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Araştırma Makalesi / Research Article
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Bor Noksanlığının Tanısı ve Borun Elbistan Çevresinde Yetiştirilen Şeker Pancarı (*Beta vulgaris* L.)'nın Verim ve Kalite Değerleri Üzerine Etkisi

Diagnosis of Boron Deficiency and Effects of Boron on Yield and Quality Values of Sugar Beet (*Beta vulgaris* L.) Grown in Elbistan District

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ÖZ

Bor (B) eksikliği dünyanın birçok bölgesinde bitkisel üretimi sınırlayan bir faktör olarak kabul edilmektedir. 2016–2017 yılı ekim sezonunda Kahramanmaraş-Elbistan yöresinde şeker pancarının mevcut beslenme durumunu belirlemek amacıyla bir saha çalışması yapılmıştır. Toprak ve bitki bor eksikliğine işaret eden saha çalışmasının sonuçları nedeniyle, 2017–2019 yılları arasında borun şeker pancarının verim ve kalitesine etkisi belirlemek amacıyla tarla denemeleri yapılmıştır. Saha çalışma sonuçlarında toprak ve bitki örneklerinin sırasıyla %85 ve %75'den fazlası kritik sınırların altında bor içerdiği tespit edilmiştir. Bitkilerin toplam bor kapsamı ile toprakların alınabilir bor kapsamı arasında düzeyinde önemli pozitif ilişki tespit edilmiş ve $r=0{,}7611^{***}$ olarak hesaplanmıştır ($y=57{,}3703x+29{,}0349$). İki yıllık tarla denemeleri sonuçlarına göre şeker pancarı topraktan bor uygulamasına önemli ölçüde yanıt vermiştir. Şeker pancarı kök verimi ve arıtılmış şeker verimi istatiksel olarak anlamlı düzeyde artarken, şeker varlığı ve arıtılmış şeker varlığındaki artışlar anlamlı bulunmamıştır. Bor uygulaması melas yapıcı maddelerden şeker pancarı kökü potasyum, sodyum ve zararlı azot kapsamı üzerine etki yapmamıştır. Arıtılmış şeker veriminde kontrole göre artış; 150 g da^{-1} bor seviyesinde %13,2, 300 g da^{-1} seviyesinde %14,5, 450 g da^{-1} bor seviyesinde %18,7, 600 g da^{-1} bor seviyesinde ise %13,4 olarak gerçekleşmiştir.

Anahtar Kelimeler: Bor noksanlığı, şeker varlığı, kök verimi, şeker pancarı

ABSTRACT

Boron deficiency is considered to be a limiting factor in plant production in many parts of the world. A field study was conducted to determine the current nutritional status of sugar beets in the Kahramanmaraş-Elbistan region in the 2016–2017 season. Due to the results of the field study indicating the lack of soil and plant boron, field trials were conducted between 2017 and 2019 to determine the effect of boron on the yield and quality of sugar beet. In the results of the field studies, it was determined that more than 85% and 75% of the soil and plant samples, respectively, contain boron below the critical limits. A significant positive relationship was determined between the total boron content of the plants and the available boron content of the soils and it was calculated as $r=0.7611^{***}$ ($y=57.3703x+29.0349$). According to the results of the field trials of two years, sugar beet responded significantly to the application of boron from the soil. While sugar beet root yield and purified sugar yield increased statistically significantly, the increase in the presence of sugar and the presence of refined sugar was not found to be significant. Boron application did not affect the content of sugar beet root potassium sodium and harmful nitrogen content. Increase in purified sugar yield; 13.2% at 150 g da^{-1} boron level, 14.5% at 300 g da^{-1} level, 18.7% at 450 g da^{-1} boron level, and 13.4% at 600 g da^{-1} boron level.

Keywords: Boron deficiency, purified sugar yield, root yield, sugar beet

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Giriş

Şeker pancarı önemli bir şeker bitkisi olup dünya şeker üretiminin yaklaşık %20 (35,9 milyon ton)'sini karşılamaktadır. Ülkemiz 3,700,000 ton şeker üretim ile dünyanın 5. büyük pancar şekeri üreticisidir (TŞFAŞ, 2020). Şeker pancarı ülkemizde yetiştirilen önemli endüstri bitkisi olup 2020 yılı şeker pancarı ekimi 3,363,480 da, üretim ise 23.025,738 ton olarak gerçekleşmiştir (Tarım ve Orman Bakanlığı, 2021). Elbistan Şeker Fabrikası ekim sahasında her yıl yapılan yaklaşık 31,500 da ekim ve 420,000 ton üretimle şeker pancarı yetiştiriciliği önemli bir tarımsal faaliyettir (TŞFAŞ, 2017).

Şeker pancarı (*Beta vulgaris* L.) mikro besin elementlerinden bor (B)'u; asit ve nötr toprakta borik asit (H_3BO_3), alkali topraklarda ise borat iyonu ($H(BO)_4^-$) formunda almaktadır. Bitkilerin erken büyüme döneminde bor noksanlığı; yaprak klorofil içeriğinin artmasına, yaprak stomalarına ait iletkenliğin ve net fotosentez oranını düşmesine ve sonuçta yapraktan yapısal olmayan karbonhidrat taşınmasının azalmasına neden olmaktadır (Zhao & Oosterhuis, 2002). Bu nedenle bor diğer bitkilerde olduğu gibi şeker pancar için de gerekli olan temel bir bitki besin maddesidir. Bor bitkiler için temel bir mikro besin elementi olmasına rağmen toprakta fazla birikmesi durumunda toksik olmaktadır (Sakamoto ve ark., 2011; Shorrocks, 1997). Şeker pancarı genel olarak bora toleranslı bir bitkidir (Rozema ve ark., 1992). Ancak bor uygulaması sonrası özellikle kil bakımından yoksun topraklarda yetişen bitkilerde bor zararı görülebilmektedir.

Şeker pancarı, ortalama bir kök verimi için yılda dekardan 30–35 gr bor kaldırmakta olup bitki su stresi yaşamaması durumunda ihtiyacı olan boru, eşik değerin altındaki topraklardan da karşılayabilmektedir (Draycott, 2006). Ayrıca kullanılan kimyasal gübrelerde bulunan eser miktardaki bor veya sulama suyunda bulunan bor da bitkinin ihtiyacını giderebilmektedir. Şeker pancarı yeteri kadar bor ile beslenemediği durumlarda yaprak ayası kıvrılmakta, koyulaşmakta ve yaprak sapında çatlaklar oluşmaktadır. İletken dokuda meydana gelen zarar nedeniyle solmaya ve yaprak ayasında şurubumsu maddenin akmasına neden olmaktadır. Yaprak ayasının üst yüzeyi beyaz ağ gibi parçalanmış bir görüntü almakta, büyüme noktasındaki meristem doku dağılmakta ve saçak kök gelişimi azalmaktadır. En önemli belirti ise şeker pancarının orta (göbek) kısmının ölümüdür (Draycott & Cristenson, 2003).

Şeker pancarı yetiştiriciliğinde gübreleme daha çok NPK temelli yapılmakta ve mikro element noksanlığı olan yörelere özgü gübreleme programlarına yeterince önem verilmemektedir (Turhan & Mühürdaroğlu, 2002). Pancar ekim alanları bor durumunun belirlenmesi ve bor yetersizliği görülen alanlarda bor gübrelemesi yapılması pancar ve şeker verimini olumlu yönde etkilemesi beklenmektedir. Ülkemiz şeker pancarı ekim alanları bor durumuyla ilgili çok az çalışma bulunmaktadır. Gezgin ve ark. (1999) Konya Ovasında yaptıkları çalışmada şeker pancarı ekim alanlarının %52'sinde borun noksan olduğunu tespit etmişlerdir. Özgür (2015) de şeker pancarı ekim alanlarının %26,6'sının borca yoksul olduğunu bildirmiştir. Çolak ve ark. (2013) Çarşamba Ovası pancar ekim alanlarının %63,6'sında, Bafra Ovasının ise %33,0'ünde bor noksanlığı olduğunu belirtmişlerdir.

Şeker pancarı bor gübrelemesiyle ilgili dünyada ve ülkemizde pek çok çalışma yapılmıştır. Dünyada yapılan çalışmaların bazılarında bor gübrelemesi, şeker pancarının verim ve kalitesine olumlu katkı yaparken (Dewdar ve ark., 2015; Kristek ve ark., 2006; Mekdad & Shabaan, 2020) bazılarında etki görülmemiştir (Cattanach, 1991; Giles ve ark., 1991). Bor gübrelemesiyle ilgili yapılan çalışmalarda birbiriyle uyumlu olmayan sonuçlarla karşılaşılabilmektedir. Bor gübrelemesinin olumlu etkisinin görüldüğü bir lokasyonda (Voth ve ark., 1979) belirli sure sonra yapılan başka bir çalışmada etki görülmeyebilmektedir (Chiristenson ve ark., 1991). Ülkemizde yapılan çalışmalarda da benzer olumlu ve olumsuz sonuçlar bulunmaktadır. Gezgin ve ark. (2001) elverişli bor kapsamı 0,55 mg kg^{-1} olan kireçli toprakta yaptığı çalışmada pancar kök verimi, şeker varlığı ve arıtılmış şeker oranının 300 g da^{-1} bor uygulamasında arttığını, 600 g da^{-1} dozunda ise önemli ölçüde azaldığını bildirmişlerdir. Yine Gezgin ve ark. (2007) üç farklı lokasyonda yaptıkları çalışmada 300-450 g da^{-1} bor uygulamasının pancar verimini artırdığını, özellikle bor kapsamı yeterli düzeyde olan lokasyonda 600 g da^{-1} bor uygulamasında verimin düştüğü, şeker varlığında ise verime bağlı artış ve azalışların olduğunu ifade etmişlerdir. Durak ve Ulubaş (2017), yarayışlı bor kapsamı 0.46 mg kg^{-1} olan kireçli toprakta yaptıkları çalışmada bor uygulamasının şeker pancar kök verimini artırdığını, şeker varlığını ise etkilemediği tespit etmişlerdir.

Ülkemizde yapılan çalışmalar genel olarak orta ve yeterli düzeyde bor kapsamı olan topraklarda yapıldığı görülmektedir. Topraktaki borun yarayışlığını toprak pH'sı, tekstür, organik madde, kireç, nem, sıcaklık ve diğer besin maddeleriyle ilişkiler etkilemektedir (Emir, 2017). Şeker pancarı ekim alanlarımızın bor durumunun yöresel olarak belirlenerek noksan alanlar için gübreleme önerileri amaçlı tarla denmelerinin yapılması önem arz etmektedir. Bu araştırmanın amacı; saha çalışmasıyla, ağırlıklı olarak kahverengi, kireçsiz kahverengi ve alüvyon toprak tiplerin hakim olduğu Kahramanmaraş-Elbistan yöresinde yetiştirilen şeker pancarının bor (B) beslenme durumunu tanımlamak ve bor uygulamasının tarla koşullarında şeker pancarın verim ve kalite değerleri üzerine etkisini belirleyerek gübreleme önerilerine katkı yapmaktır.

Yöntem

Saha Çalışması

Tarla denemelerine başlamadan önce Doğu Anadolu Bölgesi Batı Fırat Bölümünde (Elbistan Şeker Fabrikası ekim sahası) bor noksanlığının tespiti amacıyla şeker pancarı ekim alanlarında 2016–2017 vejetasyon döneminde saha çalışması yapılmıştır. Afşin, Elbistan, Göksun ve Tufanbeyli ilçelerinde 40 farklı çiftçi tarlasından toprak, bitki ve pancar örneği alınmıştır. Bitki örnekleri temmuz ayı ortasında, toprak ve pancar örnekleri hasattan sonra alınmıştır. Toprak örneklerinde pH, kireç, organik madde, bitkilerce alınabilir magnezyum ve bor, bitki ve pancar örneklerinde ise toplam bor analizleri yapılmıştır. Çalışmanın yapıldığı yörede ağırlıklı olarak kahverengi toprak (%40,4) hakim olup kireçsiz kahverengi, kırmızımsı kahverengi ve alüvyon toprak tipleri de yaygındır (Esen, 2014).

Tarla Denemeleri

Tarla denemeleri için Elbistan Şeker Fabrikası üretim tarlaları seçilmiştir. Kahramanmaraş ili Elbistan ilçesi Hasankendi köyü mevkiinde yürütülen deneme vejetasyon süresince 2018 yılında 384,4 mm, 2019 yılında ise 436,0 mm toplam yağış almıştır.

Ekim öncesi kahverengi toprak grubunda olan deneme alanlarından 0–30 cm derinlikli toprak örnekleri alınmıştır. Toprak örneklerinde yapılan verimlilik analiz sonuçlarına göre (Tablo 1) denemenin kurulduğu alanlarda (Elbistan) tuzluluk problemi bulunmamakta,

Tablo 1.
Deneme Alanından Ekim Öncesi Alınan Toprak Örneklerinin Bazı Fiziksel ve Kimyasal Özellikleri

Toprak Özelliği	Yöntem	Birim	Bulunan Değerler	
			2018	2019
Tekstür sınıfı	Bouyoucos (1951)	-	Tın	Tın
Kil	-	%	24,7	23,0
Silt	-	%	32,8	31,8
Kum	-	%	42,5	45,2
Kireç ($CaCO_3$)	Hızalan ve Ünal (1966)	%	21,1	25,9
Elektriksel iletkenlik (EC)	Jackson (1962)	dS m^{-1}	915	803
pH 1:2,5 (toprak: su)	Jackson (1962)	-	8,4	8,3
Organik madde	Jackson (1962)	%	2,1	2,0
Alınabilir fosfor	Olsen ve ark. (1954)	mg kg^{-1}	22,5	24,0
Alınabilir K_2O	Knowels and Watkin (1967)	mg kg^{-1}	90,0	107,0
Bitkiye yarayışlı SO_4	$Ca(H_2PO_4)_2H_2O$	mg kg^{-1}	54,0	52,0
Alınabilir Mg	Jackson (1962)	mg kg^{-1}	716,0	700,0
Bitkiye yarayışlı Zn	Lindsay and Norvell (1978)	mg kg^{-1}	0,7	0,8
Bitkiye yarayışlı bor (B)	Sıcak su	mg kg^{-1}	0,34	0,23

toprak pH'sı ise orta alkali reaksiyon göstermektedir. Çok kireçli sınıfta olan deneme alanı topraklarının organik madde kapsamı az, alınabilir fosfor ve potasyum kapsamı orta düzeydedir. Kükürt, magnezyum ve çinko sorunu bulunmayan sahanının bor kapsamı ise düşük sınıftadır.

Konuların tamamına toprak analiz sonucuna göre iki yılda da 16 kg da^{-1} N, 8 kg da^{-1} P_2O_5 ve 4 kg da^{-1} K_2O verilmiştir. Bu amaçla gübrelemede 12-30-12 kompoze gübresi kullanılmış, bakiye azot üre (%46 N) ile tamamlanmıştır. Azotlu gübrenin yarısı ile fosfor ve potasyumun tamamı ekim öncesi bor uygulamasıyla beraber parsellere verilmiştir. Azotun diğer yarısı ise 2. çapa önüne verilerek çapayla toprağa karıştırılmıştır. Ekim öncesi toprak yüzeyine elle homojen olarak parsellere verilen boraks diğer gübrelerle birlikte kombi kürümler kullanılarak 8–10 cm derinliğe karıştırılmıştır.

