulutürk, 2016).

MATERIAL AND METHOD

Sandıklı district is affiliated with Afyonkarahisar province and located in the Aegean region. The geographical location of Sandıklı, which has a surface area of 1036 km², is between 29°50'-30°30' Eastern meridians (Longitude) and 38°15'-38°45' Northern parallels (Latitude). Sandıklı district has a hot and very dry climate in summer and a cold and snowy climate in winter. According to the data between 1929-2022 in Sandıklı, which has a continental climate, the lowest average temperature is -3°C in January and the highest temperature is +26°C in August (MGM, 2023). The vegetation cover of the area varies according to the local climate, with a diverse range of species including black pine, red pine, Scots pine, and white pine, as well as skunk juniper, gray juniper, Finike juniper, dwarf juniper, Turkish oak, alder, elm, maple, ash, and sweetgum trees. Short trees of the maquis flora species are encountered. The plains are completely open and thorny plants can be seen. Willows, poplar trees, blackberries, grapes, and rosehips appear along the edges of the streams (URL 1.). Although farmers mostly deal with dry farming (barley, wheat, vetch), they also engage in irrigated agriculture (poppy, potatoes, sugar beet, onion, walnut, sour cherry).

The study was carried out in the Sandıklı region between January 2023 and May 2024. Camera traps were installed in ten different locations (Table 1) by the Opportunity point method, and direct (Bushnell 8-16x40 binoculars, DSLR CanonEOS 750D) and indirect (footprint, quill, feces) observations, which are among wildlife observation techniques, were carried out in and around these locations. Bushnell brand camera traps were used in the study. The camera trap recordings underwent inspection on a biweekly basis, with battery replacements conducted as required. In addition, local people and hunters were interviewed and information was collected about wild animals in the field, the presence of porcupines and their habitats.

Table 1. Locations where camera traps are set up.
Çizelge 1. Kamera tuzaklarının kurulduğu lokasyonlar.

No	Location	Coordinates	Altitude
1	Alamescid	38°20'23.65"N, 30°08'10.11"E	1054
2	Celiloğlu	38°23'20.51"N, 30°9'18.88"E	1105
3	Yayman	38°23'49.74"N, 30°6'42.14"E	1208
4	Asmacık	38°19'29.19"N, 30°6'18.45"E	1203
5	Alamescid	38°20'16.67"N, 30°8'37.54"E	1058
6	Çamoğlu	38°21'36.58"N, 30°5'10.27"E	1190
7	Alamescid	38°20'19.90"N, 30°8'24.06"E	1065
8	Asmacık	38°20'33.34"N, 30°7'44.76"E	1134
9	Asmacık	38°20'12.12"N, 30°7'30.69"E	1087
10	Alamescid	38°20'23.80"N, 30°8'17.56"E	1070

RESULTS AND DISCUSSION

The fields in the Sandıklı district were scanned using direct and indirect observation techniques, and camera traps were set in areas that porcupines can use as nests. It was determined that the target species was very sensitive and did not leave its nest during night observations. To avoid disturbing the species, only camera traps were utilized on the remaining days, with a preference for indirect observations.

Camera traps were set up at 10 locations using the point of opportunity method, and 11 porcupine images were recorded at location 1. The images were recorded inside the cave and in front of the cave at location 1. in differend days. Sandıklı, Alamescid village is located at 38°20'23.65"N, 30°08'10.11"E and 1054m altitude (Figure 1.) One porcupine individual was recorded in the images captured by the camera trap at the Alamescid location.

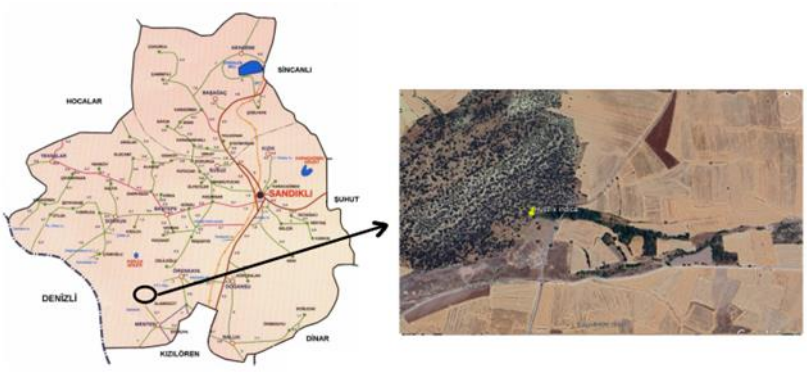

Figure 1. Porcupine recorded location 1 Alamescid village. 38°20'23.65"N, 30°08'10.11"E.
Şekil 1. Hint oklu kirpisi kaydedilen lokasyon 38°20'23.65"N, 30°08'10.11"E.

It was estimated that the species lived in a cave located at the intersection triangle of agricultural areas, forest borders and wetlands in the region. However, a camera trap set up at the entrance to the cave at (Alamescid location 1) showed that the species was nesting in the cave (Figure 2).

Figure 2. a) Cave entrance, b) Indian crested porcupine (*H. indica*).
Şekil 2. a) Mağara girişi, b) Hint oklu kirpisi (H. indica).

It has been determined that the species is sensitive to smell and sound, like other wild mammalian species. At the Alamescid location, a porcupine was seen sniffing the camera in a 20-minute photocapture.

The cave is at an altitude of 1050m and its view is in a southern location. According to the results of a similar study, it is understood that porcupines generally prefer areas with low altitude (700-900m), slope (50-75%) structures as habitats. It has been observed that there are nests or caves especially in areas close to the stream passing through the study area (İnaç et al., 2011).

The cave where our target species nests aspect is south. Similar to our study results, in another study it was reported that porcupines prefer southern exposures and only a few data were recorded in northern (N) exposure (İnaç et al., 2011). Diggable soil and southern aspects are preferred elements for ground-nesting wild animals (Aksan et al., 2014).

The cave entrance, where the target species resides and builds its nest, measures 80cm in height and 192cm in width. Cave entrance has a width of 5m².The cave's interior extends with a passage that measures 70cm in height and 90cm in width. During interviews with local people, one person who entered the cave stated that, the length of the cave was 200m. He stated that there were multiple galleries in the cave,some of which contained water while others were dry. He reported seeing bone remains and porcupine quill in some of the galleries.

The cave is located at the intersection of dry and irrigated agricultural lands and the forest (*Juniperus communis* and *Quercus ithaburensis*) border (Figure 3). Right next to the cave (near the cave, up to 50 m),

there is a wetland formed because of the accumulation of an underground water source with a diameter of 50m. Similarly, İnaç et al., (2011), stated that porcupines prefer areas covered with Anatolian bonito oak (*Q. ithaburensis*) and holm oak (*Quercus ilex)* species for nesting and agricultural areas for feeding. Another study on porcupines found that their habitat is sparsely covered with coniferous forests and has similar types of hilly habitats and vegetation (Khan et al., 2022).

Figure 3. Habitat of *H. indica* a) Forest border, b) Wetland, c) Dry and irrigated agricultural areas.
Şekil 3. H. indica habitatı a) Orman sınırı, b) Sulak alan, c) Kuru ve sulu tarım arazileri.

Like as our results the place where porcupines nest in Batman province is on the banks of the Tigris River and the dominant vegetation consists of oak (Yürümez and Ulutürk, 2016). In the study by Fattorini and Pokheral (2012), analysis of habitat selection between forests and grasslands showed that porcupines preferred grasslands. The factors influencing this selection could include the distribution of food resources or the presence of major forest predators, for instance, the leopard (*Panthera pardus*). Aksan (2018) stated that in her study (2018), the diversity of herbaceous and woody plant species along with the structural diversity in the area increases the habitat richness that wild animals can use for activities such as shelter, shelter, hiding, feeding and resting. Our findings are like Arslan (2008) in terms of the species' habitat and the cave characteristics in which it nests. Moreover, Arslan (2008) discovered the presence of a river or a waterhole in proximity to five burrows excavated by porcupines in the regions of Ceyhan and Bozyazı. The author indicated that the burrows were found on the side of heavily forested areas, the entrance of burrows had 40cm height and this height went on throughout tunnel which is average 4.5m length. Aksan and Akbay (2018) reported that the presence of water resources, agricultural areas and natural areas around it led to an increase in species diversity.

It is known that porcupines use agricultural areas for both feeding and hiding. It was determined from the indirect traces/signs (path, gnaw marks, feathers, porcupine quills, etc.) and feces found in the field that porcupines feed on potatoes, sugar beets, barley, wheat grown in agricultural areas, vegetable gardens in the fields, various fruits (grapes, jujubes, apples, pears, cherries, plums, etc.) and fruits of forest trees and shrubs such as acorns, blackberries, and rosehips that grow naturally. It was observed that they gnaw on tree bark when they cannot find enough food. In the study by Yürümez and Ulutürk (2016), it was found that the primary dietary sources for porcupines included grains, fruits, vegetables, and cultivated crops. The nests of these animals were also found to be in close vicinity to the fields where watermelons were

grown (Yürümez and Ulutürk, 2016). Arslan reported in his study that there were roots in the stomach contents of porcupine and that, unlike the study of Kadhim (1997) the stomach contents did not contain any traces of animal remains (Arslan, 2008). Although it is a herbivorous animal that generally feeds on tuber and bulbous plants and both natural and agricultural products such as grain, its diet also includes insects and small vertebrate animals such as birds and mice (Albayrak, 2022). Khan et al., (2022) stated that 31 plant species were identified from the feces of the Indian Crested Porcupine in their research; these are categorized as vegetables (8), fruits (6), trees (5), cereal grains (3), herbs (3) shrubs (2) grasses (2) and flowering plants (2).

The research conducted by Khan et al., (2022) indicated that the stem constitutes the primary dietary component for the Indian crested porcupine. Following this, seeds were identified as the second most consumed part, while underground plant parts were also recognized as significant dietary items across various seasons in the present study. Roots, rhizomes, and tubers are noted for their high carbohydrate content (Alkon and Saltz, 1985; Lovari et al., 2013). Additionally, Mori et al., (2017) described the inclusion of roots and tubers in the diet of the Indian crested porcupine throughout the year in both Türkiye and central Italy.

In our study, it was observed that porcupines did not leave their burrows during the day or full moon phases and windy nights. Similar to our results, Fattorini and Pokharel (2012), reported that a clear tendency of *H. indica* to avoid moonlight and no diurnal activity was recorded. In this study the times when the porcupine left and returned to the cave were determined as 10:16 pm. in 19 September 2024 and 04:50 am. in 20 September 2024, respectively (Figure 4). Similar to our study results, Ngcobo et al (2019) stayed that porcupines are nocturnal and are on the move from sunset to sunrise in summer 07:00 pm.- 04:00 am. and in winter between 05:00 pm.-08:00 am. (Fattorini and Pokheral, 2012). In only one recording, the porcupine was recorded leaving the cave and came back entering the cave by passing in front of the camera, at the mouth of the cave. On other days, although there were two different cameras installed to see the mouth of the cave, no recordings were made of the porcupine leaving and returning to the nest on the same day. When the porcupine entered the cave, it may have passed through the rocks at the cave entrance, which may not have triggered the camera sensor and prevented it from starting to record. The reason for the record of exiting the nest but not entering the nest on the same day could be due to a technical problem or the camera trap not working, as reported by Özkazanç (2018), or there could be another secret entrance to the nest. The fact that the cave where the porcupine lives is frequently visited by treasure hunters and that the area right in front of the cave is used as a picnic and resting place by poachers at night strengthens the idea that the porcupine may be disturbed and may reach the cave through a second entrance.

Figure 4. Time when the *H. indica* leave the nest 10:16 pm. in 19 September 2024 and back to nest 04:50 am. in 20 September 2024.

Şekil 4. Eylül 2024'te H. indica'nın yuvadan çıkış saati 10:16 gece 19 Eylül 2024 ve yuvaya dönüş saati 04:50 sabah 20 Eylül 2024.

Fattorini and Pokheral, (2012), made the following comment on the porcupine's temporal activity patterns, activity patterns and home range size for out-of-nest time vary with distance from food and food abundance: As the proximity to food and the abundance of food increases, the time spent outside the nest

will decrease, similarly, as the abundance of food and the nutritional quality of the food increase, home range size will decrease. Based on the work of Fattorini and Pokheral, (2012), we can say according to Figure 4, when the time spent by the porcupine outside the nest is taken into consideration, it can be said that porcupine meets its nutritional needs with dry and irrigated agricultural products and wild plants in its habitat and returns to its safe nest in a short time. Similarly, Sonnino (1998) reported that in agricultural areas characterized by high environmental diversity, these porcupines exhibited smaller home ranges.

Other wild animals that share the habitat of the *H. indica* in our study area are as follows. Domestic small and large cattle, horses, donkeys, dogs and cats that come to drink water from the pond next to the cave where the *H. indica* nests, as well as wild animal species such as water turtles, little egrets, purple herons, coots, rabbits, martens, badgers, foxes, jackals, wolves, wild boars and deer coming down from Akdağ have been observed and recorded both directly and indirectly (Figure 5). It has been determined that carnivorous species both benefit from the water directly and use it to hunt other animals that live in the pond (worms, snails, frogs, fish and water turtles, etc.) or come to the lake to drink water.

Figure 5. Recorded in location observations a) Stone marten, b) Jackal, c) Wolf feces.
Şekil 5. Lokasyon gözlemlerinde kaydedilen a) Kaya sansarı, b) Çakal, c) Kurt dışkısı.

It is also seen in the camera trap video footage that the porcupine shares the cave it uses as its nest with many mice and bats. Camera trap images of cats, martens and foxes entering the cave to hunt mice and bats were recorded (Figure 6). Similar to our findings, Siler (2023), who observed the animal presence in Akçatepe Cave, reported that both bats (Chiroptera) and porcupines (*H. indica*) used the cave as a habitat.

Figure 6. Other mammals caught in the camera trap in the porcupine cave a) Mouse, b) Fox.
Şekil 6. Oklu kirpi mağarasında fotokapana yakalanan diğer memelilerden a) Fare, b) Tilki.

During the observations made in the field both day and night, poachers were encountered. Many cartridges were found next to the pond (Figure 7). It is estimated that they hunted wild animals that came to the pond to drink water.

Figure 7. a) Catriges near pond, b) Hunted wild boar.
Şekil 7. a) Gölet kenarında bulunan fişekler, b)Avlanmış yaban domuzu.

Although the nest of the target species is known, it has not been caught in order not to disturb it. In case of capture, its health status and genetic relationship with other porcupines registered in our country can be explained through morphological (gender, weight) and physiological (blood, DNA) tests. Arslan (2006) performed karyotypic analyzes on blood samples taken from porcupines in İçel and Adana regions and give the diploid number of chromosomes is 2n=66 at *H. indica.* However, for the animal not to be stressed and to continue its existence and generation, we are currently researching its daily, monthly and annual behavioral states, circadian rhythms, habitat and ecology through direct and indirect observations.