Tarla denemeleri Tesadüf blokları deneme deseninde 3 tekerrürlü olarak kurulmuştur**.** Deneme konuları; kontrol (bor uygulanmamış), 150 g B da^{-1}, 300 g B da^{-1}, 450 g B da^{-1} ve 600 g B da^{-1} uygulama dozlarından oluşmuştur. Doz aralığı ve miktar belirlemede daha önce yapılan çalışmalar, ülkemiz şeker pancarı bor gübrelemesi doz önerisi (Er ve ark., 2017) ve toprak analiz sonucu dikkate alınmıştır. Bor uygulaması için %11,35'lik boraks ($Na_2B_4O_7.10H_2O$) kullanılmıştır. Teknik sınıfta ve toz yapıda olan boraks (BORAKS DEKAHİDRAT) ETİMADEN'den temin edilmiştir.

Ekimler, *Rhizomania* ve *Cercospor*a hastalıkların toleranslı Serenada KWS şeker pancarı (*Beta vulgaris* L.) çeşidiyle yapılmıştır. Ekim parseli büyüklüğü; 4,50 (10 sıra) × 10,00 m = 45 m², hasat parseli; 2,70 (6 sıra) × 7,4 m = 20 m² olarak belirlenmiştir. Ekim, hassas pancar mibzeriyle sıra arası mesafe 45 cm, sıra üzeri 8 cm olacak şekilde yapılmıştır. Sıra üzere mesafe 20 cm olacak şekilde tekleme ve seyreltme yapılarak hasat için parselde 220 bitki bırakılmıştır.

Pancar ekimi; 1.yıl 25.04.2018 tarihinde, 2. yıl 20.04.2019 tarihinde gerçekleştirilmiştir. Her iki yılda da gerekli bakım işlemleri zamanında aksatılmadan yapılmış, şeker pancarının verim ve kalitesini etkileyecek önemli bir hastalık veya zararlı ile karşılaşılmamıştır. Her iki yılda da 6 kez yağmurlama şeklinde ile sulama yapılmıştır.

Bitkilerin makro ve mikro besin maddeleri açısından beslenme durumlarını belirlemek üzere yaprak örnekleri alınmıştır (Ulrich ve ark., 1959). Alınan yaprak örneklerinin ayaları saplarından ayrıldıktan sonra aya ve saplar ayrı ayrı kâğıt torbalar içerisine konularak hiç zaman kaybetmeden laboratuvara getirilmiştir. Alınan aya örnekleri, laboratuara getirildikten sonra yıkanarak gerekli temizleme işlemleri yapılmış, 65–70°C'de kurutulmuş, paslanmaz çelik değirmende öğütülerek analize hazırlanmış ve bordan ari küçük cam şişelerde korunmuştur (Ulrich ve ark., 1959). Şeker pancarı yaprak ayası ve pancar kökü B kapsamı Milestone Plus mikrodalga ekstraksiyon cihazı ile elde edilen ekstraktlarda, Perkin Elmer 4300 DV marka ICP OES cihazı ile belirlenmiştir (Kacar & İnal, 2008).

Fizyolojik olgunluğa erişen şeker pancarı 1. yıl 24.10.2018 tarihinde 2. yıl 20.10.2019 tarihinde hasat edilmiştir. 10,00 (1,35 m × 7,41 m) m²'lik hasat parseli alanındaki pancarların hasadı sökme beli kullanılarak el ile yapılmıştır. Parsellerden alınan pancarların tamamı bez torbalara konarak Şeker Enstitüsü laboratuarlarına taşınmıştır. Laboratuarda pancar kök verimi her parsel için ayrı ayrı belirlendikten sonra, hasat parsellerinden alınan pancarların tamamı frezeden geçirilerek elde edilen kıyımdan alınan örneklerde soğuk digestion yöntemine göre şeker varlığı (ICUMSA, 2003), α-amino azotu kapsamı (Kubadinow & Wieninger, 1972), sodyum ve potasyum kapsamı (Kubadinow, 1972) belirlenmiştir. Arıtılmış şeker varlığı (AŞV) = ŞV-{0.343 (Na+K)+(0.094 a-aminoN)+0.29} formülü (Reinefeld ve ark., 1974), arıtılmış şeker verimi (AŞVE) = AŞV × kök verimi/100 eşitliği ile belirlenmiştir.

İstatistiksel Analiz

Alan çalışmalarında toprakların bor kapsamı ile yaprak ayası ve pancar kökü bor kapsamaları arasındaki ilişkiye belirlemek için doğrusal regresyon analizleri yapılmıştır. Tarla denemeleri tesadüf blokları deneme deseninde ve üç tekrarlamalı olarak tasarlanmıştır. Elde edilen veriler varyans analizine tabi tutulmuştur (Minitab, 1995). Uygulamalar arasındaki farkların belirlenmesinde, LSD (asgari önem fark) çoklu karşılaştırma testi uygulanmıştır.

Bulgular

Saha Çalışmaları Sonucu

Doğu Anadolu Bölgesi Yukarı Fırat Bölümünde bulunan Elbistan Şeker Fabrikasına (Kahramanmaraş) ait pancar ekim bölgeleri olan Afşin, Elbistan, Göksun ve Tufanbeyli ilçelerinden toplan 40 adet toprak ve yaprak örneklerinin bor (B) durumuna ait sonuçlar Tablo 2'de sunulmuştur.

Alınan 40 adet toprak örneğinin alınabilir bor (B) kapsamı 0,12 mg kg^{-1} ile 1,49 mg kg^{-1} arasında değişmiş, ortalama ise 0,37 mg kg^{-1} olmuştur. Şeker pancarı bor noksanlığının en ayırt edici noksanlık belirtisi olan "pancar göbek çürüklüğü" toprakların alınabilir bor kapsamının 0,35–0,40 mg kg^{-1}'dan düşük olduğu alanlarda ortaya çıkmaktadır (Draycott & Christenson, 2003). Ancak toprakların alınabilir bor kapsamı için kritik değer 0,50 mg kg^{-1} olarak belirlenmiştir. Bu değer üzerindeki alanlarda yetişen şeker pancarında bor noksanlığından kaynaklanan yaprak, kök veya şeker verimi ile ilgili herhangi bir kayıp yaşanmadığı belirtilmekle beraber bazı araştırıcılar; sulama sıkıntısı olan yerlerde alınabilir bor kapsamının 0,95 mg kg^{-1} değerinin altındaki şeker pancarı ekim alanlarına bor gübrelemesi yapılması gerektiğini ifade etmektedirler (Fürstenfeld & Bürcky, 2000). Elbistan Şeker Fabrikası pancar ekim alanlarında sulama sorununun bulunmadığı göze alındığında bölge topraklarının %85'inde bor noksanlığı olduğu görülmektedir.

Birçok araştırıcı tarafından toprakların alınabilir bor kapsamı ile toprakların pH'sı, kireç, organik madde ve magnezyum kapsamları arasında olumlu veya olumsuz ilişki olduğunu belirtilmesine rağmen bölge topraklarında yapılan çalışmada benzer ilişkiler kurulamamıştır (Akın, 2009; Gezgin ve ark., 2007).

Şeker pancarı yaprak aya örneklerinin bor (B) kapsamı 26,0 mg kg^{-1} ile 92,0 mg kg^{-1} arasında değişmiş, 40 adet örneğe ait ortalaması ise 50,0 mg kg^{-1} olarak belirlenmiştir (Tablo 2). Şeker pancarı bor noksanlık tespitinde en uygun yöntem; bitki yaprak ayası bor kapsamının belirlenmesi olup yaprak sap ve pancar kök örnek değerleri iyi bir gösterge olarak kabul edilmemektedir (Draycott & Christenson, 2003). Yaprak ayası analiz sonuçlarının değerlendirilmesinde araştırıcılar, bitki örmeği alım dönemini dikkate alarak farklı referans değerleri sunmuşlardadır. Noksanlık belirtisinin görülmediği sınır değeri; Eaton (1944) ağustos-eylül aylarında alınan yaprak aya örneklerinde 20–35 mg B kg^{-1}, Christenson ve ark. (1991) ise ekimden sonra 12. haftada alınan yaprak aya örneklerinde 34 mg B kg^{-1} olarak belirtmişlerdir. Bu çalışmada olduğu gibi temmuz ayı ortasında alınan örneklerde sınır değer, Kluge (1990) tarafından 55 mg B kg^{-1} olarak bildirilmiştir. Kluge (1990)'nin değerleri dikkate alındığında Elbistan Şeker Fabrikası ekim alanı içindeki dört bölgeden alınan 40 örneğin %75'inde şeker pancarı yaprak ayası bor kapsamı yeterli düzeyin altında bulunmuştur. Tablo 3'de görüleceği gibi bitkilerin yaprak ayası toplam bor kapsamı ile toprakların alınabilir bor kapsamı arasında önemli pozitif ilişki tespit edilmiş ve $r = 0{,}7611^{***}$ olarak hesaplanmıştır ($y = 57{,}3703x + 29{,}0349$).

Bor Uygulamasının Tarla Koşullarında Etkisi

Şeker pancarına artan seviyelerde uygulanan borun, şeker pancarı yaprak ayası bor kapsamını önemli düzeyde artırmıştır. Tablo 4'de görüleceği gibi kontrolde 49,16 mg kg^{-1} olan yaprak ayası bor kapsamı, bor uygulamalarının bütün seviyelerinde önemli ölçüde artmış, 150 g B da^{-1} uygulama seviyesinde 61 mg kg^{-1} olarak tespit edilmiştir. Diğer uygulama seviyelerinde 150 g B da^{-1} uygulama seviyesine göre kısmi bir düşüş eğilimi olsa da bütün uygulamalar aynı istatistiki grupta yer almışlar ve aralarındaki fark anlamlı bulunmamıştır. Yaprak ayası bor kapsamı 300 g B da^{-1} uygulamasında 60,13 mg kg^{-1}, 450 g B da^{-1} uygulamasında 59,11 mg kg^{-1} ve 600 g B da^{-1} uygulamasında 57,64 mg kg^{-1} olarak tespit edilmiştir. Bor uygulaması yapılan konularının yaprak ayası bor kapsamları, şeker pancarı için kritik değer kabul edilen 55 mg B kg^{-1} değerinin üstünde tespit edilmiştir (Kluge, 1990). Bor uygulaması yapılmayan kontrol parsellerden alınan örneklerin bor kapsamı ise deneme alanı toprakları bor kapsamının her iki yılda da toprak sınır değeri olan 0,40 mg B kg^{-1}'nin altında olmasına bağlı olarak yaprak ayası kritik seviyesinin altında bulunmuştur (Draycott & Christenson, 2003). Bu sonuçlar şeker pancarının bor gübrelemesine olumlu tepki verdiğini ve bitkinin topraktan verilen boru bünyesine sorunsuz şekilde aldığının bir göstergesi olarak değerlendirilebilir. Gezgin ve ark. (2007) tarafından yapılan çalışmada da benzer bulgular elde edilmiştir. Ancak çalışmada 150 g B da^{-1} ve daha yüksek bor düzeyleri arasında bitki bor kapsamı açısından anlamlı bir fark oluşmaması bitkinin daha yüksek miktarlarda verilen boru bünyesine artan oranlarda almadığını göstermektedir.

Şeker pancarı kökü bor kapsamı, uygulanan bor seviyelerinden etkilenmemiş ve seviyeler arasındaki farklar önemli bulunmamıştır ($p > ,5$). Kontrol parsel örneklerinde 16,02 mg kg^{-1} olan bor kapsamı, uygulama seviyelerinde 16,86–22,58 mg kg^{-1} arasında değişmiştir (Tablo 4). Şeker pancarı kökü bor kapsamı 15 mg kg^{-1} üzerinde olması durumunda bitkide noksanlık belirtilerinin görülmediği bildirilmektedir (Draycott, 2006). Ancak Draycott and Christenson (2003) tarafından şeker pancarı kökü bor kapsam sonuçlarının noksanlık belirlemede her zaman doğru sonuç vermemesi nedeniyle değerlendirmelerde kullanılmaması gerektiği açıklanmıştır.

Tarla koşullarında topraktan yapılan bor gübrelemesinin şeker pancarına ait pancar verimi, şeker varlığı, zararlı azot, sodyum, potasyum kapsamı, arıtılmış şeker varlığı ve arıtılmış şeker verimi üzerine etkisini gösteren iki yıllık birleştirilmiş varyans analiz değerleri Tablo 5'de verilmiştir.

Şeker pancarı kök verimi uygulanan bora tarla koşullarında önemli ölçüde tepki vermiştir. Bütün uygulamalarda istatistiki olarak %5 ($p > ,5$) önemlilik düzeyinde kontrole göre artış gözlenmiştir. Uygulamalar arasındaki farklar önemli olmamakla birlikte kontrole göre en yüksek verim artışı 450 g B da^{-1} uygulamasından elde edilmiştir. Bu uygulamada; kontrole göre %12,7 artış görülmüş ve pancar kök verimi 7223 kg da^{-1}'dan 8137 kg da^{-1}'a yükselmiştir. Diğer uygulamalar, 450 g B da^{-1} uygulaması ile aynı grupta yer almışlar ve aralarında istatistiki bir fark oluşmamıştır. Pancar kök verimleri 150 g B da^{-1} uygulamasında 8057 kg da^{-1}, 300 g B da^{-1} uygulamasında 8065 kg da^{-1} ve 600 g B da^{-1} uygulamasında kg da^{-1} olmuş, kontrole göre artışlar ise sırasıyla %11,6, %12,7 ve %9,0 olarak gerçekleşmiştir (Çizelge 5). İki yıllık verilere göre borca yoksul olan deneme alanında artan seviyelerde uygulanan bor şeker pancarı kök verimini bor uygulaması yapılmayan kontrole göre %9,0–12,7 oranında artırmıştır. Şeker pancarı kök verimine bor uygulamasının olumlu katkısına ait benzer sonuçlar birçok araştırıcı tarafından ortaya konulmuştur (Abdel-Nasser & Ben Abdalla, 2019; Gezgin ve ark., 2007; Kristek ve ark., 2006; Mekdad & Shabaan, 2020). Bor, yeni yaprak oluşumu için hücre çoğalmasında ve yapraklarda oluşan asimilasyon ürünlerinin depo organlarına taşınmasında görev almaktadır (Marschner, 2012). Bor noksanlığı çeken bitkilerin yaprakları daha küçük, sert ve kalın olması

Tablo 2.
Kahramanmaraş Elbistan Bölgesinden Alınan Toprak Numunelerine Ait pH, Kireç, Organik Madde, Alınabilir Mg, Alınabilir B ve Yaprak Ayası B Değerleri

Örnek No	Yer	pH	Kireç (%)	O. madde (%)	Alınabilir Mg (%)	Alınabilir B (mg kg⁻¹)	Yaprak ayası B (mg kg⁻¹)
1	Afşin	8,1	21,1	1,77	0,123	0,82	90,0
2		8,4	21,8	1,35	0,103	0,60	87,0
3		8,0	16,2	1,31	0,186	1,02	77,0
4		8,4	13,6	1,48	0,055	0,21	51,0
5		7,7	3,4	1,58	0,058	0,18	34,0
6		8,4	16,9	1,42	0,037	0,30	36,0
7		7,9	2,6	2,01	0,087	0,22	36,0
8		8,4	24,0	1,64	0,083	0,24	39,0
9		8,2	26,7	2,20	0,054	0,29	36,0
10		8,5	28,6	2,00	0,048	0,20	52,0
11		8,1	19,2	2,00	0,087	0,39	48,0
12		8,5	21,1	1,35	0,055	0,16	30,0
13		8,2	20,5	1,31	0,042	0,27	40,0
14		8,4	30,9	2,67	0,059	0,29	41,0
15		8,3	22,9	2,10	0,077	0,33	44,0
16	Göksun	8,2	13,5	2,80	0,026	0,20	29,0
17		8,0	3,9	1,51	0,022	0,17	26,0
18		8,3	17,6	2,82	0,026	0,21	31,0
19		8,2	4,3	1,97	0,035	0,17	43,0
20		8,3	25,8	1,81	0,016	0,17	32,0
21	Elbistan	8,3	27,9	2,00	0,079	0,23	45,0
22		8,2	12,4	2,86	0,133	1,49	92,0
23		8,5	27,6	2,30	0,077	0,33	54,0
24		8,1	27,1	1,98	0,091	0,42	52,0
25		8,5	15,9	2,67	0,058	0,50	50,0
26		8,5	14,5	1,42	0,073	0,81	85,0
27		8,3	35,5	1,97	0,068	0,39	73,0
28		8,6	41,8	2,14	0,070	0,26	36,0
29		8,6	31,8	1,97	0,091	0,24	35,0
30		8,6	13,6	2,53	0,059	0,45	82,0
31		8,1	30,6	2,20	0,105	0,42	74,0
32		8,5	35,5	2,30	0,067	0,32	42,0
33		8,6	16,1	2,23	0,075	0,40	63,0
34		8,5	40,2	2,01	0,080	0,29	85,0
35		8,4	41,1	2,24	0,159	0,39	46,0
36	Tufanbeyli	8,4	5,5	2,01	0,042	0,12	27,0
37		8,3	4,4	2,24	0,044	0,23	33,0
38		8,5	8,9	2,17	0,042	0,17	28,0
39		8,5	16,3	2,73	0,072	0,38	44,0
40		8,4	12,9	1,94	0,122	0,32	51,0
Ortalama		**8,3**	**20,36**	**2,03**	**0,072**	**0,37**	**50,0**
En az		**7,7**	**2,60**	**1,31**	**0,016**	**0,12**	**26,0**
En çok		**8,6**	**41,80**	**2,86**	**0,186**	**1,49**	**92,0**

Tablo 3.
Toprakta Alınabilir Bor Kapsamı ile Toprak pH, Kireç, Organik Madde, Alınabilir Mg ve Yaprak Ayası B Arasındaki Regresyon Analizleri ve Korelasyon Katsayıları

Parametreler	Eşitlikler	r
Toprak alınabilir B kapsamı-Toprak pH'sı	$y = {}^{-}0{,}1712x + 1{,}7881$	$^{-}0{,}1332^{öd}$
Toprak alınabilir B- Toprak kireç kapsamı	$y = {}^{-}0{,}0003x + 0{,}3716$	$^{-}0{,}0018^{öd}$
Toprak alınabilir B- Toprak organik madde kapsamı	$y = {}^{-}0{,}0418x + 0{,}2804$	$^{-}0{,}0699^{öd}$
Toprak alınabilir B- Alınabilir magnezyum kapsamı	$y = 0{,}0005x + 0{,}0169$	0,6621...
Toprak alınabilir B- Yaprak ayası B kapsamı	$y = 57{,}3703x + 29{,}0349$	$0{,}7611^{***}$

Not: Korelasyon önemlilik seviyesi: *$p < ,05$. **$p < ,01$. ***$p < ,001$. öd: önemli değil. n-1 = 39

nedeniyle (Nemeata Alla, 2017) asimilasyon olumsuz etkilenmektedir. Bor uygulaması yapılan 150 g B da^{-1} konusu ve üzerindeki konuların yaprak ayası bor kapsamları (Tablo 4), şeker pancarı için kritik değer kabul edilen 55 mg B kg^{-1} değerinin (Kluge, 1990) üstünde tespit edilmiş ve pancar kök verimindeki artış bor noksanlığının giderilmesiyle ilişkilendirilmiştir. En düşük doz olan 150 g B da^{-1} uygulamasıyla bitkinin gereksinimi olan miktarın tamamının karşılanmasına bağlı olarak 300 g B da^{-1}, 450 g B da^{-1} ve 600 g B da^{-1} dozlarında verim artışı olmadığı düşünülmektedir. Ayrıca deneme sonuçlarına göre en yüksek uygulama dozu olan 600 g B da^{-1} uygulaması sonucu kök veriminde bir azalış olmamış ve bor toksititesiyle karşılaşılamamıştır.

Artan miktarda uygulanan bor seviyeleri şeker varlığında (digestion) artışa neden olmuş ancak bu artış istatistiksel olarak anlamlı bulunmamıştır ($p > ,05$, Tablo 5). Deneme konularında şeker varlıkları %14,48–15,02 arasında oluşmuştur. İstatistiki olarak önemli düzeyde olmayan artışlar kontrole göre %2,1–3,7 arasında değişmiştir. Benzer sonuçlar Durak ve Ulutaş (2017) tarafından da gözlemlenmiştir. Bor uygulamasının şeker varlığını artırmasına ilişkin araştırmalarda mevcuttur (Abbas ve ark., 2014; Abdel-Nasser & Ben Abdalla, 2019; Dewdar ve ark., 2015; Enan, 2016; Kristek ve ark., 2006). Ancak bor uygulamalarının şeker varlığını artırdığı belirtilen çalışmalarda şeker pancarı kök veriminin de artığı bildirilmekte ve uygulamaların hem şeker varlığını hem de kök verimini aynı anda nasıl artırdığı ile ilgili bilgi verilmemektedir. Bu çalışmada uygulamaların şeker varlığında anlamlı artışlar olmamasına; Gezgin ve ark. (2007)'nin belirttiği gibi pancar kök verimindeki önemli artışlar neden olmuş olabilir. Çünkü şeker pancarı kök verimi ile şeker varlığı arasında negatif ilişki bulunduğu bilinmektedir (Draycott & Christenson, 2003; Tayfur ve ark., 2008). Bazı araştırıcılar ise bor gübrelemesinin şeker varlığını azatlığını (Gezgin ve ark., 2001) belirtmektedirler. Çalışmada şeker pancarı kök verimindeki artışa rağmen şeker varlığında azalma olmaması bor uygulamasının olumlu etkisi olarak varsayılabilir.

Şeker pancarı kalite ölçütlerinden olup şekerin fabrikasyonunda alımını etkileyen ve düşük olması beklenen melas yapıcı maddelerden şeker pancarı kökü sodyum, potasyum ve zararlı azot (α-amino azot) değerleri üzerine; artan seviyelerde uygulanan bor miktarları istatistiki olarak önemli olmayan etkiye neden olmuştur. Uygulanan bor seviyeleri şeker pancarı kökü potasyum ve zararlı azot kapsamlarında anlamlı olmayan düşüşe, sodyum kapsamında ise artışa neden olmuştur. Denemede şeker pancarı kökü potasyum kapsam 5.20–5.63 mmol 100 g^{-1} pancar, zararlı azot 2.88–3.23 mmol 100 g^{-1} pancar arasında değişirken sodyum kapsamı 3.33–4.16 mmol 100 g^{-1} pancar arasında değişmiştir (Tablo 5). Değişik araştırıcıların elde ettiği sonuçlar bu çalışma ile farklılık göstermektedir. Enan ve ark. (2016) bor uygulamasının şeker pancarı kökü potasyum ve zararlı azot kapsamını etkilemediğini ancak sodyum kapsamını azalttığını belirtmişlerdir. Nemeata Alla (2017) ise bor gübrelemesinin sodyum ve potasyum kapsamını düşürmesine rağmen zararlı azot kapsamını artırdığını bildirmektedir. Yine çalışmada şeker varlığında olduğu gibi pancar kök veriminin artmasına rağmen safiyet bozucu maddelerde (α-amino N, K ve Na) anlamlı artış olmaması bor uygulamasının olumlu etkisi olarak düşünülebilir. Çünkü şeker pancarında kök verimi ile safiyet bozucu maddeler arasında da pozitif ilişki bulunmaktadır (Draycott, 2006; Pişkin & İnal, 2014).

Tablo 4.
Farklı Bor Uygulamalarının Yaprak Ayası ve Pancar Kökü Bor Kapsamı Üzerine Etkisine Ait İki Yıllık Birleştirilmiş Analizi

Konular		Yaprak Ayası B Kapsamı mg kg^{-1}	Pancar Kökü B Kapsamı mg kg^{-1}
0 g B da^{-1} uygulaması (kontrol)		49,16b	16,02
150 g B da^{-1}		61,00a	16,86
300 g B da^{-1}		60,13a	20,87
450 g B da^{-1}		59,11a	18,52
600 g B da^{-1}		57,64a	22,58
Varyasyon Kaynakları	**Serbestlik Derecesi**		
Tekerrür	2	öd	öd
Yıllar	1	*	öd
Doz	4	*	öd
Yıl x Doz	4	öd	öd
Hata	18	-	-
Genel	29	-	-

Not:*$p < ,05$, öd: önemli değil

Tablo 5.
Farklı Bor Uygulamalarının Şeker Pancarı Verim ve Kalite Üzerine Etkisi Ait İki Yıllık Birleştirilmiş Analizi

Konular		Pancar Kök Verimi (kg da^{-1})	Şeker Varlığı (%)	Sodyum (mmol 100 g^{-1})	Potasyum (mmol 100 g^{-1})	Zararlı Azot (mmol 100 g^{-1})	Arıtılmış Şeker Varlığı (%)	Arıtılmış Şeker Verimi (kg da^{-1})
0 g B da^{-1} uygulaması (kontrol)		7 223b	14.48	3.33	5.63	3.23	10.81	781b
150 g B da^{-1}		8 057a	14.78	4.43	5.24	3.21	10.97	884a
300 g B da^{-1}		8 065a	14.86	4.16	5.20	3.02	11.08	894a
450 g B da^{-1}		8 137a	15.02	3.39	5.48	3.10	11.40	927a
600 g B da^{-1}		7 873a	14.87	3.50	5.42	2.88	11.25	886a
Varyasyon Kaynakları	**Serbestlik Derecesi**							
Tekerrür	2	öd	öd	öd	öd	öd	öd	öd
Yıllar	1	öd	öd	öd	öd	öd	öd	öd
Doz	4	*	öd	öd	öd	öd	öd	*
Yıl *Doz	4	öd	öd	öd	öd	öd	öd	öd
Hata	18	-	-	-	-	-	-	-
Genel	29	-	-	-	-	-	-	-

Not: *p < ,05, öd: önemli değil

Arıtılmış şeker varlığı; şeker varlığı, zararlı azot, sodyum ve potasyum değerlerinden hesapla elde edilmekte olup verilen değerlerin artış veya azalışından etkilenmektedir. Bu nedenle Tablo 5'de görüldüğü gibi artan seviyede uygulanan bor dozların arıtılmış şeker varlığına yaptığı olumlu etki, şeker varlığında olduğu gibi istatiksel olarak anlamlı olmamıştır. Denemeden elde edilen arıtılmış şeker varlıkları %10,81–11,40 arasında değişmiş, anlamlı olmamakla birlikte kontrole göre de %1,5–5,5 arasında artış görülmüştür. Durak ve Ulubaş (2017) benzer bulgular elde etmelerine rağmen Gezgin ve ark. (2001) yaptıkları çalışmada bor gübrelemesinin pancar çıkışını olumsuz etkileyerek bitki sıklığını azaltması sonucu arıtılmış şeker varlığının düştüğünü bildirmişlerdir.

Bor uygulamaları, pancar kök verimi ile arıtılmış şeker varlığından hesapla elde edilen arıtılmış şeker verimi üzerine güçlü pozitif etki yapmış ve önemli artışa neden olmuştur (p < ,05). Kontrol parselinden 781 kg da^{-1} arıtılmış şeker verimi alınırken 150 g da^{-1} bor uygulamasından 884 kg da^{-1}, 300 g da^{-1} bor uygulamasından 894 kg da^{-1} alınmıştır. 450 g da^{-1} bor uygulamasında ise 927 kg da^{-1} şeker verimine ulaşılmıştır. Denemede en yüksek doz olan 600 g da^{-1} bor uygulamasında ise arıtılmış şeker veriminde istatistiki olarak anlamlı olmamakla birlikte bir miktar düşüş olmuş ve 886 kg da^{-1} olarak belirlenmiştir. Kontrole göre oransal artış 450 g B da^{-1} uygulamasında %18,7 seviyesinde olmuştur. 150 g da^{-1} bor seviyesinde %13,2, 300 g B da^{-1} seviyesinde %14,5, 600 g B da^{-1} seviyesinde ise %13,4'lük artışlar olmuştur. Ancak bor uygulama dozlarının etkisiyle arıtılmış şeker veriminde görülen önemli olumlu artışlar kendi aralarında bir fark oluşturmayarak aynı istatistiki grupta yer almışlardır (Tablo 5). Çalışma sonucuyla uyumlu olarak pek çok araştırıcı bor uygulamasının arıtılmış şeker verimini artırdığını bildirmişlerdir (Dewdar ve ark., 2015; Gezgin ve ark., 2007; Kristek ve ark., 2006; Mekdad & Shabaan, 2020). Şeker pancarı kalite değerlerinden şeker varlığı ile safiyet bozucu maddeler olan sodyum, potasyum ve zararlı azot(α-amino azot) kapsamına bor uygulamalarının olumsuz bir etkisinin olmamasına bağlı olarak pancar verimindeki artışlar, arıtılmış şeker veriminin kontrole göre anlamlı şekilde artmasına neden olmuştur.

Sonuç ve Öneriler

Bitki besin maddelerinin tarım topraklarında azalışının ana nedeni bitkisel üretimdir. Bitki tarafından alınan besin maddeleri gübreleme yoluyla karşılanmazsa denge bozulmaktadır. Buna bağlı olarak da toprağın üretim kapasitesi düşmesi sonucu bitkilerin verimi düşmekte ürünün kalitesi bozulmaktadır. Son yıllarda bitkisel üretimin azot, fosfor ve potasyumlu kimyasal gübre kullanımıyla artacağı inancı hakimdir. Bu da mikro besin elementlerinin bitkisel üretimdeki öneminin gözden kaçmasına neden olabilmektedir. Şeker pancarı üretim alanlarında verim ve kaliteyi sınırlandıran mikro elementlerden bora yeterli önem verilmemektedir. Yapılan çalışmada şeker pancarı üretiminde önemli bir yere sahip olan Kahramanmaraş Elbistan yöresi topraklarında önemli derecede bor noksanlığı tespit edilmiştir. Yine bölgede yetiştirilen şeker pancarında bor noksanlığının yaygın olduğu ve topraktaki noksanlık ile bitkideki noksanlık arasında yüksek pozitif ilişki olduğu ortaya konulmuştur.