It has been determined that the cave where the porcupine nests arouses curiosity among people and that the species is disturbed by frequent visits. At the same time, picnicking in the wetland right next to the cave and illegal hunting increase the risk of human-animal encounters and seriously negatively affect the species' ability to safely survive and reproduce in the area. When local people near the porcupine habitat were interviewed, many of them stated that they had no knowledge of the species and had not observed any damage to their fields or crops. The local people were informed that the species was harmless and needed to be protected for biodiversity.

Although some publications state that arrowed porcupines are harmful to agricultural areas (İnaç et al., 2011; Khan et al., 2022), this is not the case for our study area. With human intervention (agriculture and some forestry practices), as areas become more uniform, wild animals are drawn to areas that are suitable for them and become trapped in these areas. Due to the decrease in suitable areas to meet the needs of wild animals, human and wild animal encounters and thus conflicts of interest (crop/food) are increasing. Animals are forced to approach agricultural areas or settlements for their needs such as food and water. Enclosing agricultural areas with wire fences prevents wild animal damage. The most appropriate way to prevent wild animals from entering agricultural areas is to ensure that wild animals remain in their natural habitats by applying methods such as planting and planting plant species that have a positive relationship with wild animals in natural areas and creating water resources. However, these practices can be realized through renovation and rehabilitation works that will not disrupt the natural structure of the area.

CONCLUSION

H. indica is the IUCN Red List at the international level and is listed as Endangered category (EN) in Türkiye. Conservation measures can be implemented more effectively if the distribution areas of the species and the ecological characteristics of these areas are known. In this study, the presence of the species has been proven in Afyonkarahisar province. For conservation in its own habitat where it naturally occurs, habitat information, wild animal/domestic animal species with which it shares its habitat and findings about human impacts are presented. The study compares the fossil findings related to the species with the areas where it lives today and provides background data to create distribution maps realized as a result of climate, human, etc. factors over time. DNA information gained from porcupines living in different locasions to be obtained from the species, studies on kinship levels can be carried out. However, to carry

out all these studies, the existence of the species must first be proven and it must be protected in the area where it is found.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding this article.

DECLARATION OF AUTHOR CONTRIBUTION

The ŞA designed and laid out the field work, collected data and writing the original draft and review and editing.

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Research Article

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Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Avian Diversity and Conservation Value of the Gölköy-Yumrukaya Wetland: A University Campus as a Biodiversity Hotspot on the Urban Fringe

Gölköy-Yumrukaya Sulak Alanının Kuş Çeşitliliği ve Koruma Değeri: Şehir Sınırlarında Biyoçeşitlilik Sıcak Noktası Olarak Bir Üniversite Kampüsü

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Abstract: Urbanization and habitat fragmentation increasingly threaten global avian biodiversity, leading to biotic homogenization and declining community heterogeneity. University campuses, particularly those with wetland ecosystems, are emerging as important refugia for bird species. This study examines avian diversity, dominance patterns, and community structure across the Gölköy-Yumrukaya (GY) wetland and surrounding campus habitats of Bolu Abant İzzet Baysal University, Türkiye. Between 2017 and 2023, systematic field surveys recorded 173 bird species from 45 families. The results underscore the ecological significance of the GY wetland as a complementary habitat, particularly for summer visitor and passage migrant species. Seasonal analyses reveal peak species richness and diversity during the breeding and migration periods, while winter exhibits lower diversity and increased dominance concentration, especially among urban-adaptive species. The study highlights the importance of artificial wetlands in fragmented landscapes, provided they maintain ecological connectivity with natural wetland systems. Additionally, a newly proposed ecological metric, the Heterogeneity Ratio (H_r), is introduced, offering a higher-resolution assessment of community structure dynamics compared to traditional diversity indices. Due to its sensitivity to temporal fluctuations in species abundance and evenness, H_r is recommended as a valuable tool for future biodiversity assessments.

Keywords: Avian Diversity, Habitat Fragmentation, Artificial Wetlands, Heterogeneity Ratio, Biotic Homogenization

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Öz: Küresel ölçekte şehirleşme ve habitat parçalanması, kuş biyoçeşitliliğini tehdit ederek biyotik homojenizasyona ve komünite heterojenliğinde azalmaya neden olmaktadır. Özellikle sulak alan ekosistemine sahip üniversite kampüsleri, kuş türleri için önemli sığınaklar haline gelmektedir. Bu çalışma, Türkiye'deki Bolu Abant İzzet Baysal Üniversitesi kampüsünde ve yakın çevresinde yer alan Gölköy-Yumrukaya (GY) sulak alanının kuş çeşitliliğini, baskın tür desenlerini ve komünite yapısını incelemektedir. 2017-2023 yılları arasında yapılan sistematik arazi çalışmaları sonucunda 45 familyaya ait toplam 173 kuş türü tespit edilmiştir. Sonuçlar, GY sulak alanının özellikle göçmen ve transit göçmen türler için tamamlayıcı bir habitat olarak önemli bir ekolojik role sahip olduğunu göstermektedir. Mevsimsel analizler, tür zenginliğinin ve çeşitliliğinin üreme ve göç dönemlerinde zirve yaptığını, kış aylarında ise çeşitliliğin düştüğünü ve özellikle şehirleşmeye uyum sağlayan türlerin baskın hale geldiğini ortaya koymuştur. Çalışma, yapay sulak alanların doğal sulak alan sistemleriyle ekolojik bağlantılar kurduğunda, parçalanmış peyzajlarda kritik ikincil habitatlar olarak hizmet edebileceğini vurgulamaktadır. Ayrıca, bu araştırmada geleneksel çeşitlilik indislerine kıyasla topluluk yapısındaki değişimleri daha yüksek çözünürlükle değerlendiren Heterojenite Oranı (H_r) adlı yeni bir ekolojik metrik önerilmektedir. Tür bolluğu ve eşitliğindeki zamansal dalgalanmalara duyarlılığı nedeniyle H_r'nin, gelecekteki biyoçeşitlilik değerlendirmelerinde önemli bir araç olarak kullanılabileceği önerilmektedir.

Anahtar Kelimeler: Kuş Çeşitliliği, Habitat Parçalanması, Yapay Sulak Alanlar, Heterojenite Oranı, Biyotik Homojenizasyon

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INTRODUCTION

Exponential human population growth is recognized as the primary driver of the five major threats to biodiversity: pollution, habitat loss, climate change, invasive species, and overexploitation (Dhyani, 2024; Inbit et al., 2024; Ogidi and Akpan, 2022; Ogwu et al., 2022). This rapid increase is expected to intensify these pressures, particularly affecting bird and mammal species by 2050 (Rodrigues et al., 2021; Simkin et al., 2022). These threats not only reduce species diversity but also impact functional diversity, leading to shifts in ecosystem stability (Stewart et al., 2022). Consequently, protected areas and biodiversity hotspots are gaining increasing importance for conservation. However, urban expansion is encroaching upon these critical areas, exacerbating biodiversity loss (Wang et al., 2023).

Urbanization, driven by human population growth, has profound effects on global biodiversity, with biotic homogenization being one of its most significant consequences (Lepczyk et al., 2017; McKinney, 2006; Reis et al., 2012). As cities expand, university campuses are emerging as potential refuges for biodiversity, offering eco-friendly landscapes that support various species (Guthula et al., 2022; Sanllorente et al., 2023). Initially, most universities were established in rural or forested areas at higher elevations, incorporating extensive green spaces that preserved aspects of the original natural environment (Guthula et al., 2022). From this perspective, university campuses can function as urban/peri-urban biodiversity hotspots, providing habitat continuity within increasingly fragmented landscapes (Guthula et al., 2022; Liu et al., 2017, 2021).

Large university campuses, particularly those containing wetlands and diverse habitat types, serve as essential refuges for bird species (Davros II, 2020; Yadav et al., 2024). Wetland ecosystems within campuses provide key feeding and breeding grounds, particularly for waterbirds. However, many natural wetlands have been modified for purposes such as water reservoirs, artificial ponds, and urban landscaping, leading to habitat degradation and biodiversity loss. Despite these alterations, artificial wetlands can function as secondary habitats, particularly for water-dependent species that prefer shallow aquatic environments (Davros II, 2020; Yadav et al., 2024).

While numerous studies have been conducted on campus bird communities in Türkiye, most have focused primarily on species inventories rather than ecological analyses (Gümüş et al., 2024; Özkan and Keten, 2020; Şahin et al., 2021). In contrast, recent studies have evaluated the ecological functions of university campuses, emphasizing their roles in land management and conservation (Guthula et al., 2022; Liu et al., 2021; Sanllorente et al., 2023; Zhang et al., 2018). Simply cataloging species presence provides limited ecological insight. However, many Turkish university campuses are situated in relatively undisturbed habitats, including forests, wetlands, and lakes, yet their ecological significance remains largely understudied.

One such example is Bolu Abant İzzet Baysal University's Gölköy Campus, which is situated in a forested area and contains Gölköy Pond, an artificial reservoir supplying city water. Adjacent to this, the Yumrukaya wetland further enhances the ecological value of the landscape. Collectively, these interconnected habitats (hereafter referred to as GY) form a critical network of habitat patches within an urbanized landscape. Given its ecological features and proximity to other green spaces, the GY wetland likely serves as a key site for breeding, foraging, and refuge, particularly for water-dependent bird species.

This study aims to assess the temporal variations in species richness, diversity, relative abundance, and dominance of birds within the GY wetland ecosystem. Additionally, this research seeks to:

1. Evaluate the role of university campuses in mitigating urbanization pressures on bird communities.
2. Investigate the ecological function of artificial wetlands as complementary habitats for avifauna.
3. Introduce and test the Heterogeneity Ratio (H_r) as a new ecological metric for assessing community structure dynamics.

By addressing these objectives, this study provides a comprehensive evaluation of a university wetland ecosystem, contributing to both regional conservation efforts and global discussions on urban biodiversity management.

MATERIAL AND METHOD

Study Area

The study was conducted within the Gölköy Campus of Bolu Abant İzzet Baysal University and the adjacent Yumrukaya Wetland (Figure 1). While the study area shows some urban influences (e.g., infrastructure), its dominant characteristics align with peri-urban ecosystems containing agricultural, natural/artificial wetland and forest elements. Located at an elevation of 776 meters above sea level, Gölköy Lake was constructed in the mid-20th century for irrigation, fisheries, and recreational activities. Since 2011, it has also served as a tap water source for Bolu. The lake's surface area fluctuates seasonally between 150 and 180 hectares. It is primarily fed by the Mudurnu Stream, Abant Stream, and groundwater sources. Gölköy Lake is classified as mesotrophic, and pollution in and around the lake originates from recreational activities, poultry farms, and agricultural practices (Çelekli et al., 2007; Külköylüoğlu, 2005; Türker, 2006).

Figure 1. Gölköy-Yumrukaya wetland ecosytem.
Şekil 1. Gölköy-Yumrukaya sulak alan ekosistemi.

Before 1965, the Yumrukaya wetland was a marshland. However, with the construction of the Gölköy Dam Lake on the Abant Stream, which supplies water to the area, the wetland transformed into a shallow pond with reed beds. The wastewater discharge from Bolu Abant İzzet Baysal University and construction debris have been identified as major pollutants in the wetland. The reservoir water in Yumrukaya exhibits a meso-eutrophic character (Külköylüoğlu, 2005). A concrete channel connects Yumrukaya Wetland and Gölköy Lake, facilitating water transfer from Yumrukaya to Gölköy during spring and summer. Since both wetlands are utilized for irrigation and the municipal water supply, they experience significant seasonal water level fluctuations.

Field Survey and Data Collection

The study commenced in November 2017 and was conducted throughout 2018, with additional surveys focused on the breeding and migration periods in 2019 and 2023 (Table 1). The fieldwork followed both line transect and point count methods, with a total of 48 field surveys carried out from sunrise to sunset. Due to the relatively small size of the study area, fixed observation stations were not established.

Field observations were conducted using 10×42 binoculars and a DSLR camera, with photographs taken during the surveys used for species identification. Additionally, the Collins Bird Guide (Svensson et al., 2010) was utilized for species verification. To facilitate various ecological assessments of the avifauna in the GY wetland ecosystem, individual counts of recorded bird species were systematically documented during field surveys. A minimum of one and a maximum of three observers participated in these surveys, and to minimize repeated counts of the same individuals, the coordinates and timestamps of each observation were rigorously recorded on standardized forms. All daily observations were systematically documented on standardized bird survey forms to ensure data consistency and reliability.

Table 1. Monthly and annual distribution of field surveys.
Çizelge 1. Saha çalışmalarının yıl ve aylara göre dağılımı.

	2017	2018	2019	2023	Total
January		1	1	1	**3**
February		2	2		**4**
March		3	3		**6**
April		4	3	1	**8**
May		3	2	1	**6**
June		3		1	**4**
July		2	1		**3**
August		1		1	**2**
September		2			**2**
October		3			**3**
November	1	4			**5**
December		2			**2**
Total	**1**	**30**	**12**	**5**	***48***

Analysis of Avian Diversity and Dominance Patterns

In this study, the avian community in the area was investigated in terms of species richness, abundance, dominance patterns, and overall diversity. Regarding species conservation status, IUCN Red List categories were presented. Additionally, temporal habitat use patterns of bird species were assessed using BirdLife International's species distribution maps (BirdLife International, 2025).

Species dominance within a community is determined by calculating the proportion of individuals of a species relative to the total number of observed individuals in the community (Hubálek, 2000). Accordingly, dominance values (Dom_i) were calculated for bird species observed in the study area and were presented temporally to identify the most dominant species. In natural communities, species are generally categorized into three abundance classes: approximately 60–65% of species are rare, 25% are of moderate abundance, and only about 10% are common. Additionally, species frequency is classified into five categories based on observation frequency (Aydın, 2021): **81–100%:** "Abundant"; **61–80%:** "Common"; **41–60%:** "Frequent"; **21–40%:** "Occasional"; **1–20%:** "Rare". The frequency analysis of avifauna in the GY wetland ecosystem was categorized according to these five classes and evaluated temporally. To account for seasonal variations in species occurrence, we assessed avian community structure in the GY wetland across four defined periods: winter (December–February), breeding (March–May), summer (June–July), and autumn migration (August–November). Additionally, annual dominance and frequency analyses were conducted for 2018, the only year with continuous data collection throughout the entire year. At this stage, a Whittaker plot (rank-abundance curve) was used to clearly illustrate the seasonal and annual distribution patterns of the community structure. This approach aimed to determine the species abundance

distribution profile and provide a comprehensive understanding of how the avian assemblage varies across different periods and throughout the year.

Species richness (S), the most fundamental and commonly used measure of diversity, is influenced by rare species. This effect is primarily due to sampling errors, as rare species often go undetected even in detailed surveys. To estimate the effective (true) species richness, various approaches and non-parametric estimators have been utilized (Aydın, 2021; Krebs, 2014). In this study, the non-parametric estimator 'Chao 1' developed by A. Chao, was used to estimate effective species richness (Chao, 2005; Chao and Chiu, 2012). The Chao 1 approach provides a minimum estimate of species richness and is assessed within the framework of Hill numbers (Krebs, 2014). This estimator predicts the number of undetected species by utilizing singletons and doubletons, as rare species information is predominantly derived from low-frequency observations (Chao, 2005; Chao and Chiu, 2012; Krebs, 2014).

The data obtained from the study area were analyzed using the Shannon diversity index and Hill effective species numbers. The Shannon-Weaver index (H'), one of the most widely used diversity metrics, is based on information theory. It aims to quantify the uncertainty in predicting the species identity of the next observed individual, where greater uncertainty corresponds to higher diversity. This uncertainty is directly proportional to community heterogeneity. As a result, the more uncertain the information content per individual (measured in bits per individual), the greater the diversity (Krebs, 2014).

Hill numbers, proposed by Hill (1973), are widely used due to their simplicity and ease of interpretation (Krebs, 2014). These numbers provide a functional or effective count of species within a sample, avoiding the complex and ecologically ambiguous units (e.g., bits, probability measures) found in other indices. Hill diversity numbers include species richness (S), as well as N_1 (the exponential form of Shannon entropy) and N_2 (the inverse of Simpson's index), both of which serve as heterogeneity indices. In most cases, calculating N_1 and N_2 is sufficient to answer questions that heterogeneity indices aim to address (Chao and Jost, 2015; Gotelli and Chao, 2013; Krebs, 2014; Peet, 1974). N_1 represents the number of effective typical species in a community, weighted by their relative frequencies or abundances. N_2, on the other hand, approximates the number of highly abundant (dominant) species in the community. In a perfectly even community, N_1 and N_2 are equal to species richness (Gotelli and Chao, 2013).

Our analyses of diversity (N_1, N_2), heterogeneity (H'), and species richness (Chao1) follow established ecological methods (Chao 2005; Krebs 2014), including frequency and dominance calculations for avian community characterization. To estimate species diversity and richness using various ecological indices, the online SpadeR (Species-richness Prediction and Diversity Estimation in R) program, developed by Chao et al. (2016), was used.

Furthermore, despite the existence of various ecological assessment methods, most are either sensitive to common species or rare species, but no single index can evaluate both simultaneously. In this study, for the first time, we assessed the ratio, $H_r=f_1/N_2$ which we named the "heterogeneity ratio," and made inferences about its temporal trends. We believe that applying this newly proposed heterogeneity ratio can be beneficial for diversity profiles.

Theoretical Framework of the Heterogeneity Ratio

The proposed heterogeneity ratio, $H_r=f_1/N_2$, quantifies the tension between rarity (singleton species count, f_1) and dominance (inverse Simpson index, N_2). This metric captures a fundamental ecological trade-off in species abundance distribution functions: as dominance concentration increases (higher N_2), singleton representation (f_1) declines, reflecting shifts in community evenness.Theoretical bounds and behavior of H_r reveal its ecological interpretation:

- N_2 ranges from 1 (single-species dominance) to S (perfect evenness; all species equally abundant).
- f_1 spans 0 (no singletons) to $S-1$ (all species except one are singletons).

- $H_r \rightarrow 0$**:** Indicates high evenness, approximating a **broken-stick distribution** (A log-normal abundance distribution approaching the "broken stick" model; idealized equilibrium community).
- $H_r \rightarrow S-1$**:** Reflects extreme dominance, aligning with a **geometric series** (highly uneven, anthropogenic communities).

Unlike traditional indices (e.g., Shannon H'), H_r explicitly links rarity loss to dominance amplification—a critical dimension for assessing anthropogenic impacts.

RESULTS AND DISCUSSION

Avian Assemblage of Gölköy-Yumrukaya Wetland

During 48 days of fieldwork between 2017-2023 within the study area, a total of 173 bird species from 45 families were recorded, with an overall count of 15452 individuals (Annex 1). The average number of species observed per month was 81, while the average number of individuals recorded per month was 644. However, in 2018, when surveys were conducted year-round, the monthly average species count was 53, and the average individual count was 737.

The GY wetland hosts a relatively rich bird community compared to most university campuses and other wetland avifaunas (Bengil and Uzilday, 2010; Gümüş et al., 2024; Keten et al., 2010; Şahin et al., 2021). The area supports approximately one-third of Türkiye's total bird species richness, likely due to habitat diversity, the proximity of nearby wetlands, and its function as a local stopover, resting, and refueling site for migratory birds—factors known to positively correlate with species richness (Hamza et al., 2024; Karaardıç et al., 2006; Karaardıç and Özkan, 2017; Ünlü et al., 2024).

An analysis of the avifauna based on waterbird families designated by Wetlands International (2012) revealed that 35.84% (14 families, 62 species) of the bird species in the GY wetland are waterbirds or wetland-dependent species, emphasizing the area's importance for waterbird conservation. The most species-rich families recorded were *Anatidae* (ducks, geese, and swans; 15 species), *Accipitridae* (hawks and eagles; 14 species), and *Muscicapidae* (flycatchers; 12 species). The dominance of waterbirds and wetland-dependent raptors in the area is expected, given its wetland ecosystem characteristics. Additionally, the presence of open landscapes (e.g., agricultural fields), forested areas, riparian vegetation, and urbanized structures supports a diverse range of bird species with varying habitat preferences (Rajashekara and Venkatesha, 2017). Further studies on habitat and microhabitat diversity in the area are recommended to explore these patterns in greater detail.

Monthly species richness peaked in April 2018 (77 species) and April 2019 (66 species), while the lowest species counts were recorded in January 2018 (14 species) and January 2019 (13 species) (Figure 2). The high species richness observed in April, coinciding with the breeding season, suggests that the wetland provides high-quality habitat and sufficient ecological niches (Hamza et al., 2024). In contrast, the low species richness recorded in January is likely due to the limited presence of wintering bird species.

Although species richness was generally lower in winter, the highest individual count was recorded in December 2019 (2532 individuals), while the lowest was in January 2018 (100 individuals). Data from the International Mid-Winter Waterbird Census indicate a partial improvement in population trends in Ramsar sites (Wetlands International, 2012, 2018). However, a decline in species richness coupled with an increase in individual counts is frequently observed in Important Bird Areas (IBAs) under urbanization pressure, where population increases tend to be driven by species more adaptable to urban environments (Kirazlı, in press). The combination of low species richness and high individual counts suggests temporal dominance shifts within the bird community (Figure 2). Therefore, evaluating the site alongside dominance analysis data will provide more accurate ecological insights.

When assessing the annual utilization of the GY wetland by bird species, approximately 59% of the recorded species were classified as summer visitors (M) or passage migrants (P), while only 26% were resident (R) and 13% were winter visitors (W). The fact that nearly two-thirds of the observed species are present only during the breeding or migration periods suggests that the campus and wetland ecosystem

primarily provide suitable niches for stopover, resting, and energy replenishment (Karaardıç et al., 2006; Karaardıç and Özkan, 2017).

According to the IUCN Red List, three species observed in the study area are classified as Vulnerable (VU): *Aythya ferina*, *Aquila heliaca*, and *Streptopelia turtur*. Additionally, two species are categorized as Near Threatened (NT): *Aegypius monachus* and *Lanius senator*, while the remaining 168 species fall under the Least Concern (LC) category (Annex 1). The Common Pochard (*Aythya ferina*) is a winter visitor to the area, though it has not been observed in large flocks. Breeding populations of Eastern Imperial Eagle (*Aquila heliaca*) and Cinereous Vulture (*Aegypius monachus*) are present in the surrounding region (Arslan and Kirazlı, 2022; Kirazlı, 2019), and individuals have been occasionally recorded in the wetland while foraging, albeit infrequently. The European Turtle Dove (*Streptopelia turtur*) is primarily a summer visitor, observed in low numbers, with no evidence of breeding recorded within the study area. Similarly, the Woodchat Shrike (*Lanius senator*) has been observed rarely, primarily during migration periods. These findings highlight the conservation priority of these species and suggest that the GY wetland plays a complementary habitat role in supporting their populations.

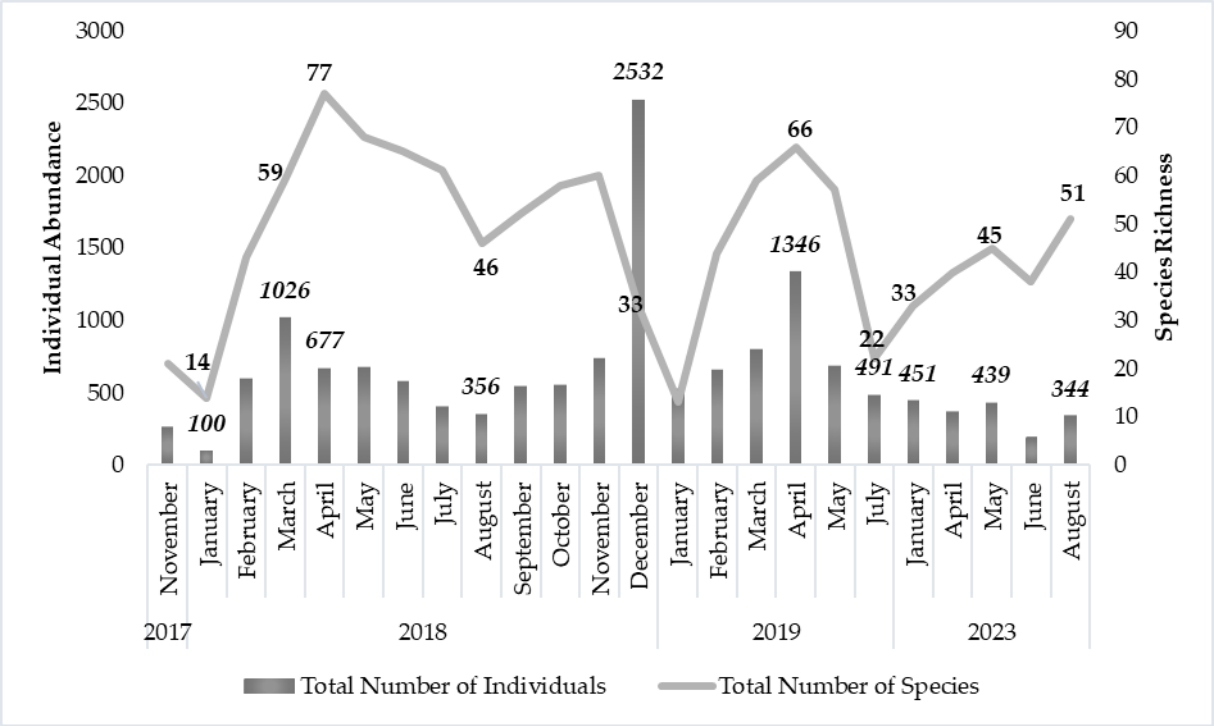

Figure 2. Monthly dynamics of species richness and individual abundance.
Şekil 2. Aylara göre toplam tür ve birey sayılarındaki değişim.

Increasing urbanization pressure and habitat fragmentation in natural areas (Guthula et al., 2022; Reis et al., 2012), coupled with high interspecies competition in shallow natural wetlands used during migration, may further increase the importance of artificial wetlands for breeding migrants and passage bird species. In this context, non-eutrophic artificial wetland systems, such as reservoirs, could function as temporary protective and complementary buffer zones, serving as small habitat islands connected to primary wetland areas (Davros II, 2020; Guthula et al., 2022). The findings of this study support this perspective.

The application of island biogeography theory to terrestrial systems—where habitats are viewed as islands and the areas connecting them as matrices, including transition corridors—has long been recognized (Matthews, 2021). Recently, increasing attention has been given to the role of small refuge islands, particularly university campuses, in preserving habitats and species while facilitating connectivity between primary habitats (Guthula et al., 2022; Tulloch et al., 2016). Considering that matrix quality influences

community structure within habitats—acting as a resource, corridor, or habitat itself (Cook et al., 2002; Kupfer et al., 2006)—the two wetlands in the study area, one artificial and the other natural, along with the campus area connecting them, form a significant wetland ecosystem composed of small habitat patches. The GY wetland habitat islands serve as essential components of the local bird community, reinforcing their ecological importance in maintaining species diversity. Given the potential of campus areas to enhance matrix quality, these small wetland islands are likely to provide ecological connectivity between primary habitats such as Yeniçağa Lake and its peatlands (IBAs), thereby supporting local avian communities. In this context, a critical consideration is the location of artificial wetlands and their connectivity with other natural habitat islands. Future research should examine the connectivity of the GY wetland ecosystem with other natural wetlands from an avian perspective. Additionally, long-term migration monitoring and breeding status assessments of the avifauna would further highlight the area's ecological significance.

Avian Community Structure: Dominance and Frequency Trends in Gölköy-Yumrukaya Wetland

In natural ecosystems, communities typically follow a log-normal distribution model (Krebs, 2014). However, in areas experiencing biotic homogenization, community structure tends to shift toward a geometric series distribution (Aydın, 2021). In this context, the data obtained from this study were analyzed both seasonally and annually to assess species abundance distributions and frequency patterns. The primary aim was to determine whether the community structure reflects natural evolutionary and ecological mechanisms or if urbanization pressure has influenced homogenization within the assemblage.

During the winter season, the bird community comprised 71 species, yet it was predominantly dominated by a single species, the Eurasian Coot (*Fulica atra*), accounting for nearly half of the total abundance. Approximately 80% of the community, excluding the European Goldfinch (*Carduelis carduelis*), consisted of waterbirds (Table 2). Wintering species such as the Eurasian Teal (*Anas crecca*), Common Pochard (*Aythya ferina*), and Tufted Duck (*Aythya fuligula*) were observed in relatively low numbers. The Whittaker plot derived from the collected data indicates a log-normal species-abundance distribution within the area (Figure 3). However, the pronounced dominance of a single species suggests an imbalance beyond normal evolutionary and ecological mechanisms. The findings align with the results of the Mid-Winter Waterbird Census conducted across Türkiye (Kirazlı, in press; DKMP, 2023). The presence of individuals belonging to conservation-priority species, such as the Vulnerable Common Pochard, further highlights the role of the GY wetland as a supportive habitat for wintering waterbirds.

Table 2. Dominant bird species comprising 80% of the total winter abundance.
Çizelge 2. Kış döneminde komünitenin %80'ini oluşturan türler.