Yapılan tarla denemelerinde bor gübrelemesinin şeker pancarı kök verimi ve arıtılmış şeker verimini önemli ölçüde artırdığı ortaya konulmuştur. Kahramanmaraş Elbistan yöresine benzer iklim ve toprak özelliklerine sahip, bor bakımından yoksul şeker pancarı ekim alanlarında minimum 150 g da^{-1} bor gübrelemesi yapılmasının şeker pancarı kök verimi ve arıtılmış şeker verimini artıracağı görülmektedir. Ancak gübreleme yapılırken şeker pancarından sonra ekilecek bitki göz önünde bulundurulmalıdır. Fazla bor uygulaması bora hassas bitkilere toksik etki yapabilmektedir.

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Feed Usage and Feeding Practices in Cattle Farms in İspir County of Erzurum Province

Erzurum İli İspir İlçesi Sığırcılık İşletmelerinde Yem Kullanımı ve Sığır Besleme Uygulamaları

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ABSTRACT

The aim of this study was to determine the current situation on feed usage and cattle feeding practices and reveal the concerning problems in cattle enterprises in İspir county of Erzurum Province to suggest solutions for these problems.

For this purpose, a face-to-face survey was conducted with the owners of 394 randomly selected cattle breeders. Data obtained were statistically analyzed using the chi-square independence and frequency analysis test. Results: According to the findings, it was determined that 97.7% of the enterprises made plant production. Silage, which is an important source of roughage, was utilized at a very low level (2.8%) in the county. It was also determined that the breeders generally fed their animals based on their own knowledge and experience. They started offering roughage and concentrate feed to the calves in the fourth week (97.5%) and watering in the third week (98.7%) after birth. It was found that 99.7% of the enterprises initiated pasture grazing in April (95.4%) and animals were grazed in the pasture for more than 5 months.

It was concluded that there is a lack of information about animal feeding among breeders in the county. For this reason, training activities by the relevant institutions, increasing the knowledge and skills of the breeders, and encouraging silage production will benefit the development of the region's livestock production.

Keywords: Cattle, feed usage, feeding practices, forage, silage

ÖZ

Bu çalışmanın amacı, Erzurum ili İspir ilçesindeki sığırcılık işletmelerinde yem kullanımı ve hayvan besleme uygulamalarına ilişkin mevcut durumu belirlemek ve ilgili sorunları ortaya koyarak bu sorunlara çözüm önerileri getirmektir. Metot: Bu amaçla şansa bağlı olarak seçilmiş 394 sığır yetiştiricisiyle yüz yüze anket yapılmıştır. Elde edilen veriler istatistiksel olarak Ki-kare Bağımsızlık testi ve frekans analiz metodu kullanılarak analiz edilmiştir. Elde edilen bulgulara göre yetiştiricilerin %97,7'sinin bitkisel üretim yaptığı saptanmıştır.

Önemli bir kaba yem kaynağı olan silaj ise ilçede çok düşük düzeyde (%2,8) kullanılmaktadır. Yetiştiricilerin yemleme uygulamasını genellikle kendi bilgi ve tecrübelerine göre yaptıkları belirlenmiştir. Yetiştiricilerin buzağılara kaba ve kesif yem vermeye doğumdan sonra dördüncü haftada (%97,5), su vermeye ise üçüncü haftada (%98,7) başladıkları tespit edilmiştir. İşletmelerin %99,7'sinin mera kullandığı, genellikle Nisan ayında (%95.4) meraya çıkıldığı ve 5 aydan daha fazla merada kalındığı belirlenmiştir. Sonuç: İlçede hayvan yemleme ve besleme konularında bilgi eksikliği bulunduğu sonucuna varılmıştır. Bu nedenle ilgili kurumlar tarafından eğitim çalışması yapılması, yetiştiricilerin bilgi ve becerilerinin arttırılması ve silaj üretiminin teşvik edilmesi bölge hayvancılığının kalkınmasına fayda sağlayacaktır.

Anahtar Kelimeler: Sığır, yem kullanımı, besleme, kaba yem, silaj

Introduction

The Eastern Anatolia Region has an important potential in terms of animal production, with its wide and fruitful pastures and plateaus besides quality lands suitable for forage crops cultivation. Although it is the most important region of Turkey in terms of animal husbandry with its potential, it is one of the regions where structural problems are observed the most in animal production.

Livestock production in İspir county of Erzurum province is an important source of livelihood in areas that are unsuitable for growing cultivated plants due to its topographic and climatic conditions. However, this type of animal husbandry is mostly carried out with traditional techniques and is quite simple compared to animal husbandry in developing countries (Akbay & Boz, 2005). Therefore, the only way to survive in today's dairy cattle industry, where competition is severe, is to follow and apply the innovations in the sector. The acceptance and spreading of agricultural innovations are extremely important for the development of agriculture and the society living in rural areas. One of the ways to increase the profit in animal production is to use new technologies that are proved to be effective in reducing the costs of the enterprises. Adoption of new technologies by farmers will help economic profitability in the short-term and improve the living conditions of the society and the sustainability of the sector in the long-term (Boz et al., 2002).

The breeders of the Eastern Anatolia region do not meet the requirements to increase the yield in animal production. In order for the region's enterprise owners to continue their work profitably, it is highly required to give up working with low-yielding breeds that increase the production cost and decrease the quality and to improve the conditions and techniques for livestock production (Koçyiğit et al., 2015).

İspir county is located 143 km north of Erzurum city center and the total area of the county is 22,44 km². There are many large and small mountains at an altitude of between 2400 and 3900 meters within the boundaries of the county. Small and large livestock and plant productions are highly important in the livelihood of the local community (Anonymous, 2021).

According to TÜİK (Turkish Statistical Institute) 2021 first period data, Erzurum province constitutes 5.03% of Turkey's cattle stock with 920,642 animals. With this number, this province is in second place after Konya in terms of cattle population. İspir county constitutes 2.67% of the cattle present in the Erzurum province.

Methods

The survey study was carried out on the owners of randomly selected dairy cattle enterprises in the İspir county of Erzurum province, and the data obtained from the questionnaire constituted the material of the study. The enterprises were visited and the current situation was tried to be revealed through observation together with survey questions.

Since the variance is unknown as well as the population is limited and there are qualitative variables dependent on probability, the method whose formula is given below was utilized for the determination of the sample size of the research (Arıkan, 2007).

$$n = \frac{N.t^2.p.q}{(N-1).D^2 + t^2.p.q}$$

In this formula,

n = minimum number of necessary samples, N = population size, D = acceptable or desired sampling error (5%), t = table value (t = 1.96 for $\alpha = .05$), p = the rate to be calculated (.5), $q = 1 - p$.

$$n = \frac{2107.(1.96)^2.0.5.(1-0.5)}{(2107-1).(0.05)^2 + (1.96)^2.0.5.(1-0.5)} = 325$$

With the formula written above, the estimated sample size was calculated to be approximately 325. According to this result, the number of surveys was increased by 21.23% and the number of surveys to be conducted in the villages of the İspir county of Erzurum province was determined as 394. The data obtained from surveys were transferred to Excel 2010 computer program. The percentage values were obtained by using frequency analysis in descriptive statistical method available in the IBM Statistical Package for the Social Sciences version 20.0. (IBM SPSS Corp., Armonk, NY, ABD). Graphs were produced by using the proportional values and the results were interpreted. The effects of number of animals (0–10, 11–20, 21–30, 31–40, and 41+ head cattle) raised in the enterprises and the educational status of the owners of the enterprises (illiterate, literate, primary school graduate, secondary school graduate, and high school graduate) on the parameters investigated in the current study were analyzed statistically by using the Chi-Square test in the SPSS package program (Yıldız & Bircan, 2006).

Results

Feed costs constitute the largest share of expenses in dairy cattle farms. For this reason, enterprises are required to make plant and animal production together in order to reduce feed or feeding costs. It was determined that 97.7% of the surveyed enterprises are engaged in plant production in the county (Figure 1a). The majority of these enterprises (86.0%) were determined to have been making crop production for more than 5 years (Figure 1b).

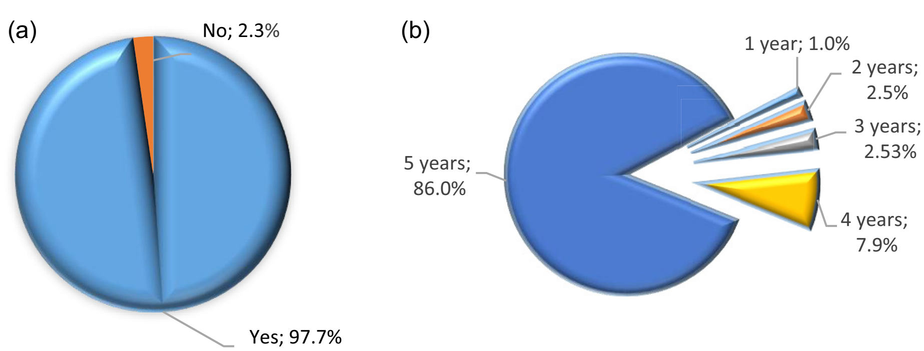

Figure 1.
(a) Do You Make Plant Production? (b) How Long Have You Been Cultivating Forage Crops?

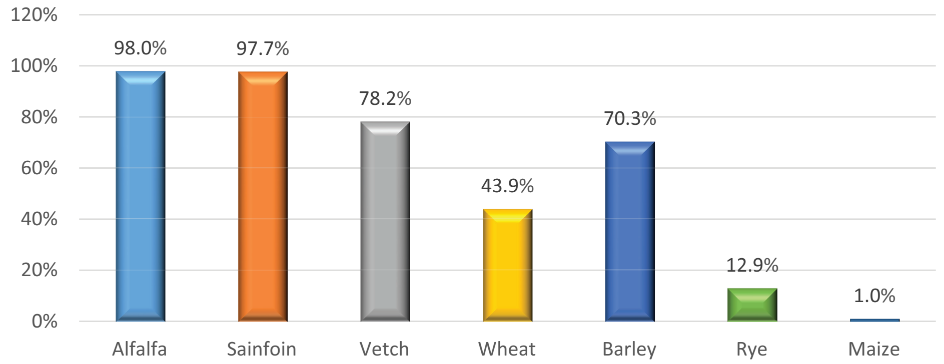

Figure 2.
Types of the Roughage and Concentrate Feeds Produced in the Enterprises.

Mostly alfalfa, sainfoin, and vetch were produced as roughage in the enterprises, while barley, wheat, rye, and corn were the most produced as concentrate feed (Figure 2). Corn silage production in the county was at a very low level.

In terms of forage and concentrate feed production, findings related to alfalfa, sainfoin, vetch, barley, and wheat production were similar to other literature findings. However, the data concerning corn production in the county was quite lower than the results of many studies. Sezer et al. (2020) reported that 91.4% of the enterprises in Nevşehir province produced alfalfa, 83.8% corn for silage, 33.3% oats, 36.2% vetch, and 96.2% straw. Similarly, Öztürk et al. (2019) determined that 91.67% and 81.82% of the breeders in Tekirdağ and Kırklareli provinces, respectively, produced forage crops and barley, silage corn, and alfalfa most commonly. Bakır and Kibar (2018) reported that 87.8% of the enterprises in Muş province produced forage crops and the most produced forage crop was alfalfa (33.82%). Vural (2018) reported that enterprises in Kırıkkale mostly produce barley and wheat straw (74.6%), barley (62.3%), and alfalfa (22.0%). Diler et al. (2018) determined the percentages of forage crops cultivated in the cattle enterprises in Narman county as 61.5% alfalfa, 60.1% barley, 45.7% vetch, and 37.5% sainfoin. Hozman (2014) stated that 90.2% of the farms in Sivas have wheat, 62.4% alfalfa, and 48.9% barley production, but vetch and silage corn production is quite low. Demir et al. (2013) stated that 88.7% of the enterprises in Kars Province produce forage crops. On the other hand, in some studies conducted in Turkey, the production rate of forage crops was reported at a lower rate (Akkuş, 2009; Diler et al., 2016; Sürmen et al., 2008; Tugay & Bakır 2008). In the aforementioned studies, it can be seen that the production of silage corn, which is an important source of forage for dairy cattle, is quite low in the provinces in the Eastern Anatolia Region and higher in other regions.

In the multi-select question, it was asked to breeders "Which type of roughage do you use in your enterprise?" and the majority of the enterprise owners stated that they used alfalfa, sainfoin, dry meadow, grass, and vetch. Corn silage usage was found to be very low (Figure 3).

It was determined that the rate of those who buy roughage from outside in the enterprises in İspir county was extremely low (0.8%), while the breeders who make their own production were the majority (Figure 4). Of all the self-producing enterprise owners, 44.2% of them stated that they use their own land for production and 35.0% of them noted that they produce the roughage on rented land. Moreover, 19.8% of these breeders stated that they meet their roughage needs by purchasing when their production is not enough.

Similarly, Diler et al. (2018), Bakır and Kibar (2018), Demir et al. (2013), Bogdanović et al. (2012), and Dou et al. (2001) reported that roughage was mostly produced in the enterprises in Narman county, Muş Province, Kars Province, in Serbia, and the United States, respectively. On the contrary, Sezer et al. (2020), Diler et al. (2016), Daş et al. (2014), Ayman (2014), and Kaygısız and Tümer (2009) reported that the percentages of the enterprises that purchased the roughage instead of producing was considerably high in Nevşehir province (98.1%), Hınıs county of Erzurum province (63.0%), Bingöl province (88.7%), and Kahramanmaraş

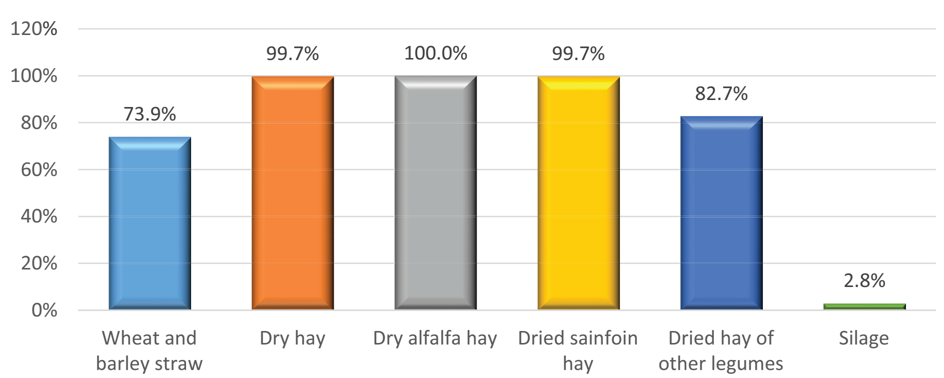

Figure 3.
Types of the Roughage Used in the Cattle Farms (%).