Winter	Abundance	Dominance %	Frequency %
Fulica atra	2449	50.13	77.78
Anas platyrhynchos	364	7.45	77.78
Anas crecca	265	5.42	44.44
Tachybaptus ruficollis	180	3.68	66.67
Carduelis carduelis	172	3.52	66.67
Podiceps cristatus	169	3.46	66.67
Aythya fuligula	167	3.42	55.56
Aythya ferina	116	2.37	66.67

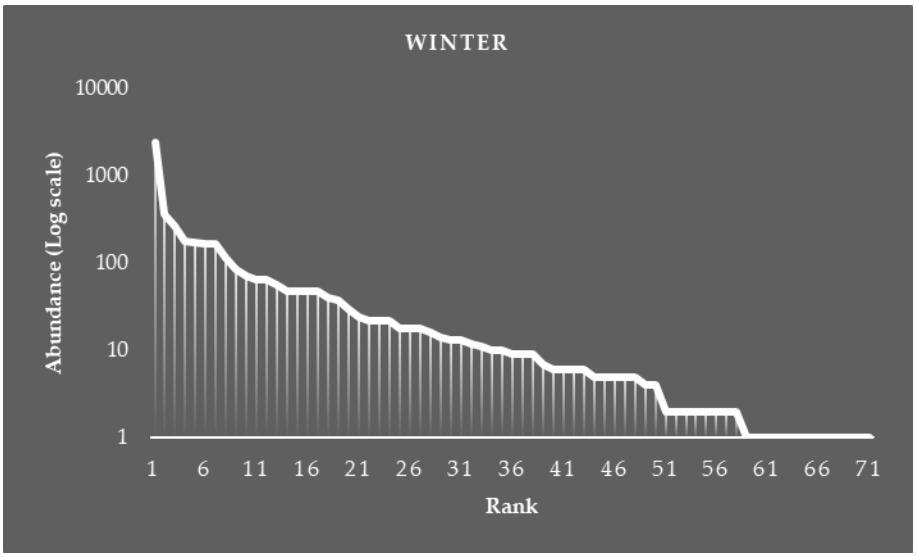

Figure 3. Whittaker plot of winter period.
Şekil 3. Kış dönemi Whittaker grafiği.

During the breeding season, the avian community comprised 142 species, exhibiting a mosaic dominance structure shaped by the inclusion of adaptive passerine species capable of nesting in urbanized areas, rather than being predominantly composed of waterbirds (Table 3). The Whittaker plot derived from the collected data indicates a log-normal species-abundance distribution within the area (Figure 4), with an increase in the number of widespread species compared to the winter period. This pattern was also observed during the summer (85 species recorded) and migration (113 species recorded) seasons, as well as in the overall 2018 dataset (145 species recorded) (Tables 4–6; Figures 5–7).

Accordingly, the Eurasian Coot (*Fulica atra*) and Mallard (*Anas platyrhynchos*) were the most widespread species in the GY wetland, while urban-adaptive passerines such as the House Sparrow (*Passer domesticus*) and Common Starling (*Sturnus vulgaris*) were among the dominant songbirds. Although campus areas are recognized as refugia for avian communities (Guthula et al., 2022), the urbanization pressure associated with human activity and infrastructure—manifesting as noise, crowding, and construction—may have played a role in shaping the observed community structure (Perillo et al., 2017; Vallejo Jr et al., 2008). These results align with previous studies (Jumilawaty et al., 2024; Vallejo Jr et al., 2008; Yadav et al., 2024), which reported similar dominance structures and species diversity patterns in urban-associated campus areas with aquatic habitats. In this context, 'refugia' refers particularly to the role of the artificial wetland as a temporary shelter for migratory species rather than a stable breeding habitat. Thus, a campus area with an artificial wetland, where a few species dominate but overall species richness remains high, may function as a local biodiversity hotspot. As with other campus areas that include aquatic habitats (Guthula et al., 2022; Yadav et al., 2024), the GY wetland maintained a relatively stable species richness, potentially due to its habitat heterogeneity and size (Sillén and Solbreck, 1977).

Furthermore, seasonal and annual data obtained from frequency analysis (Table 7) reinforce this conclusion, highlighting the role of the GY wetland habitat islands as crucial stopover, foraging, and short-term resting sites. The campus area with aquatic systems acts as a secondary habitat, facilitating movement between primary wetland sites, in line with the concept of habitat patches proposed by other studies (Guthula et al., 2022; Tulloch et al., 2016). These findings highlight the ecological importance of the GY wetland within a sheltered campus environment, emphasizing its crucial role in sustaining avian biodiversity during migration periods.

Table 3. Dominant bird species comprising 50% of the total breeding period abundance.
Çizelge 3. Üreme döneminde komünitenin %50'sini oluşturan türler.

Breeding Period	Abundance	Dominance %	Frequence %
Fulica atra	700	11.58	90.00
Delichon urbicum	692	11.44	75.00
Hirundo rustica	604	9.99	75.00
Passer domesticus	354	5.85	100.00
Sturnus vulgaris	350	5.79	90.00
Aythya fuligula	272	4.50	70.00

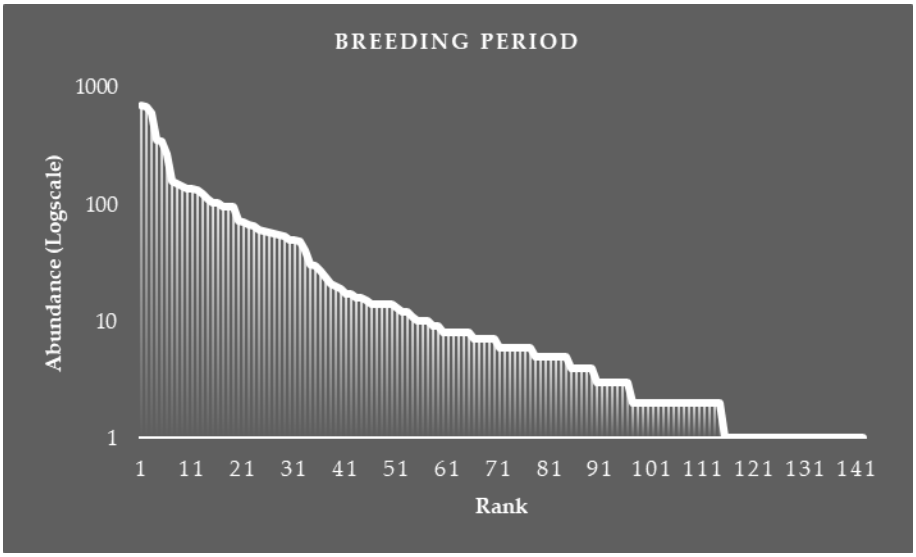

Figure 4. *Whittaker plot of breeding period.*
Şekil 4. Üreme dönemi Whittaker grafiği.

Table 4. Dominant bird species comprising 50% of the total summer abundance.
Çizelge 4. Yaz döneminde komünitenin %50'sini oluşturan türler.

Summer	Abundance	Dominance %	Frequence %
Fulica atra	397	23.46	100.00
Sturnus vulgaris	146	8.63	100.00
Anas platyrhynchos	81	4.79	85.71
Hirundo rustica	77	4.55	100.00
Passer domesticus	76	4.49	100.00
Emberiza calandra	74	4.37	85.71

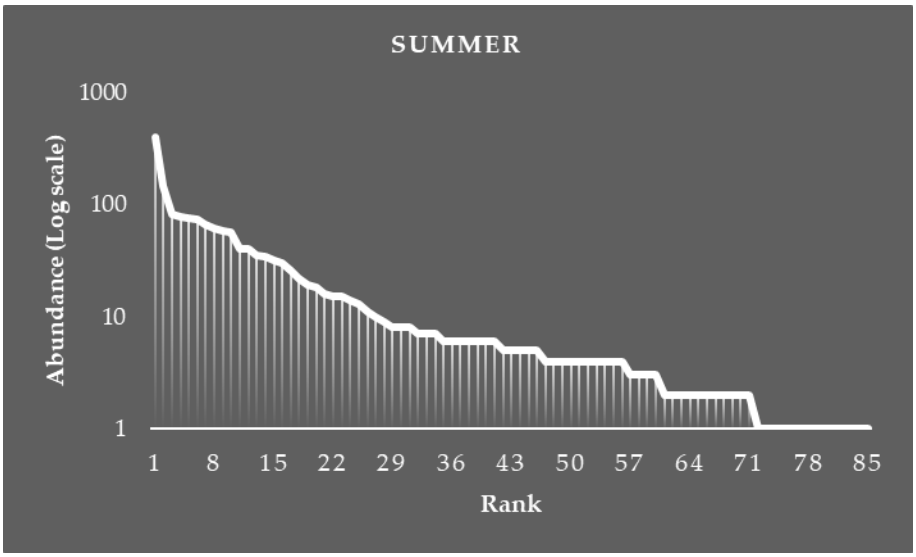

Figure 5. Whittaker plot of summer period.
Şekil 5. Yaz dönemi Whittaker grafiği.

Table 5. Dominant bird species comprising 50% of the total migration period abundance.
Çizelge 5. Göç döneminde komünitenin %50'sini oluşturan türler.

Migration Period	Abundance	Dominance %	Frequence %
Fulica atra	415	14.67	75.00
Anas platyrhynchos	280	9.90	83.33
Carduelis carduelis	140	4.95	75.00
Passer domesticus	131	4.63	83.33
Sturnus vulgaris	108	3.82	58.33
Podiceps cristatus	100	3.54	83.33
Hirundo rustica	88	3.11	33.33
Emberiza calandra	75	2.65	75.00
Corvus corone	67	2.37	83.33

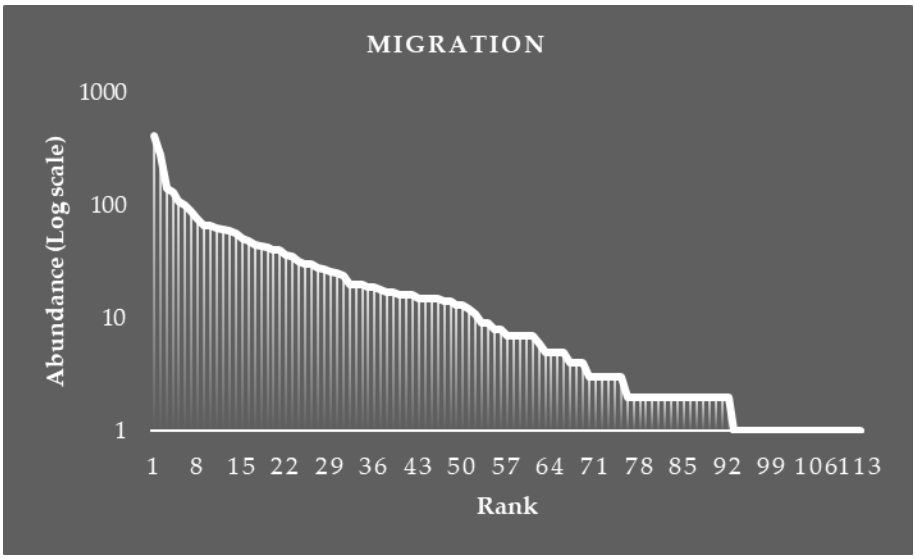

Figure 6. Whittaker plot of migration period.
Şekil 6. Göç dönemi Whittaker grafiği.

Table 6. 2018 GY wetland bird community: species constituting 50% of the total abundance.
Çizelge 6. 2018 yılı GY sulak alan komünitesinin %50'sini oluşturan türler.

2018	Abundance	Dominance %	Frequence %
Fulica atra	2350	26.58	80.00
Anas platyrhynchos	603	6.82	76.67
Passer domesticus	358	4.05	90.00
Sturnus vulgaris	323	3.65	66.67
Tachybaptus ruficollis	252	2.85	83.33
Podiceps cristatus	251	2.84	83.33
Hirundo rustica	246	2.78	53.33
Delichon urbicum	236	2.67	50.00

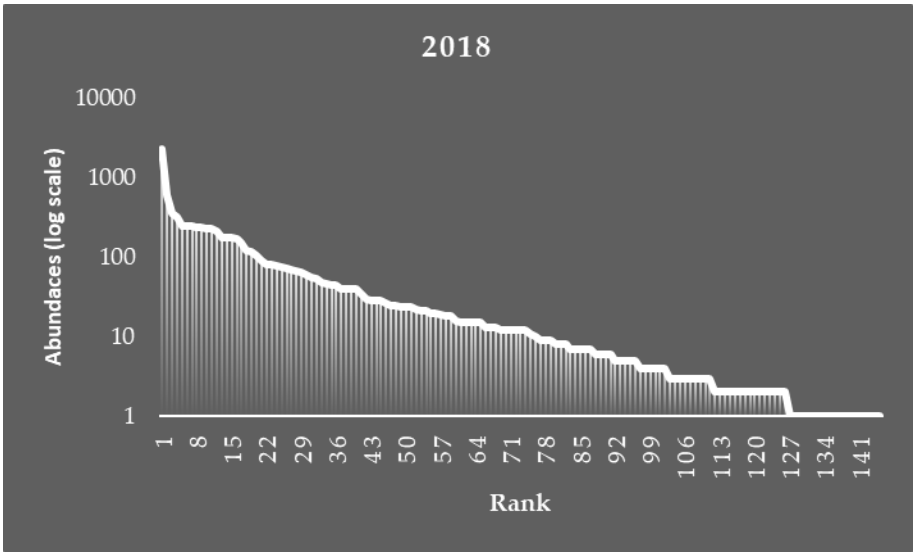

Figure 7. Whittaker plot of 2018.
Şekil 7. 2018 yılı Whittaker grafiği.

Table 7. GY wetland bird community: temporal species frequency profile.
Çizelge 7. GY sulak alan komünitesinin temporal gözlem sıklığı profili.

Period/Frequency	Winter (%)	Breeding (%)	Summer (%)	Migration (%)	2018 (%)
Abundant	5.63%	7.04%	25.88%	7.08%	4.14%
Common	16.90%	9.86%	12.94%	8.85%	6.90%
Frequent	8.45%	6.34%	21.18%	15.04%	11.72%
Occasional	30.99%	14.79%	8.24%	22.12%	20.69%
Rare	38.03%	61.97%	31.76%	46.90%	56.55%

Avian Community Structure: Species Richnes and Diversity Trends in Gölköy-Yumrukaya Wetland

The GY wetland, which hosts approximately one-third of Turkey's avifauna and two-thirds of Bolu's avifauna (243 species) (Nuh'un Gemisi, 2025), exhibits species richness, dominance, and frequency patterns similar to those reported in studies on other campus ecosystems (Guthula et al., 2022; Liu et al., 2021; Rajashekara and Venkatesha, 2017; Sanllorente et al., 2023; Vallejo Jr et al., 2008; Yadav et al., 2024). These findings suggest that the area qualifies as an Important Bird Area (IBA), functioning as a complementary habitat, particularly for migratory bird species. However, the dominance of urban-adaptive species is evident, with a notable inequality in species distribution, particularly during the winter season.