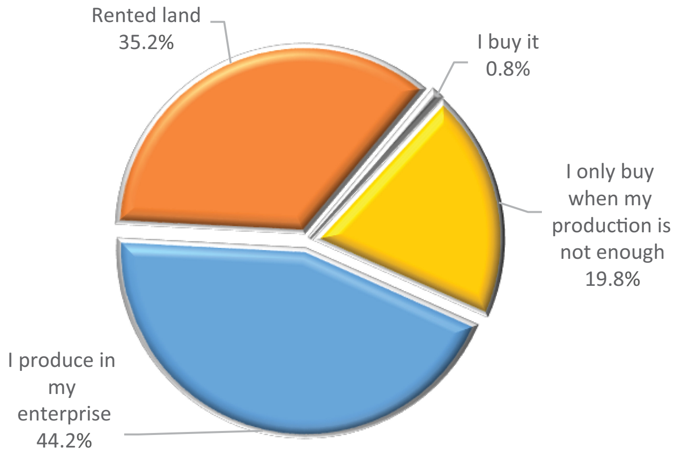

Figure 4.
Sources of Roughage Supply (%).

province (61.0%). Also, Kurt et al. (2020) and Oğuz et al. (2013) reported that in Burdur and Muş Provinces, the percentages of the enterprises who used both methods for roughage supply were 82% and 50.7%, respectively.

In this study, it was found out that in almost all of the surveyed enterprises (99.7%), dry hay was produced (Figure 3). It was also determined that the dry hay produced in the enterprises was mostly used for feeding the animal (97.7%) in their own enterprises, only 2.3% of the enterprise owners stated that they sell their surplus dry hay (Table 1).

The silage usage rate (2.8%) in the farms was determined to be considerably low and enterprises supplied the silage either by own production (0.8%) or by purchasing (2%). The longest silage using enterprise was determined to be feeding their animal with silage for 4 years (Table 1). Similarly, Diler et al. (2016) reported that the use of silage was quite low (0.25%), while Kurt et al. (2020) (18.8%), Aydın and Keskin (2019) (30%), Özyürek et al. (2014) (13%), and Önal and Özder (2008) (96.5%) reported different results in their studies.

Table 1.
Dry Hay and Silage Production

If you produce dry hay, how do you evaluate it?	Quantity	Proportion (%)
I feed my animals	385	97.7
I sell the surplus	9	2.3
Total	394	100.0
How long have you been using silage as roughage?		
I do not use silage	383	97.2
1–2 years	5	1.3
2–4 years	6	1.5
Total	394	100.0
How do you supply silage in your enterprise?		
I produce it	3	.8
I buy it	8	2.0
Total	11	2.8

The types of concentrate feed used in the enterprises and their percentages are given in Figure 5. The most commonly used concentrate feed sources by breeders were determined to be bran, crushed barley, and fattening feed, respectively. Dairy cattle feed and heifer feed were used at low levels. In addition, 8.4% of the respondents stated that they do not use concentrate feed.

Vural (2018) reported that almost all of the enterprises used commercial factory feed (96.2%), and barley (80.7%) usage was quite high; however, bran (14.6%), vetch (2.3%), and wheat use (10.0%) was considerably low in the enterprises in Kırıkkale province. Furthermore, Diler et al. (2018) determined that 34.0%, 23.0%, 22.0%, and 18.0% of the enterprises in Narman county of Erzurum province used crushed barley, fattening feed, dairy cattle feed, and bran, respectively.

It was asked to breeders, "Where do you supply concentrate feed?" and breeders answered the multi-select question by stating that they either produce their own feed (69.3%) or they supply their needs by purchasing from outside (62.7%) in addition to their production, the (Figure 6). In addition, it was determined that a significant amount of concentrate feed was purchased from the feed factories (31.7%) and the agricultural credit cooperative (22.3%) in the county. The fact that the breeders produce their own feed to a large extent can be considered as an effort to make livestock economically without being dependent. In addition, the high feed prices may also have an impact on this practice.

Similarly, Vural (2018), Bogdanović et al. (2012), Önal and Özder (2008), and Dou et al. (2001) stated that concentrate feed was mostly produced by the enterprises themselves in their studies. On the contrary, Kılıç and Eryılmaz (2020), Bakır and Kibar (2018), Diler et al. (2016), Ayman (2014), Daş et al. (2014), Boz (2013), and Kaygısız and Tümer (2009) noted that concentrate feed was mostly purchased from a feed factory or feed mills. Tugay and Bakır (2008) and Diler et al. (2016) reported the percentages of breeders who prefer feed mills to be 83.4% and 64%, respectively. On the other hand, Kılıç and Eryılmaz (2020) and Soyak et al. (2007) reported that 65.7% and 65% of the enterprises preferred feed dealers, while Demir et al. (2013) stated that agricultural cooperatives were preferred by 42.5% of the enterprises for concentrate feed supply in their study. It is seen in Figure 7a that most of the breeders are satisfied (78.4%) with factory feed. One of the most important reasons for dissatisfaction is thought to be high feed prices.

A statistically significant ($p < .01$) relationship was found between satisfaction with factory feed and the education level of the breeders and the size of the farm. Literate and illiterate breeders were less satisfied with factory feed compared to other education groups. While the satisfaction percentage was found between 96.3% and 100% in the enterprises possessing 21–30 heads and above animals, a relatively lower satisfaction level was determined (61.5%–78.3%) in the enterprises having 1–10 and 11–20 heads and below animals.

It was determined that all of the enterprises kept the factory feed, other grain, and concentrate feed in a closed store (100%). Similarly, Vural (2018) reported that 74% of the enterprises stored concentrate feed in a separate feed storehouse.

The animals were fed either 2 (73%) or 3 (27.0%) times a day in the enterprises of the county (Figure 7b). Similarly, percentages of the enterprises feeding their animals two times a day were reported

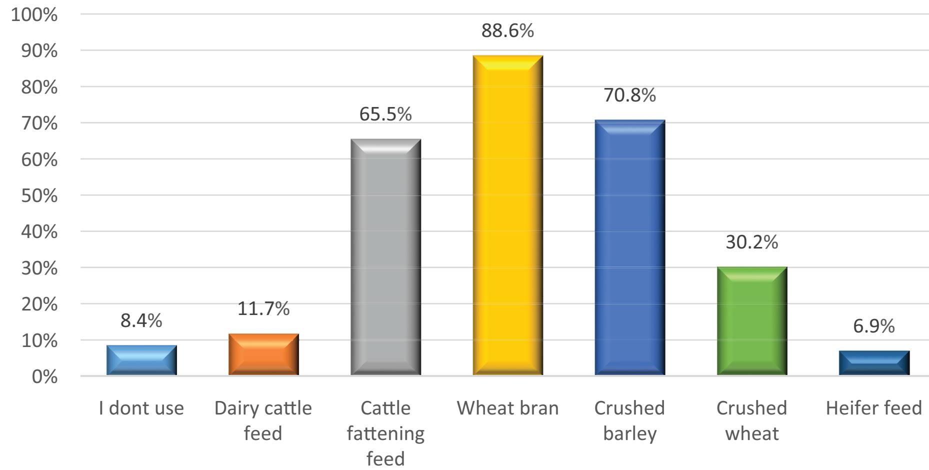

Figure 5.
Types of the Concentrate Feed Used in the Farms (%).

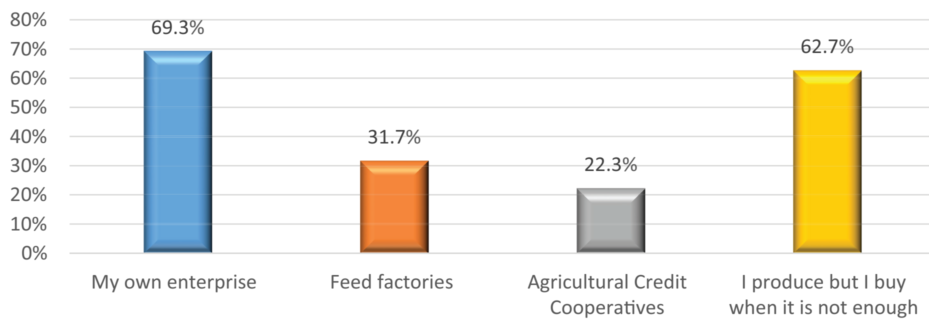

Figure 6.
Sources of the Concentrate Feed Supply (%).

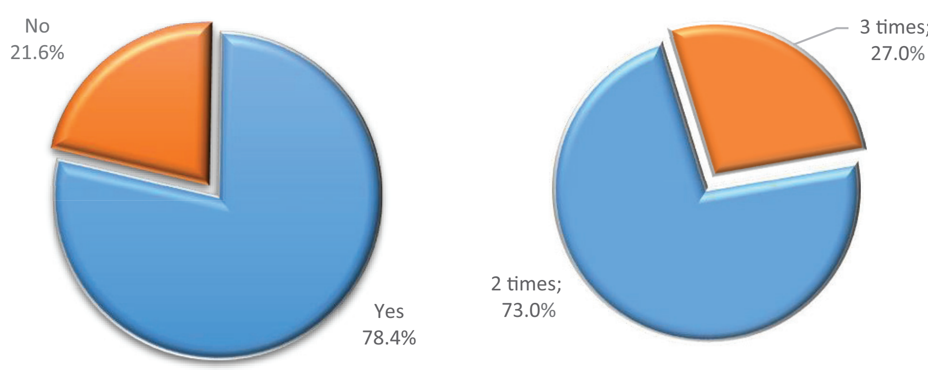

Figure 7.
(a) Are You Satisfied with The Factory Feed? (b) How Many Times a Day Do You Feed Your Cattle?

as 91.5%, 78.1%, and 63.2% by Vural (2018), Sezer et al. (2020), and Önal and Özder (2008), respectively.

The majority of the enterprise owners stated that they first feed concentrate and then roughage (60.2%), and 29.7% stated that they gave both feeds mixed together (Figure 8). The breeders, constituting 9.0% of the enterprises, stated that they only give roughage or concentrate feed mixed with straw.

Unlike the presented study, Akkuş (2009) determined that 70.5% of the enterprises in Konya gave mixed feed with roughage and concentrate, 22.9% of them gave roughage first and then concentrate, and 6.5% of them gave concentrate first and then roughage. Sezer et al. (2020) stated that 56.2% of the enterprises gave a mixed feed of roughage and concentrate.

In order to achieve profitability in animal production, breeders are expected to feed the animals consciously. For conscious feeding, it is required to obtain technical information support from qualified persons or relevant institutions. For determining the breeder's information sources and the situation of the enterprises in terms of receiving information support it was asked to the participants "What is your information sources to

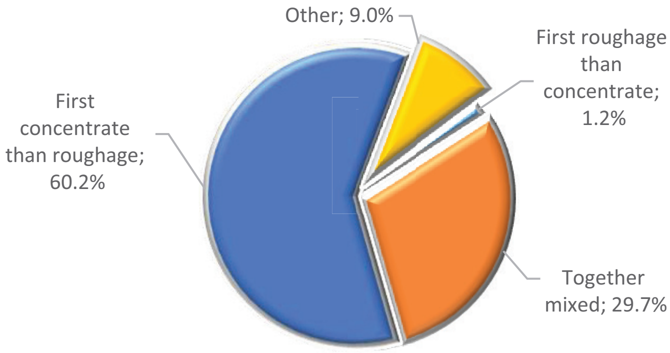

Figure 8.
Percentages of the Methods of Feeding Animals.

feed the animals?" and to this multi-select question, 99.0% of the breeders answered that they feed their animals based on their own knowledge and experiences (Figure 9). In addition to their own knowledge about feeding, it was also determined that breeders benefited relatively from veterinary advice (32.7%), feed factory recommendation (14.5%), unions and cooperatives (8.6%), and agricultural engineers (animal scientists) at a very low level (.3%).

Similarly, Sezer et al. (2020) stated that 62.9% of the breeders practiced animal husbandry according to traditional methods without any training education, and the amount of feed given to animals was determined by rough estimate (42.0%) or based on the experience of the breeders (38.1%). Oğuz et al. (2013) reported that 92.6% of the enterprises in Burdur province determined the amount of feed given to animals according to their own knowledge, while 5.6% and 2.8% of them determined the feed amount based on the recommendations of the factory where they bought feed and veterinarians, respectively. Vural (2018) stated that 81.5% of the enterprise owners in his study believed that they have sufficient knowledge and experience about animal breeding and 61.5% of these enterprises received information support for animal feeding. It has been reported that 65.7% of the enterprises in Ağrı province did not receive technical information support, and 59.0% of these enterprises continued their breeding with traditional methods (Bakan & Aydın, 2016). Akkuş (2009) found out that 71.7% of the enterprises in Konya province received technical information support.

It was also determined that the calves are generally fed by dry hay or straw as a source of roughage and almost half of the enterprises used calf growth feed (48.2%) as a concentrate feed source. In addition, it was determined that the calves were fed by crushed barley, fattening feed, crushed wheat, calf starter, and dairy cattle feed from most to least, respectively. Moreover, 24.1% of the participants stated that they did not use concentrate feed for calf feeding (Figure 10).

Similar to the findings in the study, Sezer et al. (2020) determined that 98.1% of the farms used concentrate feed and 100% use roughage in the feeding of calves in Nevşehir province. On the contrary, Tugay and Bakır (2008), Bayındır (2008), and Diler et al. (2016) reported that 98.9%, 91.3%, and 60% of the enterprises did not offer concentrate feed to the calves.

Information about the period of roughage, concentrate, and water feeding of calves after birth, the dates that the calves were

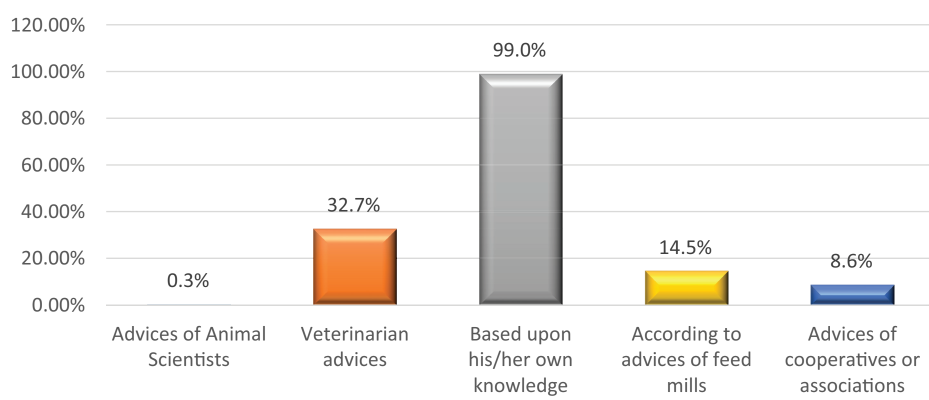

Figure 9.
Percentages of Sources of Information Concerning Cattle Feeding.

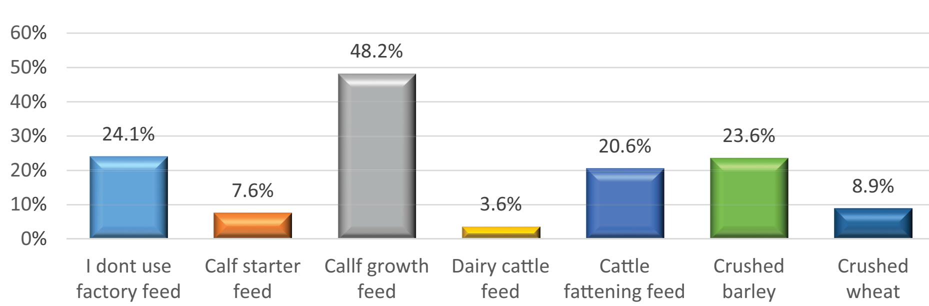

Figure 10.
Types of Feeds Bought from Feed Factories.