To enhance the ecological resolution of the study area and gain a more comprehensive understanding of community composition, further analyses are needed to examine how relative abundances vary among species. Particularly, assessing heterogeneity dynamics is crucial for understanding the organization of the

GY wetland bird community and predicting future trends. In this context, temporal trends in heterogeneity may offer clearer insights into ecosystem dynamics (Aydın, 2021; Krebs, 2014). The temporal diversity levels and trends were analyzed using effective species richness values (Ef-S, N_1, N_2), the Shannon diversity index (H'), and a newly proposed ecological index, the "heterogeneity ratio" (H_r), which we introduce as a novel metric for assessing heterogeneity due to its ease of interpretation.

Analyses evaluating the presence of rare and sensitive species reveal that effective species richness (Ef-S), as estimated by the Chao 1 model, ranged from a maximum of 187 species in April 2019 to a minimum of 13 species in January 2019. Notably, in 2018, when field surveys were conducted systematically throughout the year, species richness peaked in April (85 species) and reached its lowest level in January (15 species) (Figure 8). These findings indicate a moderate increase in species richness during the breeding season, whereas a pronounced decline is evident in winter, consistent with seasonal trends (Figure 9). The anomaly observed in April and May 2019, when compared to the 2018 and 2023 data, appears to represent a temporary fluctuation rather than a persistent trend.

The annual trend in species richness was evaluated for January, April, and May, revealing a decreasing trend during the breeding season but an increasing trend in winter (Figure 10). Although Rajashekara and Venkatesha (2017) reported an increase in diversity and species richness during winter, the GY wetland showed a relatively low number of wintering visitors in contrast to an increasing trend. Factors such as wetland size, habitat diversity, and proximity to other wetlands may influence species richness and diversity (Hamza et al., 2024). Accordingly, the campus's location, the diversity of habitats it provides, and its proximity to key IBAs are considered major determinants of species richness in the area.

Seasonal analysis results indicate that the highest species richness occurs during the breeding season (Figure 9), which aligns with findings from studies on the avifauna of Yeniçağa Wetland (Kirazlı and Gözütok, 2017). Although detailed breeding data for the GY wetland avifauna are currently lacking, future studies are necessary to address this gap. However, current findings support the hypothesis that the wetland serves as a complementary and supporting habitat for the regional avifauna, particularly in connection with Yeniçağa IBA. The GY wetland functions as a stopover corridor for migratory species (e.g., Aythya ferina) en route to regional IBAs (e.g., Yeniçağa Wetland), providing temporary refueling habitats in a fragmented landscape.

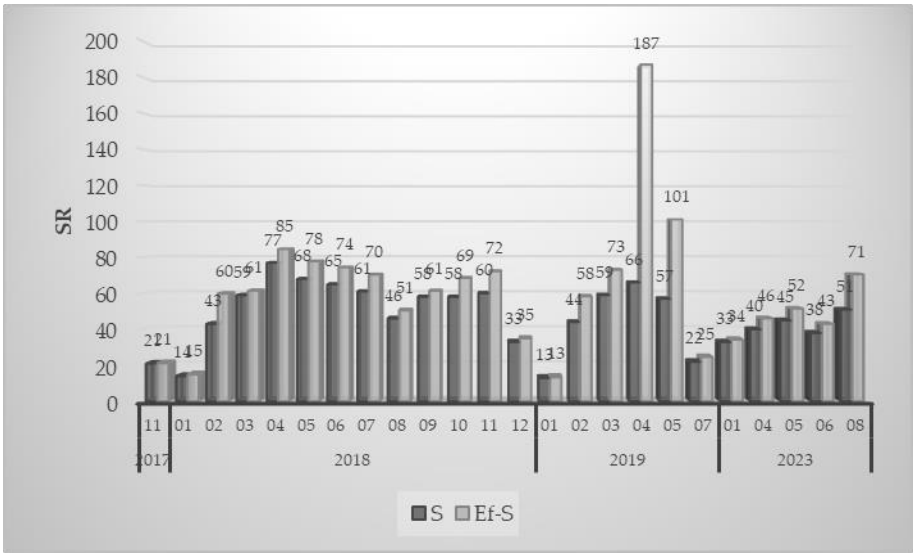

Figure 8. Monthly variation in species richness at GY wetland.
Şekil 8. GY sulak alanı için aylık tür zenginliği profili.

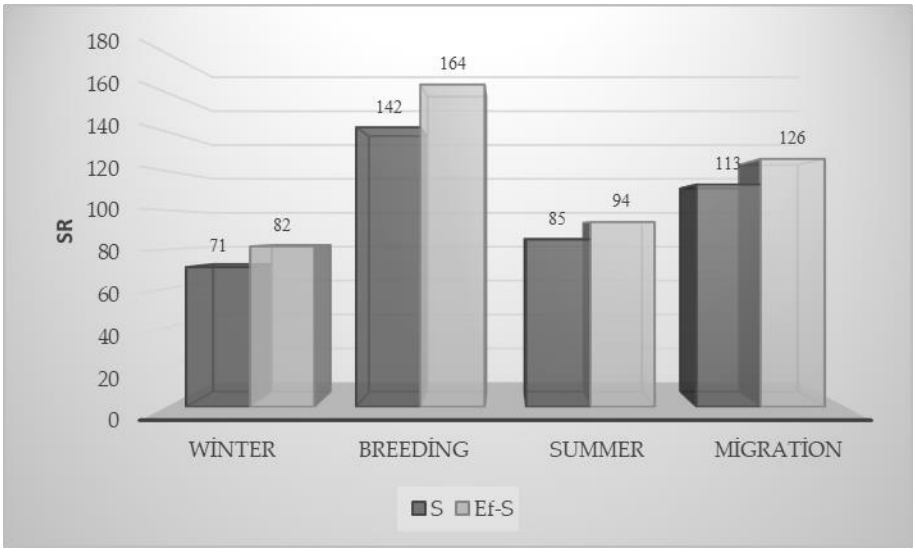

Figure 9. Seasonal trends in species richness at GY wetland.
Şekil 9. GY sulak alanı için dönemlere göre tür zenginliği profili.

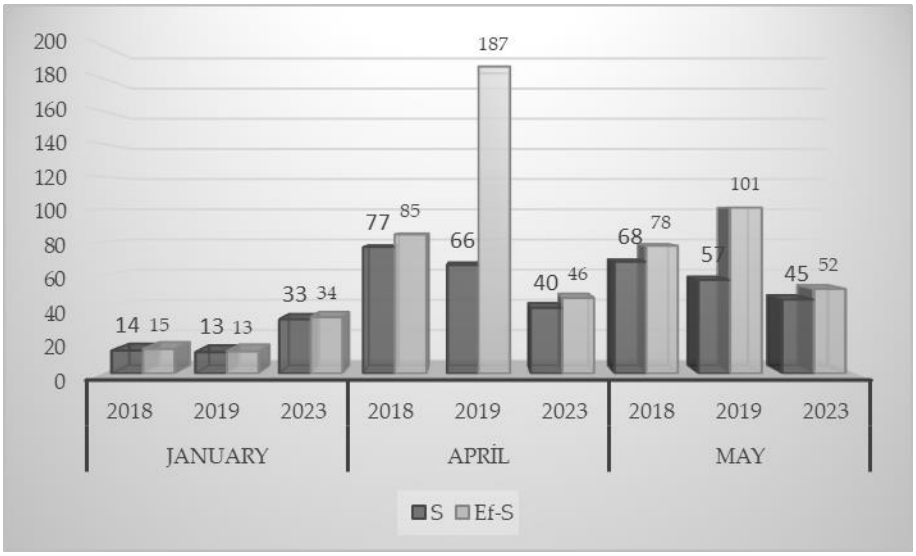

Figure 10. Annual trends in species richness at GY wetland.
Şekil 10. GY sulak alanı için yıllara göre tür zenginliği profili.

An analysis of the N_1, N_2, H′, and H_r index values reveals that avian diversity was highest in April (April 2018: $N_1 = 41$, $N_2 = 27$, $H' = 3.66$), while seasonally, the greatest diversity was observed during the migration period ($N_1 = 42$, $N_2 = 22$, $H' = 3.71$, $H_r = 0.98$). In contrast, the lowest diversity was recorded in January (January 2019: $N_1 = 3$, $N_2 = 2$, $H' = 1.12$), with the winter season exhibiting the lowest overall diversity ($N_1 = 10$, $N_2 = 4$, $H' = 2.30$, $H_r = 3.47$) (Figures 11–15).

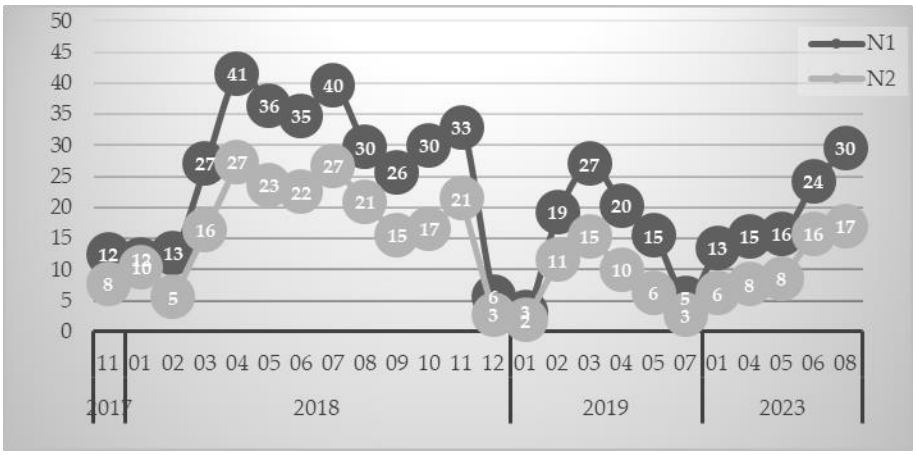

Figure 11. Monthly variation in N_1 and N_2 diversity ındices at GY wetland.
Şekil 11. GY sulak alanı için aylık N_1 ve N_2 indis profili.

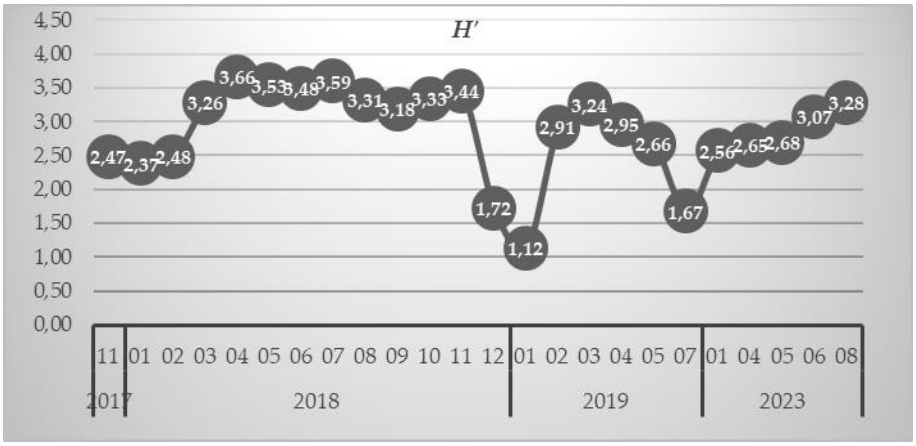

Figure 12. Monthly variation in Shannon diversity ındices at GY wetland.
Şekil 12. GY sulak alanı için aylık Shannon çeşitlilik indis profili.

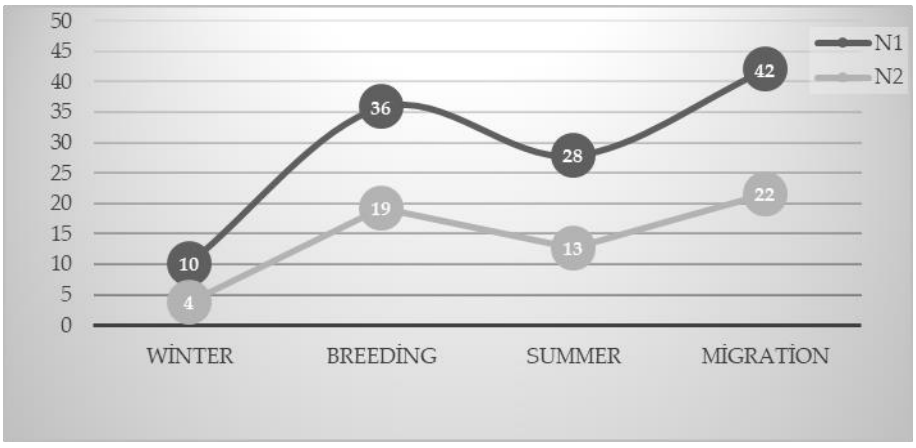

Figure 13. Seasonal trends in N_1 and N_2 diversity indices at GY wetland.
Şekil 13. GY sulak alanı için dönemlere göre N_1 ve N_2 indis profili.

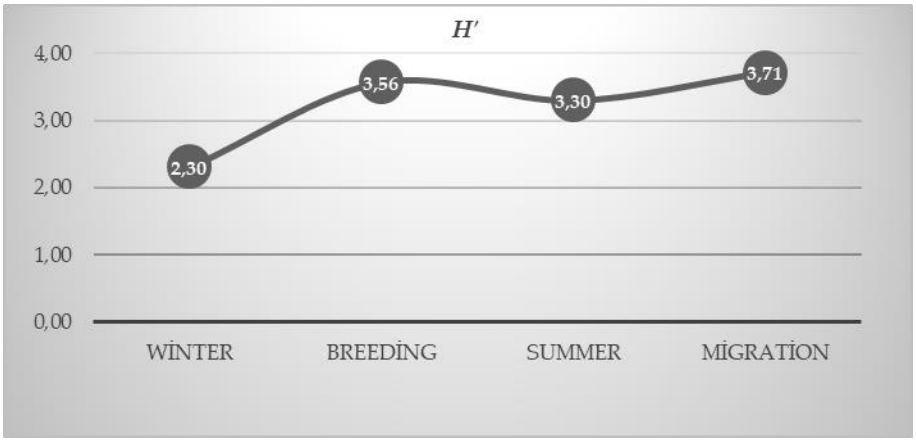

Figure 14. Seasonal trends in Shannon diversity ındices at GY wetland.
Şekil 14. GY sulak alanı için dönemlere göre Shannon çeşitlilik indis profili.

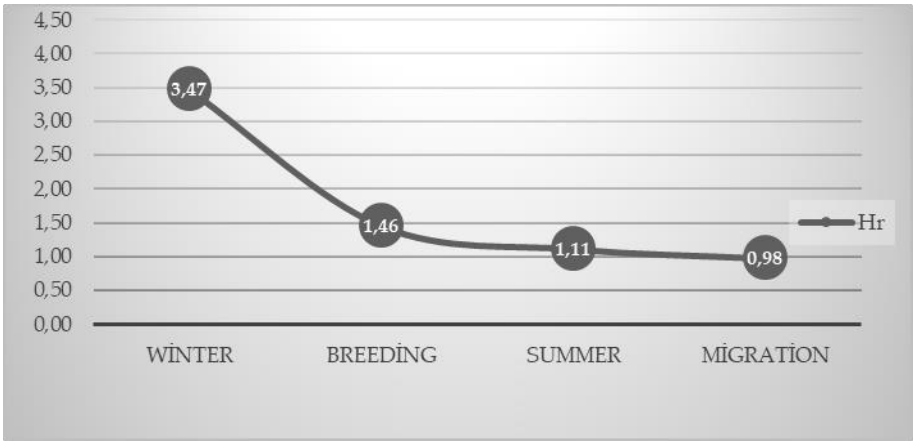

Figure 15. Seasonal trends in heterogeneity ratio ındices at GY wetland.
Şekil 15. GY sulak alanı için dönemlere göre heterojenite oranı çeşitlilik indis profili.

Additionally, a comparison of January, April, and May across different years suggests a slight decline in community heterogeneity over time, accompanied by an increase in dominance and inequality (Figures 16–18).

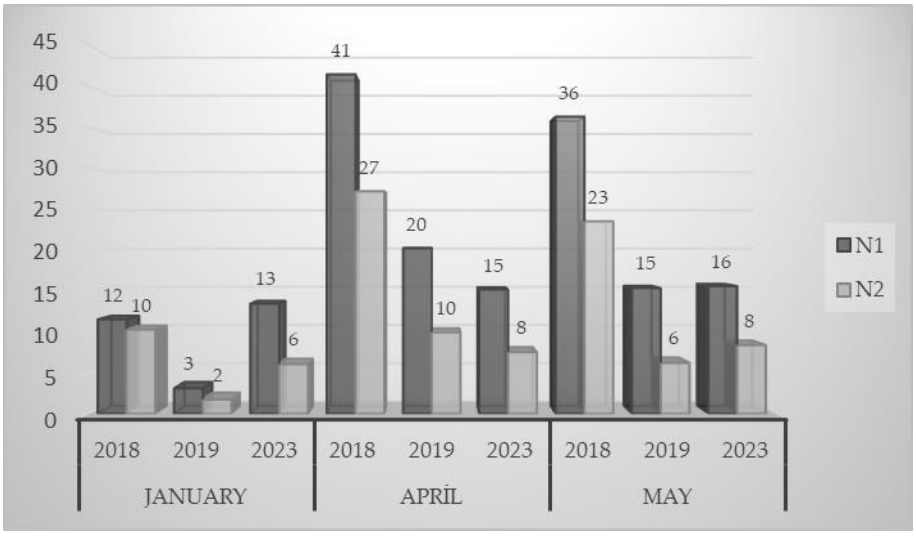

Figure 16. Annual trends in N_1 and N_2 diversity ındices at GY wetland.
Şekil 16. GY sulak alanı için yıllara göre N_1 ve N_2 indis profili.

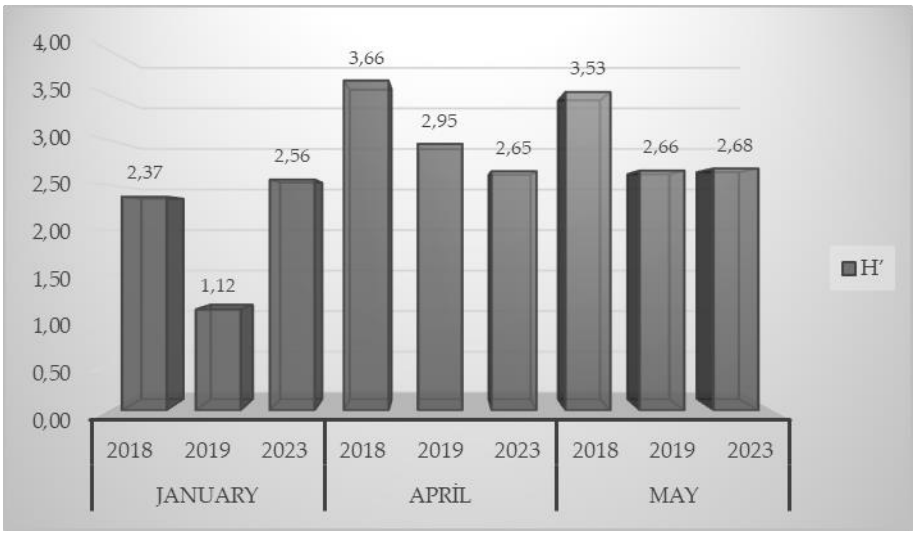

Figure 17. Annual trends in Shannon diversity ındices at GY wetland.
Şekil 17. GY sulak alanı için yıllara göre Shannon çeşitlilik indis profili.

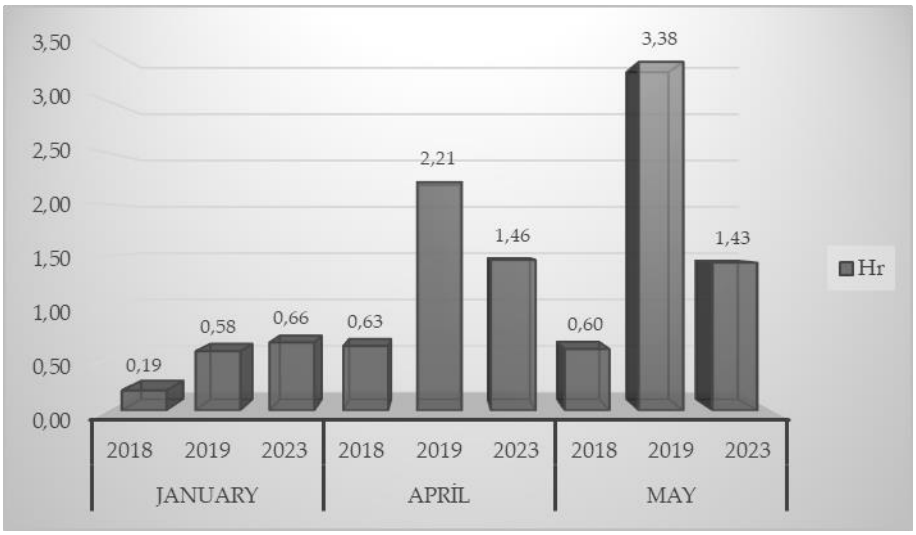

Figure 18. Annual trends in heterogeneity ratio ındices at GY wetland.
Şekil 18. GY sulak alanı için yıllara göre heterojenite oranı çeşitlilik indis profili.

As observed in the Yeniçağa IBAs (Kirazlı and Gözütok, 2017) and other natural wetlands in Türkiye (Bengil and Uzilday, 2010; Keten et al., 2010), species richness and diversity were notably higher during the breeding season, particularly in April, and the migration period, whereas both metrics were lower in winter, especially in January. This pattern is largely driven by the presence of breding migrants and passage migrant species, alongside increased avian activity during these periods. Notably, the habitat islands within the study area support exceptionally high species richness and diversity, underscoring their ecological significance.

Furthermore, the findings indicate that the GY wetland harbors greater taxonomic diversity than many other campus areas and wetlands across Türkiye. For example, comparative studies report 42 bird species at Düzce University (Özkan and Keten, 2020), 93 at Hacettepe University Beytepe Campus (Şahin et al., 2021), and 63 at Harran University (Gümüş et al., 2024). Notably, METU (ODTÜ) campus—one of Türkiye's most biodiverse urban green spaces—supports 231 species (Oruç and Kırlangıç, 2014), though its larger size (4,500 ha vs. GY's 255 ha) and mature forest habitats differ markedly from our study area's peri-urban wetland complex.

Among protected wetlands, the Kocaeli-Yuvacık Dam Basin (near an IBA) hosts 130 species (Keten et al., 2010), while the Küçük Menderes Delta sustains 120 species (Bengil and Uzilday, 2010). The GY wetland's richness (173 species) surpasses these sites and aligns with recognized IBAs like Gediz Delta (113 breeding species; Arslan et al., 2023) in community structure. While formal IBA designation requires meeting quantitative thresholds (e.g., ≥1% of a biogeographic population; BirdLife International, 2023), GY's provisional compliance with Criteria A4 (species richness) and B1a (regular presence of threatened species) underscores its conservation value. These results justify its recognition as a local biodiversity hotspot, though long-term monitoring is recommended to confirm IBA eligibility.

Studies on university campus avifauna in China have identified a positive correlation between bird species richness, phylogenetic and functional diversity, elevation range, and mean annual precipitation (Zhang et al., 2018). Similarly, research on Spanish university campuses found taxonomic diversity differences between campuses and randomly selected sites, though no significant variations in phylogenetic or functional diversity were detected (Sanllorente et al., 2023). While no studies have yet explored phylogenetic or functional diversity within the GY wetland, nor the environmental and climatic factors shaping its avian community, such research is essential for future ecological assessments. Nevertheless, the current findings highlight the considerable ecological value of the GY wetland in terms of avian diversity.

Urbanization-driven biotic homogenization has been widely documented in campus avifauna, particularly in developing countries (Liu et al., 2021; Vallejo Jr et al., 2008). A similar trend is evident in the GY wetland, where community heterogeneity has shown a gradual decline alongside increasing dominance and imbalance. Given this, it is essential to investigate not only the impacts of urbanization but also other potential threats to the bird community. University and local authorities should incorporate bird diversity into site management strategies, such as preserving green spaces adjacent to faculty buildings, creating rooftop and pocket gardens in high-traffic areas, and planting native fruit-bearing trees suited to the local flora. Recent studies emphasize the importance of small habitat patches in maintaining regional biodiversity by linking them with primary diversity areas (Guthula et al., 2022; Liu et al., 2017; Tulloch et al., 2016). In this context, the habitat islands within the GY wetland hold significant conservation value and should be managed accordingly.

Heterogeneity Ratio: A Novel Metric for Assessing Ecological Diversity

Traditional avian diversity studies in Turkish wetlands have primarily focused on species richness, often failing to capture key community dynamics (Aydın, 2021). However, species richness alone does not provide sufficient ecological resolution, particularly in the context of biotic homogenization driven by urbanization (Ferenc et al., 2014). To address this limitation, we introduce the heterogeneity ratio (H_r), a novel metric that quantifies the relationship between rare species (singletons) and dominant species (inverse Simpson index, N_2). This approach offers a more nuanced understanding of avian diversity by integrating both dominance and rarity, two critical components of community structure.

Applied to the Gölköy-Yumrukaya wetland, H_r revealed: (1) pronounced winter dominance by urban-adapted species (H_r = 3.47; 4 dominant species vs. 82 estimated species), (2) near-equilibrium during the breeding season ($H_r \approx 1$), reflecting balanced abundance distributions, and (3) superior sensitivity to short-term fluctuations compared to traditional diversity indices. Notably, winter communities exhibited high dominance concentrations, particularly of species well-adapted to anthropogenic environments, such as the Common Coot (*Fulica atra*) and Mallard (*Anas platyrhynchos*). Meanwhile, the breeding season was characterized by a more balanced species abundance distribution, suggesting a temporally dynamic avian community.

H_r's unitless value is scaled to species counts, enabling intuitive interpretation of community structure while maintaining statistical rigor. Unlike conventional indices that rely on abstract mathematical units (e.g., Shannon entropy in bits), H_r provides direct ecological meaning, making it highly applicable for long-term biodiversity monitoring. Given its ability to detect both seasonal and short-term diversity fluctuations, H_r emerges as a promising tool for assessing community health under urbanization pressures.

While H_r effectively captures community heterogeneity in our research, its theoretical behavior in artificial communities remains unexplored. Future research should investigate whether H_r exhibits the expected

mathematical properties in simulated ecological datasets and whether it aligns with patterns observed in empirical studies. Validating H_r in controlled artificial communities could provide deeper insights into its potential applications and limitations, further refining its role in biodiversity assessment and conservation planning. Additionally, future applications could assess H_r's utility in detecting early signals of biotic homogenization across varying degrees of anthropogenic influence.

CONCLUSION

The Gölköy-Yumrukaya Wetland, located within and around the Bolu Abant İzzet Baysal University campus, serves as a local biodiversity hotspot, with 173 recorded bird species. Beyond being a protected green space under urbanization pressure, this wetland demonstrates significant ecological value and should be considered for designation as an Important Bird Area (IBA). However, the observed decline in community heterogeneity, consistent with global trends in biotic homogenization, underscores the need for long-term monitoring and detailed reproductive data collection.

This study highlights the role of artificial wetlands as secondary habitats, particularly when ecologically connected to natural wetlands. The conservation of small habitat patches is crucial for maintaining primary bird communities, and further research should explore the connectivity between the GY wetland and nearby IBAs. Additionally, matrix quality in fragmented landscapes must be managed to prevent biodiversity loss due to edge effects and the spread of urban-adaptive or invasive species.

The newly introduced Heterogeneity Ratio (H_r) demonstrated strong potential for capturing community structure dynamics with higher resolution than traditional diversity indices. Future studies should further validate H_r's applicability and compare its measurement accuracy with other ecological metrics. Given its ability to detect temporal fluctuations in species abundance and evenness, H_r is recommended as a valuable tool for future biodiversity assessments.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to the content of this article.

DECLARATION OF AUTHOR CONTRIBUTION

All authors contributed to every step of the study. The fieldwork was conducted collaboratively by the author team, while the analyses were carried out by Cihangir Kirazlı. The initial draft of the manuscript was written by Cihangir Kirazlı and was finalized with contributions from the other authors.