Table 2.
Times to Start Roughage, Concentrate and Water Feeding of Calves and Dates and Duration of Starting Pasture and Plateau Feeding

When do you start roughage and concentrate feeding of calves after birth ?	**Quantity**	**Proportion(%)**
2 weeks	1	.3
3 weeks	2	.5
4 weeks	384	97.5
5 weeks	7	1.7
Total	394	100.0
When do you start rouwatering calves after birth?		
2 weeks	2	.5
3 weeks	389	98.7
4 weeks	3	.8
Total	394	100.0
Do you move your cattle to pasture?		
Yes	393	99.7
No	1	.3
Total	394	100.0
In which months do you move your cattle to pasture?		
March	14	3.6
April	375	95.4
May	4	1.0
Total	393	100.0
How long do you feed your cattle in the pasture?		
4 months	1	.3
5 months	1	.3
More than 5 months	391	99.5
Total	393	100.0
Do you move your cattle to plateau?		
Yes	68	17.3
No	326	82.7
Total	394	100.0
If yes, in which months do you move your cattle to plateau?		
April	44	64.7
May	12	17.6
June	11	16.2
July	1	1.5
Total	68	100.0
How long do you feed your cattle in the plateau?		
2 months	24	35.3
3 months	27	39.7
4 months	17	25.0
Total	68	100.0

allowed to go pasture and plateau, the time spent there are presented in Table 2.

It was determined that the breeders generally started roughage and concentrate feeding of calves at the fourth week (97.5%), and water feeding at the third week after birth (98.7%). Similarly, Vural (2018) stated that the majority of the enterprises in Kırıkkale Province and Savaş (2016) reported that 51.7% of the enterprises in Rize Province started to offer feed to the calves from the fourth week after birth. On the other hand, Bayındır (2008) stated that 79.2% of the enterprises in Van Province and Akkuş (2009) stated that calves were started to be fed when they were 3 weeks old on average in Konya Province.

Hozman (2014) determined that 98.5% of enterprises in Sivas province started concentrate feeding of calves at 6–7 days of age. Oğuz et al. (2013) stated that in Burdur province, concentrate feed started to be given to calves from the ninth day on average. Diler et al. (2016) reported that breeders generally started to give roughage and concentrate feed to the calves at 4 weeks (52.0%) of age or later (30.0%) and water feeding started at 1–2 weeks (77.0%) of age.

In studies conducted abroad, Vasseur et al. (2010) reported that the average starting age of concentrate feeding for calves was 7 days; dry hay was given at 3 days of age and clean water was given at 2.5 days of age. Heinrichs et al. (1987) stated that concentrate feed (97.9%) was given in the first week, and roughage (78.7%) and water (75.1%) were given in the second week after birth.

Almost all of the surveyed enterprises (99.7%) moved their animals to pasture (Table 2). It was determined that the breeders generally started the pasture feeding in April (95.4%) and grazed their animals in the pasture for more than 5 months (99.5%). Similar to the presented study, Vural (2018) stated that 70% of the enterprises in Kırıkkale region utilized pasture, and the pasture feeding lasted about 6–9 months (57.3%). Akman (2013) determined that pasture feeding lasted for 6–7 months in Sarıkamış county and 100% of the enterprises utilized pasture in the county. Tugay and Bakır (2008) reported that 86.3% of the enterprises in the Giresun province utilized pasture and animals for 5–7 months (63.3%) in the pasture. Pasture utilization rates were reported as 78.4%, 80.0%, and 95.6% in the enterprises in the Black Sea region, Sivas Province, and Van Provinces by Surmen et al. (2008), Hozman (2014), and Bayındır (2008), respectively.

On the other hand, Ayman (2014) stated that 45.7% of the enterprises in Kahramanmaraş Province made pasture feeding and this practice was started mostly in March (43.2%). Ödevci (2016) stated that 50.8% of the enterprises utilized pastures and pasture feeding lasted mostly for 3–5 months (48.5%). Oğuz et al. (2013) reported that 16.0% of the enterprises in Burdur Province used pasture, while Bayındır (2008) reported that the average usage period of pastures in Van Province was 5 months.

Plateaus are important sources for the nutrition and health of animals. Of all the participants, 17.3% of them stated that they have the opportunity to go to the plateau. It has been determined that the date to move animals to the plateau was mostly in April (64.7%), and breeders continued to move animals to the plateau in May (17.6%) and June (16.2%) as well. It was also determined that 35.9% of the enterprises let their animals stay in the plateau for 2 months, 39.7% for 3 months, and 25.0% for 4 months (Table 2).

In other studies, the opportunity of going to the plateau and the duration of stay were 33.2% and generally 3–4 months in Giresun region (Tugay & Bakır, 2008), 8.0% and mostly 3–5 months in Kahramanmaraş Province (Kaygısız & Tümer, 2009), respectively. In Hınıs county, it was reported as 20.0% and generally 2–3 months (Diler et al., 2016).

As a result, it can be deduced that feeding practices in İspir county of Erzurum province are fairly well. It was determined that the enterprises could produce their own roughage and concentrate feeds and were satisfied with the purchased factory feeds. The applications made in terms of the dates of feeding animals in the pasture and the duration of their stay in the pasture were evaluated positively. In addition, it was concluded that the time to start roughage and concentrate feeding of calves was also appropriate.

However, April is early for countie's enterprises to start pasture feeding. For pastures to stay in proper form and to be used for a longer period of time, breeders are recommended to move their animals to pasture in May. In addition, it was determined that the enterprises used fattening feed, bran, and crushed barley at a higher rate, and dairy cattle feed and corn silage at a lower rate. The majority of the farm owners feed the animals based on their own knowledge, and they are insufficient in terms of obtaining and applying technical information in their farms. The calves should be given starter feed first, but calf growth feed usage was more common among breeders. A significant proportion of the breeders did not give concentrate feed to the calves; this application was interpreted as an important deficiency, and awareness of the farm owners should be increased about calf feeding.

It is seen that the breeders in İspir county have a lack of knowledge about animal feeding and feed usage. To eliminate these deficiencies farm owners should be trained and information support should be provided by training studies by the relevant institutions in the region.

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Effects of Pre-Sprouting and Planting Time on Quality Characteristics of Tuber Potatoes (*Solanum tuberosum* L.)

Ön Sürgünlendirme ve Dikim Zamanlarının Patatesin (*Solanum tuberosum* L.) Bazı Kalite Özelliklerine Etkileri

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ABSTRACT

This study was carried out in Erzurum in 2015 and 2016 to determine the effects of pre-shooting and planting times on some quality characteristics of potatoes. In the experiment, there were four different pre-sprouting (23 March, 3 April, 23 April, and Control), three planting times (5, 15, and 25 May), and two varieties (Binella and Slaney). The experimental design was the "Randomized Complete Blocks Design" in "Split Split Parcel" arranged as three planting times (5th, 15th, and 25th days of May), two varieties (Binella and Slaney), and four pre-shooting times (March 23, April 3, April 13, and Control) with four replications. According to the average of the trial factors, there was a statistical difference between the years in terms of tuber specific weight, dry matter, starch, protein ratios, and chips yield, but there was no difference in terms of chips' oil absorption rate. According to the pre-shooting times, the highest dry matter, protein, chip ratio, and oil absorption rates of the chips were determined in the application on March 23, while the specific gravity and starch ratio were determined from the application on April 3. According to the planting times, the maximum specific gravity was determined in the 5th and 15th May plantings, the oil absorption rate of the dry matter and chips was determined on the 3rd of April, and the protein ratio was determined in the 25th of May plantings. The specific gravity, dry matter, starch, and oil absorption ratio of chips were higher in Slaney variety, and protein ratio was lower than Binella variety. As a result, although there is no difference between pre-sprouting and planting times, there were differences between cultivars in terms of pre-sprouting time and planting time for high chips productivity and chips efficiency and low oil absorption rate of chips, and accordingly, among the examined cultivars, Slaney cultivar took longer time than the other cultivars. It has been suggested that a period of pre-sprouting should be required and a later planting should be done.

Keywords: Planting time, potato, pre-sprouting, quality

ÖZ

Bu çalışma, patatesin bazı kalite özellikleri üzerine ön sürgünlendirme ve dikim zamanlarının etkilerini belirlemek amacıyla 2015 ve 2016 yıllarında Erzurum'da yapılmıştır. Denemede dört farklı önsürgünlendirme (23 Mart, 3 Nisan, 23 Nisan ve Kontrol) üç dikim zamanı (5, 15 ve 25 Mayıs) ve iki çeşit (Binella ve Slaney) bulunmaktadır. Deneme "Şansa Bağlı Tam Bloklar" Deneme Deseninde "Bölünen Bölünmüş Parseller" düzenlemesine göre 4 tekrarlamalı olarak kurulmuştur. Deneme faktörlerinin ortalamasına göre, yıllar arasında yumru özgül ağırlığı, kuru madde, nişasta, protein oranları ve cips verimliliği yönünden istattistiki olarak farklılık olup, cipsin yağ çekme oranı yönünden farklılık olmamıştır. Ön sürgünlendirme zamanlarına göre, en fazla kuru madde, protein, cips oranı ve chipsin yağ çekme oranları 23 Mart uygulamasında, özgül ağırlık ve nişasta oranı ise 3 Nisan'daki uygulamadan tespit edilmiştir. Dikim zamanlarına göre en fazla özgül ağırlık 5 ve 15 Mayıs dikimlerinde, kuru madde ve chipsin yağ çekme oranı 3 Nisan, protein oranı ise 25 Mayıs dikimlerinde belirlenmiştir. Slaney çeşiinin özgül ağırlık, kuru madde, nişasta ve cipsin yağ çekme oranı Binella çeşidine göre yüksek, protein oranı ise düşük bulunmuştur. Sonuç olarak, ön sürgünlendirme ve dikim zamanları arasında farklılık olmamasına rağmen, yüksek cips verimliliği ve cipsin düşük yağ çekme oranı için ön sürgünlendirme süresi ve dikim zamanları bakımından çeşitler

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arasında farklılık olduğunu, buna göre incelenen çeşitlerden slaney çeşidinde diğer çeşitlere göre daha uzun süre ön sürgünlendirme ve daha geç dikim yapılmalıdır

Anahtar Kelimeler: Dikim zamanı, patates, ön sürgünlendirme, kalite

Introduction

Potato is an important food for human nutrition. Especially water, dry matter, starch, protein, minerals, and vitamins make potato an important nutrient (Esendal, 1980). It has important place in agricultural enterprises, and its production requires more labor force, for example, it needs hoeing during the growing period, compared to other field products so it enables employment in agricultural enterprises.

In order to obtain high yield per unit from potato, one of the most important factors is to use high-quality seed tubers in addition to applying practices such as irrigation, fertilization, pre-sprouting, haulm killing, and planting time. These cultural practices have important effects on the quality of potatoes.

Studies on the subject, the negative effect of late planting on some quality parameters of tuber potatoes such as dry matter and starch content, and cooking quality can be eliminated with pre-sprouting (Lunden, 1944). Pre-sprouting treatment can give the producers at least a 2-week or more advantage of growing potatoes; especially in short-season climate, it may provide a significant benefit for early planting and the longer growing season because the seed tuber potatoes are ready for planting.

A lot of research has been carried out that states that there are positive and negative aspects of early planting and pre-sprouting on quality characteristics of potatoes. According to Emilson (1950), the content of starch increases more than dry matter due to pre-sprouting. Kara and Unal (1991) stated that pre-sprouting date has no effect on tuber specific gravity, dry matter, and protein, it has effect on starch content and chip yield. As the date of pre-sprouting delays, the rate of starch decreased and the chips productivity of sprouted was less than that of non-sprouted.

Kara et al. (2005) practiced pre-sprouting on seed tubers on different dates (15 March, March 30, April 14, and Control) in Erzurum. They stated that pre-sprouting has effect on protein content, it has no effect on dry matter and starch content, and it is suitable that seed tubers can be pre-sprouted under Erzurum conditions in 14 April.

Taşkıran (1988) stated that planting date has no effect on dry matter rate of tuber, and Kara et al. (2002) detected that planting date has no effect on tuber dry matter, protein, chips yield, and oil absorption ratio of chips.

Akeley et al. (1955) stated that an early planting date increases the dry matter content of tubers and high-quality chips are obtained. Koch et al. (1969) detected that late planting decreases tuber dry matter and quality. Also, Günel (1976) detected that the late planting date delays the dry matter rate and chip yield decreased gradually, and it has no effect on the starch, protein, and oil absorption ratio of chips.

This study was carried out to determine the effects of pre-sprouting date and planting date on potato quality characteristics of potato cultivars.

Methods

Experimental Site and Materials

This study was carried out at Atatürk University, Faculty of Agriculture Experimental field in years 2015 and 2016. In the studies, cultivars of Binella and Slaney were used for their high adaptation and high yield, resistance to disease, technological characteristics. For fertilization, 24 kg nitrogen, 6 kg phosphorus, and 5 kg potassium were applied as pure substance per decare (Ilisulu, 1986; Oztürk, 2001).

Climate Properties

Between May and September, which is the vegetation period of potato in Erzurum, total rainfall was 285.1 mm in 2015, 303.7 mm in 2016, and 195.5 mm in long-term average. Average temperature was 14.8 °C in 2015, 14.8 °C in 2016, 14.5 °C in the long-term average; relative humidity was 60.4% in 2015, 53.3% in 2016, and 57.0% in the long-term average (Anonymous, 2017).

Soil Characteristics

The soil of the study field was clay and loamy, pH values varied between 7.20 and 7.73, poor in the sense of organic matter (1.04% and 2.28%), available phosphorus amount was changed between 8.7 and 11.9 kg da^{-1} and rich in potassium was136.0–154.8 kg da^{-1}

Experimental Treatments

The experimental design was the Split-Split Plot with three planting dates (May 5, May 15, and May 25) as main plots, four pre-sprouting treatments (no pre-sprouting, starting of pre-sprouting on March 23, April 3, April 13) as subplots, and two cultivars (Binella and Slaney) as sub-sub plots with four replications. In the plantings, hills were designed with 70-cm interrow spacing and 35-cm intrarow spacing (Şenol, 1973). Each plot was composed of 4 lines, and there were 10 hills on each line. There were 96 plots and the size of each plots was 9.8 m^2 (2.8 m × 3.5 m), the total experimental area was 2507.76 m^2.

Results

Variance analysis results of tuber specific gravity, dry matter content, starch content, protein content, oil absorption rate, and chips yield determined according to experiment factors were given in Table 1, and the averages were given in Table 2.

Specific Gravity of Tuber

The statistical difference in specific gravity of tubers between experiment years was significant ($p < .05$). The specific gravity of tubers was 1.077 in the first year of the experiment and 1.067 in the second year (Tables 1 and 2). This may result from the fact that the growth period in the first year of the experiment was long and the temperature was high, thereby dry matter content was high.