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Annex 1. GY Wetland avifauna

Ek 1. GY sulak alanı avifaunası

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
Podicipedidae	*Tachybaptus ruficollis*	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	RW
	Podiceps cristatus	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	RW
	Podiceps nigricollis		■	■								■		LC	P	W
Phalacrocoracidae	*Phalacrocorax carbo*	■	■	■	■			■	■			■	■	LC	RW	WR
	Microcarbo pygmaeus				■									LC	P	WR
Ardeidae	*Ardeola ralloides*				■	■								LC	M	M
	Egretta garzetta				■	■					■	■		LC	M	M
	Ardea alba	■		■	■	■					■	■	■	LC	W	W
	Ardea cinerea	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Ardea purpurea			■	■	■	■							LC	M	M
Ciconiidae	*Ciconia nigra*				■	■	■	■	■	■				LC	M	M
	Ciconia ciconia					■	■							LC	M	M
Threskiornithidae	*Platalea leucorodia*						■							LC	P	P
	Plegadis falcinellus				■	■		■						LC	PM	PM
Anatidae	*Anser anser*	■												LC	WV	MW
	Cygnus olor					■								LC	P	RP
	Cygnus cygnus	■												LC	W	WP
	Cygnus columbianus	■												LC	W	PW
	Tadorna tadorna				■									LC	P	PW
	Tadorna ferruginea							■						LC	R	RM
	Anas acuta				■									LC	P	PW
	Anas crecca	■	■	■							■	■	■	LC	W	W
	Mareca penelope		■	■	■							■		LC	PW	PW
	Mareca strepera			■	■									LC	P	RW
	Anas platyrhynchos	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Spatula querquedula		■	■	■	■								LC	MP	PM
	Netta rufina		■										■	LC	W	RW
	Aythya ferina	■	■	■	■		■				■	■	■	VU	WP	WR

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
	Aythya fuligula													LC	WP	WP
Pelecanidae	*Pelecanus onocrotalus*													LC	P	PM
Accipitridae	*Aegypius monachus*													NT	R	R
	Aquila chrysaetos													LC	R	R
	Aquila heliaca													VU	R	RW
	Haliaeetus albicilla													LC	WR	PWR
	Clanga pomarina													LC	MP	MP
	Hieraaetus pennatus													LC	P	MP
	Circaetus gallicus													LC	M	M
	Milvus migrans													LC	PM	MP
	Buteo buteo													LC	RW	RW
	Buteo rufinus													LC	R	R
	Pernis apivorus													LC	PM	MP
	Accipiter gentilis													LC	R	R
	Accipiter brevipes													LC	P	MP
	Accipiter nisus													LC	WR	RW
Falconidae	*Falco tinnunculus*													LC	R	R
	Falco subbuteo													LC	PM	M
	Falco peregrinus													LC	P	RW
Rallidae	*Gallinula chloropus*													LC	R	R
	Fulica atra													LC	R	R
Burhinidae	*Burhinus oedicnemus*													LC	P	PM
Charadriidae	*Charadrius dubius*													LC	MP	M
	Charadrius alexandrinus													LC	P	PM
Scolopacidae	*Gallinago gallinago*													LC	WP	W
	Calidris pugnax													LC	P	PW
	Calidris minuta													LC	P	WP
	Calidris temminckii													LC	P	P

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
	Tringa ochropus													LC	P	WP
	Tringa nebularia													LC	P	P
	Tringa glareola													LC	P	P
	Actitis hypoleucos													LC	PM	PM
Laridae	*Hydrocoloeus minutus*													LC	P	P
	Larus ridibundus													LC	RP	RW
	Larus michahellis													LC	P	WR
	Sterna hirundo													LC	P	MP
Columbidae	*Columba livia*													LC	R	R
	Columba palumbus													LC	S	MR
	Streptopelia turtur													VU	SP	M
	Columba oenas													LC	MR	R
	Spilopelia senegalensis													LC	W	R
	Streptopelia decaocto													LC	R	R
Cuculidae	*Cuculus canorus*													LC	PS	M
Caprimulgidae	*Caprimulgus europaeus*													LC	P	M
Apodidae	*Apus apus*													LC	M	M
	Tachymarptis melba													LC	M	M
	Apus pallidus													LC	P	MP
Alcedinidae	*Alcedo atthis*													LC	PM	RM
Meropidae	*Merops apiaster*													LC	PM	M
Coraciidae	*Coracias garrulus*													LC	PM	M
Upupidae	*Upupa epops*													LC	M	M
Picidae	*Picus viridis*													LC	R	R
	Picus canus													LC	P	R
	Dendrocopos major													LC	R	R
	Dendrocopos syriacus													LC	R	R
	Dryobates minor													LC	R	R

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
	Leiopicus medius													LC	R	R
	Jynx torquilla													LC	MP	M
Alaudidae	*Galerida cristata*													LC	R	R
	Lullula arborea													LC	MR	MR
	Alauda arvensis													LC	MR	R
Hirundinidae	*Hirundo rustica*													LC	M	M
	Cecropis daurica													LC	PM	MP
	Delichon urbicum													LC	M	M
	Riparia riparia													LC	PM	M
Motacillidae	*Anthus campestris*													LC	P	MP
	Anthus pratensis													LC	P	WP
	Anthus spinoletta													LC	P	WM
	Anthus trivialis													LC	PM	PM
	Anthus cervinus													LC	P	PW
	Motacilla flava													LC	M	M
	Motacilla cinerea													LC	PW	RW
	Motacilla alba													LC	RM	R
	Motacilla citreola													LC	P	PM
Troglodytidae	*Troglodytes troglodytes*													LC	R	R
Turdidae	*Turdus merula*													LC	R	R
	Turdus pilaris													LC	W	W
	Turdus philomelos													LC	R	R
	Turdus viscivorus													LC	R	RW
Acrocephalidae	*Acrocephalus arundinaceus*													LC	MP	MP
	Acrocephalus scirpaceus													LC	M	MP
	Acrocephalus palustris													LC	P	PM
	Acrocephalus schoenobaenus													LC	P	MP
	Iduna pallida													LC	P	M

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
Scotocercidae	*Cettia cetti*				■	■	■	■	■					LC	M	M
Sylviidae	*Curruca nisoria*					■	■	■				■		LC	MP	M
	Curruca curruca								■					LC	P	MP
	Sylvia atricapilla				■			■						LC	PS	MP
	Curruca communis				■	■		■	■		■			LC	M	MP
Phylloscopidae	*Phylloscopus collybita*		■	■	■		■		■		■	■		LC	MP	MP
	Phylloscopus trochilus									■				LC	P	P
Regulidae	*Regulus regulus*		■	■	■									LC	WP	RW
	Regulus ignicapilla	■		■	■									LC	WP	WR
Muscicapidae	*Muscicapa striata*					■	■	■	■	■				LC	M	MP
	Ficedula parva				■					■	■	■		LC	P	PM
	Ficedula albicollis				■									LC	P	P
	Ficedula hypoleuca				■									LC	P	P
	Erithacus rubecula		■	■	■	■	■	■	■	■	■	■	■	LC	R	RW
	Luscinia megarhynchos				■	■	■	■	■					LC	M	M
	Phoenicurus ochruros			■	■	■	■	■		■	■		■	LC	MP	MP
	Phoenicurus phoenicurus				■	■					■			LC	P	PM
	Saxicola rubetra			■	■	■								LC	PM	PM
	Saxicola torquatus		■	■	■	■	■	■	■	■	■			LC	M	MP
	Oenanthe isabellina				■									LC	P	M
	Oenanthe oenanthe			■	■	■	■	■	■	■		■		LC	M	M
Aegithalidae	*Aegithalos caudatus*	■	■	■						■				LC	WR	R
Paridae	*Periparus ater*		■	■	■	■			■		■	■		LC	R	R
	Cyanistes caeruleus	■	■	■	■	■	■	■	■		■	■		LC	R	R
	Parus major	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Poecile palustris		■				■	■	■		■	■		LC	R	R
Sittidae	*Sitta europaea*	■	■	■	■	■	■	■	■	■		■		LC	R	R
	Sitta krueperi	■												LC	WR	R

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
Certhiidae	*Certhia brachydactyla*			■	■	■							■	LC	R	R
	Certhia familiaris		■		■									LC	RW	R
Laniidae	*Lanius collurio*				■	■	■	■	■	■	■			LC	M	M
	Lanius minor					■								LC	P	M
	Lanius excubitor	■	■								■			LC	W	W
	Lanius senator					■	■		■	■				NT	M	MP
	Lanius nubicus					■								LC	P	PM
Oriolidae	*Oriolus oriolus*					■	■	■	■		■	■		LC	MP	M
Corvidae	*Garrulus glandarius*	■	■	■	■	■	■	■		■	■	■	■	LC	R	R
	Pica pica	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Corvus frugilegus		■								■	■		LC	W	WR
	Corvus corone	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Corvus corax		■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Corvus monedula	■	■	■		■		■	■			■		LC	R	R
Sturnidae	*Sturnus vulgaris*		■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Pastor roseus					■						■		LC	P	PM
Passeridae	*Passer domesticus*	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Passer montanus		■	■	■	■	■	■	■		■	■		LC	R	R
	Passer hispaniolensis				■	■		■						LC	M	M
Fringillidae	*Fringilla coelebs*	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Fringilla montifringilla		■							■		■	■	LC	W	W
	Serinus serinus			■		■	■	■	■			■		LC	RM	RW
	Chloris chloris			■	■	■	■	■	■		■	■		LC	RM	R
	Carduelis carduelis	■	■	■	■	■	■	■	■	■	■	■	■	LC	R	R
	Spinus spinus	■												LC	W	WR
	Linaria cannabina			■	■	■				■	■			LC	MP	RM
	Carpodacus erythrinus					■	■	■						LC	SM	M
	Pyrrhula pyrrhula		■											LC	W	RW

Family	*Species*	January	February	March	April	May	June	July	August	September	October	November	December	IUCN	Status (local)	Status (Regional)
	Coccothraustes coccothraustes													LC	W	RW
Emberizidae	*Emberiza cirlus*													LC	R	R
	Emberiza hortulana													LC	M	M
	Emberiza melanocephala													LC	MP	M
	Emberiza calandra													LC	R	R

Research Article

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Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi

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Growth and Development Traits of Morkaraman Lambs under Breeder Conditions

Morkaraman Kuzuların Yetiştirici Şartlarında Büyüme ve Gelişme Özellikleri

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Abstract: The aim of this study was to determine the growth and development characteristics of singleton unweaned male Morkaraman lambs extensively raised under breeder conditions from birth to the end of the grazing season. A total of 45 singleton male Morkaraman lambs were used in this study and live weight changes from birth to the end of pasture period (140th day of age) and some body measurements at the end of pasture period were determined of these lambs. The means of the live weight values of the lambs at the birth, 15, 30, 45, 60, 75, 90, 115, and 140th days were 4.04, 7.42, 10.03, 13.22, 16.74, 20.83, 25.91, 29.67, and 33.43 kg, respectively. At the end of the grazing season (140th day), the mean values of the lambs' wither height, chest depth, chest girth, rump height, and rump length were 61.73, 29.47, 75.13, 60.33, and 19.73 cm, respectively. As a result of the study, it was found that Morkaraman singleton male lambs raised on the pasture only grazing without weaning for up to 140 days provided adequate growth and development. However, when the live weight changes are evaluated, it can be said that it would be beneficial to make additional feeding after 90 days age. It would be appropriate to evaluate the longer feeding.

Keywords: Birth Weight, Live Weight Gain, Live Weight, Body Measurement

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Öz: Çalışmada, tekiz-erkek Morkaraman kuzuların yetiştirici koşullarinda büyüme ve gelişme özelliklerinin belirlenmesi amaçlanmıştır. Kuzular yetiştirici koşullarına uygun şekilde sütten kesim uygulanmadan doğumdan mera sonuna kadar mera olanakları ile yetiştirmiştir. Çalışma kapsamında 45 baş tekiz erkek Morkaraman kuzudan doğumdan mera sonuna (140. gün) kadar canlı ağırlık değişimleri ve mera sonu bazı vücut ölçüleri tespit edilmiştir. Kuzularda ortalama doğum ağırlığı, 15, 30, 45, 60, 75, 90, 115 ve 140. gün (mera sonu) canlı ağırlık değerleri sırasıyla 4.04, 7.42, 10.03, 13.22, 16.74, 20.83, 25.91, 29.67 ve 33.43 kg olmuştur. Kuzuların mera sonu (140. gün) ortalama cidago yüksekliği, göğüs derinliği, göğüs çevresi, sağrı yüksekliği ve sağrı uzunluğu değerleri ise sırasıyla 61.73, 29.47, 75.13, 60.33 ve 19.73 cm olmuştur. Çalışma sonucunda, Morkaraman tekiz erkek kuzuların sütten kesim yapılmadan sadece mera ile besleme yapılarak 140. güne kadar yetiştirmenin yeterli büyüme ve gelişme sağladığı belirlenmiştir. Ancak büyüme sonuçları incelendiğinde, 90. gün sonrası imkân dahilinde ilave besleme yapmanın faydalı olacağı ve beslemenin daha uzun yapılarak değerlendirilmesinin uygun olacağı önerilebilir.

Anahtar Kelimeler: Doğum Ağırlığı, Canlı Ağırlık Artışı, Canlı Ağırlık, Vücut Ölçüleri

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INTRODUCTION

Animal-based foods have a significant role for balanced and healthy diet of the people. The species of animals raised to produce these foods and the proportion of these species in total animal population vary according to the sociocultural and geographical structures of the countries. In this context, sheep are the most common livestock species utilizing pastures in regions that have steppe or continental climate condition. (Saatci et al., 2003; Elmaz et al., 2012; Güneş and Akin, 2017) The animal products obtained from sheep make a significant contribution to the economy and the production of animal food in these regions. (Akçapınar, 2000; Güngör and Ünal, 2020a; Güngör et al., 2022a). Türkiye has 54 million small ruminant population, of which 43 million are sheep, according to June 2024 data. (TUIK, 2024). Sheep breeding is carried out mostly in an extensive system. Similarly, it is known that sheep farming in Turkiye is extensive farming, and the different regions of Turkiye have their own indigenous sheep breed which are well adapted to the conditions of own region. Morkaraman, an indigenous sheep breed of the East Anadolu region, is well adapted to the climate and grazing conditions of this region. This fat-tailed sheep has low combine yields. Mutton production is the main source of income for sheep farmers in this region. (Akçapınar, 2000; Akçapınar and Aydın, 1984; Güngör and Ünal, 2020b; Güngör et al., 2022b). For these reasons, the evaluation of the growth and development traits of this breed under breeder conditions gives very valuable information for the sheep production in the region.

The growth and development traits of Morkaraman lambs in Ağrı province have not been studied yet. There are also few studies on Morkaraman lambs under breeding conditions because nearly all of the research on Morkarman sheep was conducted at the university farms (Elazig Firat University, Erzurum Atatürk University, Kars Kafkas University, and an Yüzüncü Yıl University). In addition, some body measurements of Morkarman lambs are not well described due to few studies on body measurements of Morkarman lambs. It is known that the variation of genotype in the native breeds is high, and the quality of the pasture and the length of the grazing season differ from region to region. Therefore, evaluating the growth and development of Morkaraman lambs under traditional breeding conditions is important in this region.

This study aimed to evaluate the growth and development characteristics of Morkaraman singleton male lambs traditionally raised with pasture grazing without weaning under breeder conditions in Ağrı province from birth to the end of the grazing season.