Table 1.
Variance Analysis Results of Specific Gravity, Dry Matter, Starch, Protein Content, Chips Yield, and Oil Absorption Rate of Potatoes, Which Were Pre-sprouted and Planted at Different Dates

Variation Source	*df*	Specific Gravity	Dry Matter Content	Starch Ratio	Protein Ratio	Chip Efficiency	Oil Absorption of Chips
Year (A)	1	51.8*	137.1**	160.1**	0.67 30.7*	57.9**	0.1
$Error_1$	3	–	–	–	–	–	–
Planting time (B)	2	2.0	0.5	0.6	1.9	0.3	1.1
(A) × (B)	2	0.4	0.2	0.1	1.6	1.9	0.4
$Error_2$	12	-	-	-	-	-	-
Pre-sprouting date (C)	3	1.6	0.9	1.7	0.7	0.9	1.9
(A) × (C)	3	0.7	1.6	0.6	0.1	1.7	0.1
(B) × (C)	6	0.7	2.2	1.5	1.8	1.2	0.9
(A) × (B) × (C)	6	2.1	3.8*	2.1	1.8	0.7	0.1
Error	54	-	-	-	-	-	-
PVariety (D)	1	8.9*	2.7	0.6	8.8**	0.7	4.5*
(A) × (D)	1	0.3	0.3	0.1	0.7	2.8	0.6
(B × D)	2	1.4	0.2	0.95	0.99	0.3	1.7
(C) × (D)	3	0.8	2.2	1.3	2.0	0.3	0.2
(A) x (B) x (D)	2	0.6	0.9	2.1	3.7*	0.1	0.3
(A) x (C) x (D)	3	0.3	1.6	1.03	0.8	1.2	2.7*
(B) x (C) x (D)	6	0.5	0.5	1.03	2.3*	2.7*	0.5
(A) x (B) x (C) x (D)	6	1.1	0.9	0.7	0.7	0.97	0.7
$Error_4$	72	–	–	–	–	–	–

**Marked *F* values are 1%, *Marked *F* values are significant at a 5% level.

Table 2.
Average Values of Tuber Specific Gravity, Dry Matter, Starch, Protein, Chips Yield, and Oil Absorption Rates of Chips at Different Pre-shooting and Planting Times

Treatments		Specific Gravity	Dry Matter Content	Starch Ratio	Protein Ratio	Chip Efficiency	Oil Absorption of Chips
Year	2015 2016	1.075 ± 0.001[a]	21.6 ± 0.233[A]	16.3 ± 0.168[A]	12.8 ± 0.167[a]	34.6 ± 0.240[A]	31.7 ± 0.305
		1.067 ± 0.001[b]	18.9 ± 0.233[B]	11.4 ± 0.168[B]	10.9 ± 0.167[b]	32.0 ± 0.240[B]	32.0 ± 0.305
Mean		**1.071**	**20.3**	**13.9**	**11.9**	**33.3**	**31.9**
Pre-sprouting date	23 March 13 April 3 April Control	1.072 ± 0.001	20.6 ± 0.330	13.9 ± 0.238	12.1 ± 0.236	33.7 ± 0.339	32.3 ± 0.431
		1.074 ± 0.001	20.3 ± 0.330	14.2 ± 0.238	11.7 ± 0.236	33.2 ± 0.339	31.1 ± 0.431
		1.070 ± 0.001	20.2 ± 0.330	13.4 ± 0.238	12.0 ± 0.236	32.9 ± 0.339	32.3 ± 0.431
		1.073 ± 0.001	20.0 ± 0.330	14.1 ± 0.238	11.6 ± 0.236	33.4 ± 0.339	31.7 ± 0.431
Mean		**1.072**	**20.3**	**13.9**	**11.9**	**33.3**	**31.9**
Planting time	5 May 15 May 25 May	1.073 ± 0.001	20.3 ± 0.286	14.0 ± 0.206	11.6 ± 0.204	33.5 ± 0.294	32.1 ± 0.373
		1.070 ± 0.001	20.5 ± 0.286	13.9 ± 0.206	11.8 ± 0.204	33.2 ± 0.294	32.2 ± 0.373
		1.072 ± 0.001	20.0 ± 0.286	13.7 ± 0.206	12.2 ± 0.204	33.2 ± 0.294	31.3 ± 0.373
Mean		**1.073**	**20.3**	**13.9**	**11.9**	**33.3**	**31.9**
Varieties	Binella Slaney	1.071 ± 0.001	20.0 ± 0.233	13.8 ± 0.168	12.2 ± 0.167	33.7 ± 0.240	31.1 ± 0.305
		1.074 ± 0.001	20.5 ± 0.233	14.0 ± 0.168	11.5 ± 0.167	33.2 ± 0.240	31.7 ± 0.305
Mean		**1.073**	**20.3**	**13.9**	**11.9**	**33.5**	**31.4**
5 May x 23 March		1.075	20.6	14.2	11.8	33.4	32.3
5 May x 3 April		1.071	21.2	14.8	11.0	34.5	32.2
5 May x 13 April		1.067	19.9	13.9	12.0	32.3	32.0
5 May x Control		1.067	19.4	13.3	11.7	34.4	31.9
15 May x 23 Mart		1.066	20.7	10.9	12.1	33.6	33.9
15 May x 3 April		1.067	20.0	10.6	12.4	33.1	32.4
15 May x 13 April		1.068	20.1	9.9	11.2	32.6	31.6
15 May x Control		1.068	21.2	10.9	11.5	31.1	30.9
25 May x 23 March		1.068	20.4	13.8	12.7	32.6	31.0
25 May x 3 April		1.064	19.9	13.6	12.4	34.4	31.6
25 May x 13 April		1.064	19.8	13.6	13.1	32.6	31.8
25 May x Control		1.070	20.5	13.9	10.9	33.2	30.9
5 May x 23 March x Binella		1.072	20.1	13.7	13.0	34.2	32.3
5 May x 23 March x Slaney		1.077	21.1	14.7	10.6	32.6	32.3
5 May x 3 April x Binella		1.077	22.0	15.6	11.3	34.9	30.9
5 May x 3 April x Slaney		1.073	20.3	14.0	10.7	34.0	33.4
5 May x 13 April x Binella		1.072	20.5	13.4	12.9	32.3	33.3
5 May x 13 April x Slaney		1.075	19.3	14.4	11.1	32.2	30.6
5 May x Control x Binella		1.068	19.0	12.6	12.1	33.4	31.9
5 May x Control x Slaney		1.072	19.8	14.0	11.3	34.4	31.9

15 May x 23 March x Binella	1.069	19.5	10.8	12.1	34.5	34.6
15 May x 23 March x Slaney	1.073	21.8	10.9	12.1	32.7	33.1
15 May x 3 April x Binella	1.071	20.3	11.1	12.7	32.6	32.6
15 May x 3 April x Slaney	1.074	19.7	10.0	12.0	33.6	32.2
15 May x 13 April x Binella	1.073	20.7	9.9	11.5	32.1	31.8
15 May x 13 April x Slaney	1.074	19.5	9.9	10.8	33.0	31.3
15 May x Control x Binella	1.075	22.1	11.5	11.5	32.1	31.1
15 May x Control x Slaney	1.072	20.2	10.3	11.4	30.0	30.6
25 May x 23 March x Binella	1.071	20.8	13.3	12.6	33.0	32.0
25 May x 23 March x Slaney	1.074	20.0	14.2	12.7	32.1	30.0
25 May x 3 April x Binella	1.069	19.9	14.0	12.2	35.1	32.7
25 May x 3 April x Slaney	1.068	19.1	13.1	12.5	33.7	30.4
25 May x 13 April x Binella	1.070	19.5	13.8	13.6	34.0	32.0
25 May x 13 April x Slaney	1.066	20.0	13.4	12.5	31.1	31.6
25 May x Control x Binella	1.074	21.2	14.1	10.8	33.0	30.5
25 May x Control x Slaney	1.073	19.7	13.6	11.0	33.4	31.2

Capital letters are significant at 1%, small letters are significant at 5% level.

Although there was a numerical difference, planting date and pre-sprouting time had no significant effect on the specific gravity of tubers (Table 1). The highest specific gravity of tubers was determined for tubers planted on April 3 (1.074), followed by control (1.073), March 23 (1.072), April 13 (1.070) pre-sprouting treatments (Table 2). In previous study carried out by Kara and Unal (1991), and Kara and Kavurmacı (2003), it was stated that pre-sprouting dates have no effect on the specific gravity of tuber, and therefore, it is compatible with the experiment results.

According to the planting times, the highest starch was in the May 5 and 15 plantings (1.073), followed by the May 25 (1.072) planting time. While the results obtained from the experiment were similar to the results of Günel (1976), they are unsimilar to the results of Kara et al. (2002), Taşkıran (1988), and Yıldırım et al. (2005).

There were statistically significant ($p < .05$) differences between tuber specific gravity of cultivars (Table 1). Tuber specific gravity of the Slaney cultivar was 1.074, and it was detected as 1.071 for the Binella cultivar (Table 2). Differences between cultivars may probably result from the genetic structure.

Dry Matter Content (%)

In terms of dry matter content, statistical significance ($p < .01$) was found between the study years (Table 1). Dry matter content was 21.6% in the first experiment year and 18.9% in the second year (Table 2). This may have resulted from the fact that the growth period was longer and the temperature was higher in the first study year.

In terms of planting time, the highest dry matter content of potato tubers was on May 15 plantings (20.5%), followed by May 5 and 25 plantings (Table 2). In the previous studies of Günel (1976), Kara et al. (2002), and Taşkıran (1988), it was detected that planting date had no effects on dry matter content. The average dry matter content of the Binella cultivar was 20.0%, and it was 20.5% for the Slaney cultivar (Table 2).

Due to the fact that the dry matter ratio did not show stability according to the pre-sprouting dates and planting times in the study years caused the interaction of year × pre-sprouting date × planting time to be statistically significant ($p < .05$) (Table 1, Figure 1).

Starch Content (%)

There was a statistically significant difference between experiment years in the sense of starch content of tubers ($p < .01$) (Table 1). Starch content of tubers was 16.3% in the first year of the experiment and 11.4% in the second year. This may result from dry matter content in the first study year (Table 2). Although the starch ratios of the tubers were numerically different between the pre-sprouting, planting times, and the varieties, there was no statistical difference (Tables 1 and 2).

The highest starch content of tubers was obtained from April 3 pre-sprouting treatment (14.2%) followed by the control treatment (14.1%), March 23 (13.9%), and April 13 treatments (Table 2). Results of the experiment are compatible with the results of Kara et al. (2002), incompatible with the results of Prosba-Bialoczyk (1989), and reported that pre-sprouting increased the rate of starch.

The highest starch rate determined in tubers according to planting times was obtained on May 5 (14.0%), followed by 15 (13.9%) and

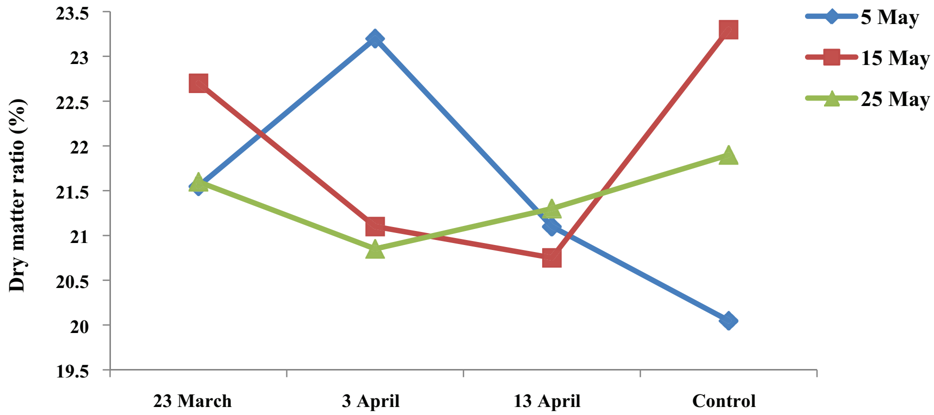

Figure 1.
Pre-sprouting Date × Planting Time Interactions in Terms of Dry Matter Rate in Average of Study Years.

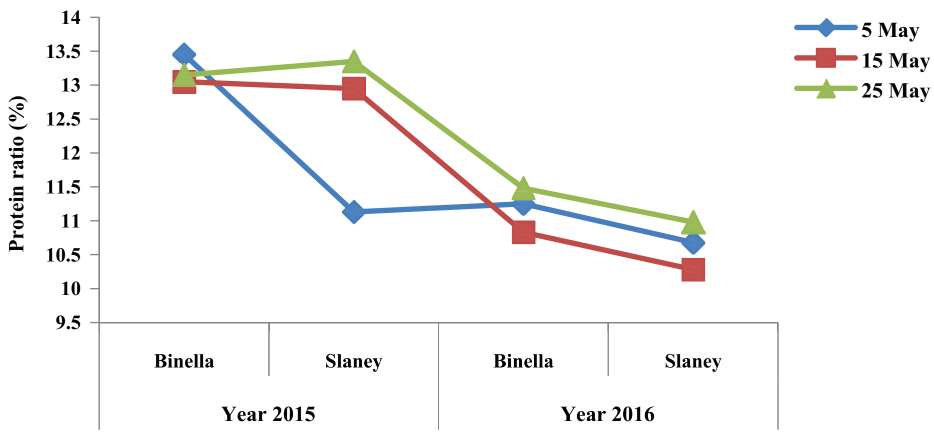

Figure 2.
Year × Planting Time × Variety Interaction in Terms of Protein Ratios in Average of Study Years.

May 25 (13.7%). The results were similar to the results of Taşkıran (1988), and it was determined that the starch ratio decreased as the planting time was delayed. The average starch ratio was 13.8% in the Binella cultivar and 14.8% in the Slaney cultivar.

Protein Content (%)

There was a statistically significant difference between experiment years in the sense of protein content of tubers ($p < .05$) (Table 1). The protein content of tubers was 12.8% in the first year of the experiment and 10.9% in the second year (Table 2).

Although there is a numerical difference between the protein content of potato tubers according to pre-sprouting date and planting time, there was no statistical difference (Tables 1 and 2).

According to the pre-sprouting times, the highest protein content was determined in March 23 treatment (12.1%), followed

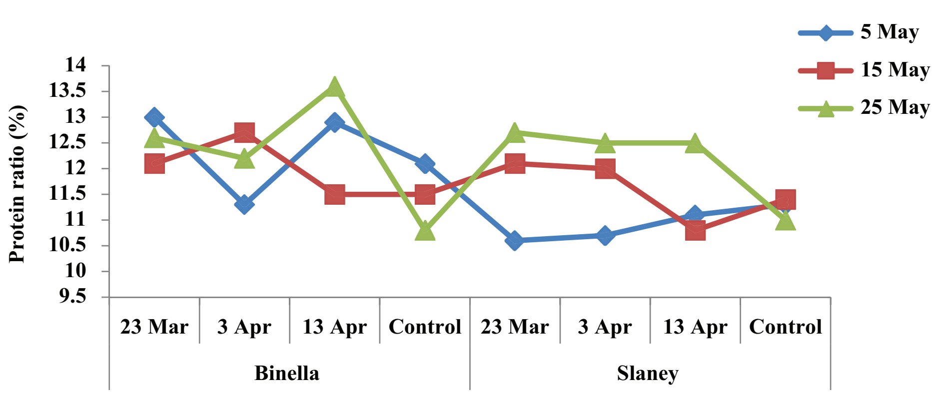

Figure 3.
Pre-sprouting Date × Planting Time × Variety of Interactions in Terms of Protein Ratios in the Average of Study Years.