MATERIAL AND METHOD

According to the data of 2023, a total of 333 thousand cattle and 1200 thousand head of sheep and goats are raised in Ağrı province. The sheep population is 1140 thousand head in this province (TUIK, 2024). Sheep breeding is obviously understood to be an important animal husbandry in Ağrı province. Most of the income of the sheep farms in this region is derived from mutton production, and sheep production is generally depended on pasture quality and length of the grazing season. In addition, the lambs are traditionally raised on pasture without weaning during the grazing season in the breeder condition in Ağrı province.

This study was conducted on routine livestock practices in the Agri Province region of Turkiye and was supported by the "General Directorate of Agricultural Research and Policies (TAGEM)" as part of the "National Genetic Improvement Project for Small Ruminants at Breeders Conditions".

Material

The study was conducted in the central province of Ağrı (39°56'44.6"N 43°08'56.5"E) in the East Anatolian Region of Türkiye. The farm has 300-head Morkaraman stock herd. Data were obtained from 45 Morkaraman singleton male lambs born in this Morkaraman herd.

Method

In this study, A flock of 300 Morkaraman stock ewes between 2 and 8 years ages was followed. The lambs were randomly selected within the singleton male Morkaraman lambs born within three days of the peak of the births in this Morkaraman herd. The obtained data was therefore not interpolated. When the lambs

were about 45 days ages, they began grazing with their dams. The herd went out to pasture at sunrise in the morning and returned to the sheepfold around 7:00 pm. The animals were provided with potable water three times a day. No additional feeding was applied to the dams and lambs except for pasture. Birth weights of lambs were determined 8-12 hours after birth and the ear tags have been applied. Live weight measurements of the 45 male lambs were determined every 15 days until day 75th. The 15 lambs were randomly selected from these 45 lambs for the slaughter and these lambs were grazed by their dams until 140th days of age without weaning. The live weight of these lambs continued to be determined at the 90th, 115th, and 140th day of age. The growth rate is high in the early stages of the ages. Therefore, measurements were taken at 15-day intervals until day 90. In addition, body measurements (wither height, chest depth, chest girth, rump height, and rump length) of these lambs were taken at the end of 140 days (end of grazing period). A 150 kg scale with a sensitivity of 50 g was used to determine live weights.

The SPSS package program was used to calculate descriptive statistics of the live weight and the body measurements.

RESULTS AND DISCUSSION

Live Weights of The Lambs

Means of lamb live weights determined at 15-day intervals from birth to 90 days of age and at 25-day intervals from 90 days to 140 days of age were shown in Table 1.

Table 1. Means of lamb live weights (kg) of Morkaraman lambs.
Çizelge 1. Morkaraman kuzularda ortalama canlı ağırlık (kg) değerleri.

Lamb live weights	n	$\bar{X} \pm S_{\bar{x}}$	CV
Lambing period			
Birth	45	4.04±0.09	15.19
15th day	45	7.42±0.17	15.71
30th day	45	10.03±0.26	17.29
45th day	45	13.22±0.28	14.05
Grazing period			
60th day	45	16.74±0.30	12.08
75th day	45	20.83±0.42	13.63
90th day	15	25.91±0.68	10.12
115th day	15	29.67±0.70	9.12
140th day	15	33.43±0.73	8.42

$S_{\bar{x}}$: Standard error, CV: Coefficient of variation

For the live weight means, the coefficient of variation results showed the values lower than 20%. This was an indication that live weights were homogeneously distributed around the mean. The mean birth weight of the lambs in the study was 4.04±0.09 kg. This mean value determined in this study was similar to the values reported for Morkaraman lambs by Akçapınar and Kadak (1982) in Elazığ province (4.0 kg), Küçük et al. (2002) in Van province (4.0 kg), Arslan et al. (2003) in Van province (3.9 kg), Öztürk et al. (2012) in Van province (4.1 kg), and Şahin (2021) in Erzurum province (3.9 kg). However, this mean birth weight was lower than the results reported by Akçapınar and Aydın (1982) (4.9 kg), Esenbuğa and Dayıoğlu (2002) (4.2 kg), Aksakal and Macit (2009) (4.2 kg) and Macit et al. (1996) (4.7 kg) for Morkaraman lambs in Erzurum province, but higher than the results reported for Morkaraman lambs by Laçin and Aksoy (2003) (3.8 kg), and Ulusan and Aksoy (1996) (3.2 kg) in Kars province, and by Arslan et al. (2003) (3.4 kg), and Odabaşıoğlu et al. (1996) (3.7 kg) in Van province. It is clear that the Morkarman lambs born in Erzurum province have higher lamb birth weights than those of Kars, Van, and Elaziğ provinces. The Food and Livestock Application and Research Centre of the Faculty of Agriculture at Ataturk University has conducted most of these Morkarman studies in Erzurum province. The high birth weights of Morkaraman lambs may be caused by a result of the selection programs at this research centr, which has been breeding Morkaraman since 1967 (Emsen and Dayıoğlu, 2011).

The 15th, 30th, 45th, 60th and 75th day live weight values obtained in this study were very similar to the results obtained from Morkaraman lambs in the in the experimental farm of Veterinary Faculty of Yüzüncü Yıl University in Van Province (Öztürk et al., 2012). However, the results of this study in these ages were higher than those of in the experimental farm of Veterinary Faculty of Kafkas University in Kars Province (Laçin and Aksoy, 2003) and Firat University in Elazığ province (Özbey and Akcan, 2003).

The 75th-day mean live weight of the lambs was 20.83±0.42 kg in this study. This value was higher than the results of the studies conducted on Morkaraman lambs at 75th days by Odabaşıoğlu et al. (1996) in Van province (19.0 kg), Esenbuğa and Dayıoğlu (2002) in Erzurum province (17.1 kg), Laçin and Aksoy (2003) in Kars province (13.6 kg), and Arslan et al. (2003) in Van province (18.7 kg). However, this value was similar or partly similar to the result of the study by Öztürk et al. (2012) in Van province (20.2 kg), by Akçapınar (1983) in Elazığ province (21.0 kg), and by Küçük et al. (2002) in Van province (22.4 kg). The 90th day mean live weight of the lambs was 25.91±0.68 kg in this study. This value was generally higher than the results of the studies conducted on Morkaraman lambs at 90 days by Akçapınar (1983) in Elazığ province (23.7 kg), Odabaşıoğlu et al. (1996) in Kars province (22.3), Ulusan and Aksoy (1996) in Kars province (21.2 kg), Laçin and Aksoy (2003) Kars province (16.1 kg), Arslan et al. (2003) in Van province (22.0 kg) and Öztürk et al. (2012) in Van province (23.2 kg), but this value was partly similar to the result of the study by Küçük et al. (2002) in Van province (26.6 kg).

When the birth weight, 75th and 90th day mean live weights of the lambs in this study are compared with the results of other studies at these times for Morkaraman lambs, it can be said that the results obtained in this study for Morkaraman lambs are adequate and even better than the results of many studies on Morkaraman lambs raised different provinces. However, the mean lamb live weight result obtained at the end of the grazing period in this study (33.43 kg) was lower than the results obtained from male Morkaraman lambs raised in Erzurum province (Macit et al., 1996; Aksakal and Macit, 2009; Esenbuğa and Dayıoğlu, 2002) (37.3, 35.5, and 36.6 kg). This can be due to the difference in the length of the grazing season between these two regions, because Macit at al. (1996) reported that the average age of Morkaraman lambs at the end of the grazing period in Erzurum province is 161 days.

The 75th and 140th-day mean the live weights of Morkaraman lambs in the study were 20.83 kg and 33.43 kg, respectively. Özbey and Akcan (2003) in Elazığ province and Aksoy et al. (1996) in Van province started their fattening studies using 21.5 kg and 20.2 kg male Morkaraman lambs, respectively. The mean lamb live weight obtained on the 75th day in this study is similar to the initial live weights of lambs in these two fattening studies. In these fattening studies with concentrated feed, the live weights of the male lambs in the Özbey and Akcan's fattening study were 31.7 kg on the 56th day and 35.6 kg on the 70th day. It can be calculated from these results that the mean live weight of the lambs on the 65th day was 34.2 kg in Özbey and Akcan's fattening study. The live weights of the male lambs in the Aksoy et al.'s fattening study were 30.8 kg on the 56th day and 31.8 kg on the 70th day. It can be calculated from these results that the live weight of the male lambs on the 65th day was 31.4 kg in Aksoy et al.'s fattening study. If the results obtained at 65 days of fattening in these two studies are compared with the results obtained at 65th days (140th day) after 75th days in this study, it is understood that feeding only with pasture until 140 days without weaning provides a sufficient result for adequate growth of Morkaraman male lambs in Ağri province.

The curve of mean live weight changes of singleton male Morkaraman lambs determined according to the time points was shown in Figure 1.

When the graph curve of the lamb live weights determined in the study is evaluated, it appears that the lambs' live wight changes show a slightly positive growth curve from the 15th day to the 90th day, but the lambs' mean live weight changes show a linear curve between 90th and 140th days. Based on this result, it can be said that it is appropriate to provide nutritional support to the lambs after 90 days of age.

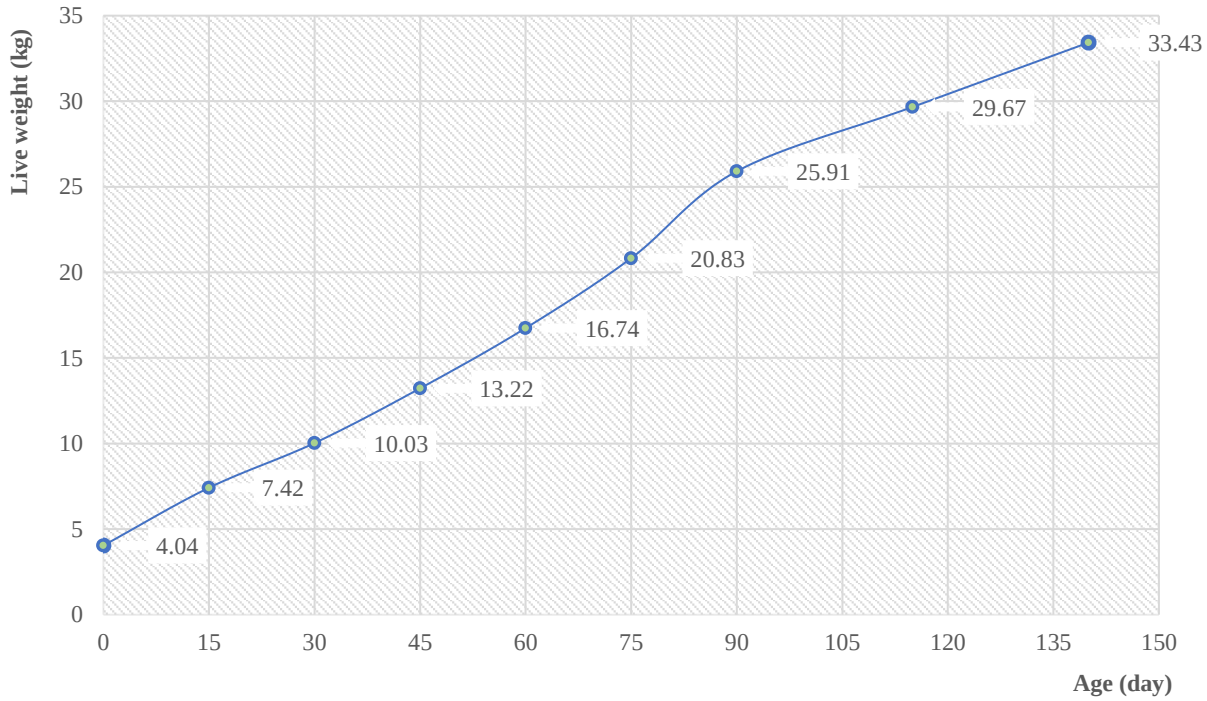

Figure 1. The curve of mean live weight changes of Morkaraman lambs over time.
Şekil 1. Morkaraman kuzularda canlı ağırlık ortalamalarının zamana göre değişim grafiği.

Body Measurements

The mean values of the body measurements (wither height, chest depth, chest girth, rump height, rump length) taken from the lambs on day 140 were presented in Table 2.

Table 2. The mean values of some body measurements (cm) of Morkaraman lambs at 140 days of age.
Çizelge 2. Morkaraman kuzularda 140 günlük yasta bazı vücut ölçüleri (cm).

Body measurements	n	$\bar{X} \pm S\bar{x}$	CV
Wither height	15	61.73±0.72	4.52
Chest depth	15	29.47±0.59	7.79
Chest girth	15	75.13±0.88	4.55
Rump height	15	60.33±0.98	6.32
Rump length	15	19.73±0.27	5.23

$S\bar{x}$: Standard error, CV: Coefficient of variation

Body measurements were understood to be more homogeneously distributed around the mean because the coefficients of variation values for body measurements were lower than 20%, as for live weight. It is reported that the ratio of wither height to chest depth is very important ratio, and that the 1/2 or close to it is a good proportion (Akçapınar and Özbeyaz, 2021). This morphological conformation can be said to be important for grazing in regions where long-term grazing is required. . Consistent with the report, the mean wither height value in this study is approximately twice the mean chest depth value. The wither height and the chest girth of the lambs in this study were 61.73±0.72 cm and 75.13±0.88 cm at the end of the grazing period (day 140), respectively. A study conducted by Ulusan and Aksoy (1996) in Kars province reported the 6-month age wither height and chest girth of Morkaraman male lambs as 57.8 cm and 73.8 cm, respectively. There is no study on Morkaraman lambs other than the study of Ulusan and Aksoy (1996) on the body measurements that were determined in this study. Comparing the results of Ulusan and Aksoy and this study, it is clear that the body measurements determined in this study were higher than those of male Morkaraman lambs in Kars. Rump height (60.33 cm) was less than wither height (61.73 cm) in this study. Rump height (63.2 cm) was reported to be higher than wither height (62.0 cm) in a study reported one year body measurements of Morkaraman (Özbey and Akcan, 2003). The difference was not high, and

this may be due to different developmental stages. It is known the high genotype variation in native breeds, and the environmental conditions (pasture quality and length of grazing season) differ from region to region; therefore, the differences between Morkaraman lambs in different provinces were due to high genotype variation and environmental differences.

CONCLUSION

Lamb live weight changes and body measurements in this study were similar or better to other studies for this breed. These results show that traditionally raising Morkaraman singleton male lambs in Ağrı province on pasture only grazing without weaning until day 140 (until the grazing period) under breeder conditions provides adequate growth and development. According to the live weight change curve up to 90 days, the lamb live weight had an upward trend. It can be suggested to try to continue this trend with supplementary feeding after 90 days. In conclusion, pasture feeding without weaning until day 90 provided adequate growth and development in this region.

CONFLICT OF INTEREST

The authors must report under this title that there are no conflicts of interest.

DECLARATION OF AUTHOR CONTRIBUTION

The authors contributed equally to the article.

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