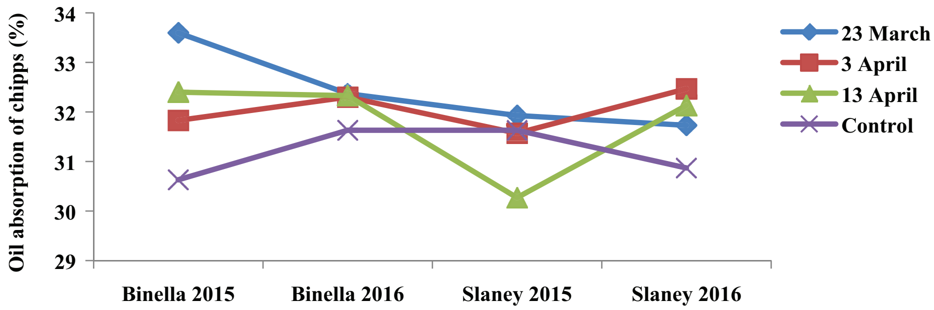

Figure 5.
Years × Pre-sprouting Time × Variety in Terms of Chips Oil Absorption Rates in Study Years.

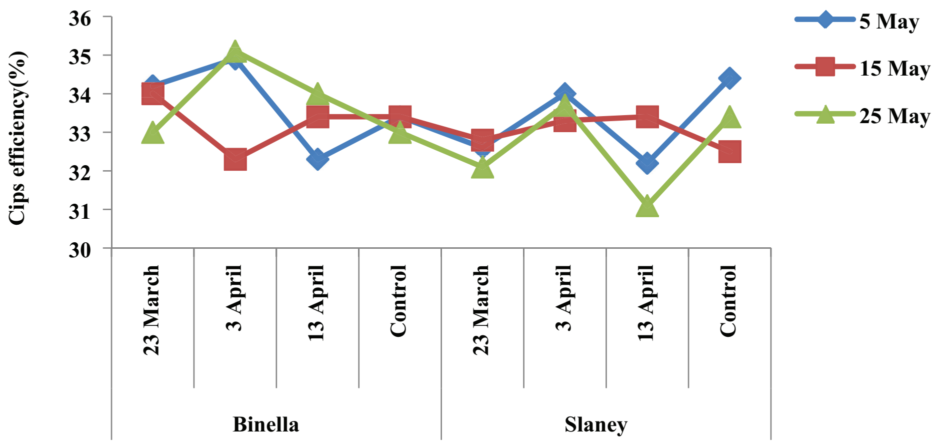

Figure 4.
Pre-sprouting Date × Planting Time × Variety in Terms of Chips Productivity in the Average of Study Years.

by April 13 (12.0%), April 3 (11.7%), and control (11.6%) treatments (Table 2).

According to planting times, the highest protein content was detected in May 25 (12.2%) plantings, followed by May 15 (11.8%) and 5 (11.6) plantings (Table 2). The results obtained from the experiment were not similar to the results of Prosba-Bialoczyk (1989).

There was a significant difference ($p < .01$) in terms of protein content between cultivars. Protein content was determined as 12.2% in Binella variety and 11.5% in Slaney variety (Tables 1 and 2).

Due to the fact that the protein contents of the cultivars were not stable according to the planting times in the average of years caused the year × planting time × variety interaction to be statistically significant ($p < .05$) (Table 1, Figure 2). Also, the protein content of the varieties did not show stability according to the pre-sprouting dates and planting times caused the pre-sprouting date × planting time × variety interaction to be statistically significant ($p < .05$) (Table 1, Figure 3).

Chips Yield

There was a statistically significant difference ($p < .01$) between experiment years in the sense of chips yield (Table 1). Chips yield was 34.6% in the first study year and 32.0% in the second year (Table 2).

In terms of chip yield, there was no significant difference between pre-sprouting and planting times and cultivars (Table 1).

According to the pre-sprouting times, the highest chip yield was determined in March 23 (33.7%), followed by control (33.4%), April 3 (33.2%), and April 13 (32.9%) pre-sprouting treatments (Table 2). The results obtained from the experiment were similar to the results reported by Kara et al. (2002).

According to the planting times, the highest chip yield was determined in the May 5 (33.5%) planting, followed by the May 15 and 25 (33.2%) plantings (Table 2). The results obtained from the experiment did not show similarity with the results reported by Günel (1976).

Chip yield was determined as 33.5% in the Binella variety and 33.2% in the Slaney variety.

Due to the fact that the chips yield of the cultivars did not show stability according to the pre-sprouting dates and planting times caused the pre-sprouting date × planting time × variety interaction to be statistically significant ($p < .05$) (Table 1, Figure 4).

Oil Absorption Ratio of Chips (%)

There was no statistically significant difference between the years, pre-sprouting, and planting times in terms of the oil absorption ratio of the chips, while it was statistically significant ($p < .05$) between varieties (Table 1).

As the average experiment factors, the oil absorption ratio of chips was 31.7% in 2015 and 32.0% in 2016, the difference between years was not found statistically significant (Tables 1 and 2).

According to the pre-sprouting dates, the highest oil absorption rate was determined in the March 23 and April 13 (32.3%), followed by control (31.7%) and April 13 (31.1%) treatments (Table 2). The results from the experiment were not similar to the results reported by Kara et al. (2002) and Kara and Unal (1991).

In terms of the oil absorption rate of chips, according to planting times, the highest oil absorption rate was determined in May 15, followed by May 5 (32.1%) and 25 (31.3%) plantings. In similar studies (Günel, 1976), it was reported that planting time had no effect on the oil absorption rate of the chips.

Oil absorption rates of chips were determined as 31.1% in the Binella variety and 31.7% in the Slaney variety (Table 2).

Due to the fact that the oil absorption ratio of the chips did not show stability according to the pre-sprouting dates on the average of the years caused the year × pre-sprouting date × variety interaction to be statistically significant ($p < .05$) (Table 1, Figure 5).

Conclusion

As a result, although there is no difference between pre-sprouting and planting times, there were differences between cultivars in terms of pre-sprouting time and planting time for high chips productivity and chips efficiency and low oil absorption rate of chips, and accordingly, among the examined cultivars, Slaney cultivar took longer time than the other cultivars. İt has been suggested that a period of pre-sprouting should be required and a later planting should be done.

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Determination of Forage Quality Properties of Plant Parts in Different Amaranth Varieties Cultivated Under Irrigated and Rainfed Conditions

Sulu ve Kuru Koşullarda Yetiştirilen Farklı Amarant Çeşitlerinde Bitki Kısımlarının Yem Kalite Özelliklerinin Belirlenmesi

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ABSTRACT

There is not enough information about how the feed quality changes according to plant parts and growing conditions in Amaranth species used as an alternative feed source. For this purpose, a three-replication study was conducted in randomized blocks according to the split plot design to determine the feed value of leaves, clusters and stems of Helios, Sterk and Ultra cultivars grown under irrigated and dry conditions in 2017-2018. The results of the study showed that the highest crude protein (HP), dry matter digestibility (KMS), metabolic energy (ME), relative feed value (NYD) and lowest natural solvent insoluble fiber (NDF) and acid solvent insoluble fiber (ADF) contents. showed that it was obtained from Ultra grown in irrigated conditions. On the other hand, the highest cluster and stem HP ratio was determined in Helios grown under irrigated conditions, while the highest cluster and stem HP were determined in KMS, ME and NYD cultivars grown in irrigated Ultra and Helios grown in dry conditions. In addition, HP, KMS, ME and NYD of leaves were higher than clusters and stems, whereas NDF and ADF contents were lower, respectively. As a result, it was revealed that the leaves and inflorescences of the examined cultivars produced a higher quality forage material under irrigated conditions, while the stems produced a lower quality forage material in dry (except HP).

Keywords: Amaranth species, feed quality, growing conditions, morphological parts

ÖZ

Alternatif yem kaynağı olarak kullanılan Amarant türlerinde yem kalitesinin bitki kısımları ve yetişme koşullarına göre nasıl bir değişim gösterdiği konusunda yeterli bilgi bulunmamaktadır. Bu amaçla, 2017-2018 yıllarında sulu ve kuru koşullar altında yetiştirilen Helios, Sterk ve Ultra çeşitlerinin yaprak, salkım ve sapların yem değerini belirlemek için tesadüf bloklarında bölünmüş parseller deneme desenine göre üç tekerrürlü bir çalışma yürütülmüştür. Araştırma sonuçları en yüksek ham protein (HP), kuru madde sindirilebilirliği (KMS), metabolik enerji (ME), nispi yem değeri (NYD) ile en düşük doğal çözücülerde çözünemeyen lif (NDF) ve asit çözücülerde çözünemeyen lif (ADF) içeriklerinin sulu koşullarda yetiştirilen Ultra'dan elde edildiğini gösterdi. Diğer taraftan en yüksek salkım ve sap HP oranı sulu koşullarda yetiştirilen Helios'da belirlenirken, en yüksek salkım ve sap KMS, ME ve NYD ise suluda yetiştirilen Ultra ile kuruda yetiştirilen Helios çeşitlerinde tespit edildi. Ayrıca yaprakların HP, KMS, ME ve NYD sırasıyla salkım ve saplardan daha yüksek, oysa NDF ve ADF içerikleri ise daha düşük bulundu. Sonuç olarak incelenen çeşitlerin yaprak ve salkımları sulu koşullar altında daha yüksek kalitede, sapları ise kuruda (HP hariç) daha düşük kalitede bir yem materyali ürettiği ortaya konulmuştur. sapları ise kuruda (HP hariç) daha düşük kalitede bir yem materyali ürettiği ortaya konulmuştur.

Anahtar Kelimeler: Amarant türleri, *yem kalitesi, yetişme koşulları, morfolojik kısımlar*

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Introduction

Knowledge of feed quality is as important as the amount of feed given to animals for achieving high animal product performance. Because quality of the fodder crop is defined as the ratio of transformation of the consumed feed to the animal product, which varies as to nutritional value and digestibility of the feed (Collins & Fritz, 2003). Nutritional value of the feed and its digestibility are significantly affected by environmental factors (climate, soil, etc.), plant characteristics (species, variety, maturity, etc.), and cultural practices (irrigation, fertilizing, etc.) (Keskin et al., 2021; Önal Aşçı & Acar, 2018; Tan & Temel, 2019; Temel & Tan, 2020; Temel & Yolcu, 2020). In general, anatomical, morphological, and chemical structures of plants may differ among species, varieties, and plant parts (Fales & Fritz, 2007). In studies conducted on different forage plant species and varieties, it was revealed that leaves contain two to three times more crude protein and lower acid detergent fiber (ADF) and neutral detergent fiber (NDF) ratios than the stems (Fales & Fritz, 2007; Hatfield et al., 2007). For example, in the quinoa plant that is considered as a feed source, it was reported that the panicles and, particularly, the leaves had at least three times higher crude protein (CP), dry matter digestible (DMD), metabolic energy (ME), and relative feed value (RFV) than that of the stems, while they had at least three times lower NDF and ADF contents (Temel & Keskin, 2020). In addition, scarcity and abundance of water in cultural practices may positively or negatively affect the quality of the feed by stressing out the plants (Buxton & Fales, 1994).

Amaranth (*Amaranthus* spp.), which can adapt well to different environmental conditions, poor soil, and scarcity of water, is a pseudo cereal with high nutritional value (Pospišil et al., 2009). Most of the species in this genus show weed characteristics (Khan et al., 2019); however, they are widely used in human nutrition because of their highly nutritional grains and leaves (Adhikary et al., 2020; Alegbejo, 2013; Amicarelli & Camaggio, 2012). The interest in amaranths has also been significantly rising in recent years due to its high yield of high nutritional forage (Peiretti, 2018), and all vegetative parts of the plant (stem, leaves, and panicles) are preferred as alternative feed sources in animal nutrition in the forms of fresh or dried forage, silage, and grain feed (Leukebandara et al., 2019; Sarmadi et al., 2016; Svirskis, 2003; Temel et al., 2020). On the other hand, although nutritional value and digestibility of amaranths, which are harvested as a whole plant, vary according to species, varieties, sowing frequency, fertilizer applications, and development stages (Keskin et al., 2020; Leukebandara et al., 2015; Rahnama & Safaeie, 2017), it was demonstrated that the feed quality is higher than the widely grown grain and many fodder species and is sufficient for animal feeding (Pond & Lehmann, 1989; Pospišil et al., 2009; Sleugh et al., 2001). However, it is seen that the number of research for determining the feed quality of the plant parts (leaf, panicle, and stem) is less and the obtained results are generally from studies conducted by considering only a single growing condition (irrigated) (García-Pereyra, 2009; Svirskis, 2003). Therefore, there are no studies that are conducted to analyze the feed quality characteristics of the varieties belonging to *Amaranthus caudatus*, *Amaranthus hiybridus*, and *Amaranthus paniculatus* × *Amaranthus nutans* species grown in irrigated and rainfed farming systems by considering different plant parts.

The present research is planned with the aim of determining the changes in feed quality of varieties belonging to *Amaranthus spp.* according to different growing conditions and plant parts. In this way, besides the contribution of plant parts to the feed quality, appropriate growing conditions and varieties with the highest feed quality were determined.

Methods

The research was carried out in the Agricultural Research and Application Center trial area of a university, located at an altitude of 876 m, between 2017 and 2018. The region where the study was conducted has Turkey's most arid climate with low annual rainfall and high evaporation ratio. Looking at some climatic values of the research area, total precipitation, average temperature, and relative humidity according to long-year averages were measured as 267.6 mm, 12.4°C, and 54.5%, respectively. In 2017 and 2018 during which the experiment was carried out, average annual temperatures were recorded as 12.4°C and 15.1°C, average relative humidity at 58.4% and 60.0%, and annual precipitation amounts as 220.8 mm and 280.0 mm, respectively. According to this data, it can be seen that 2017 was drier (220.8 mm), while there was more rainfall (280.0 mm) in 2018, according to long-year averages (267.6 mm). Moreover, average temperature (15.1°C) and rainfall (280.0 mm) in 2018 when the trial conducted was measured to be higher than those (12.4°C and 220.8 mm) in 2017 (MGM, 2019).

More than one-third of the Iğdır plain soils have lost their productivity due to salinity and remained out of production (Temel & Şimşek, 2011). Similar soil structure is also found in the field of Agricultural Research and Application Center. However, while selecting the trial area, such areas with extremely saline soil characteristics were avoided. In both research years, sufficient amount of soil samples (4.0 kg) was taken by a hole digger from different points (0–30 cm deep) to represent the research area before sowing, and the analyses were carried out at the Research Laboratory Practice and Research Center of a university. The findings of the analysis revealed that the soils had a clay-loam texture, being a medium alkaline character (pH: 8.45), with low salt (1.43 dS/m), organic matter (1.06%), available potassium (1.66 ppm) content, very low phosphorus (2.29 ppm), and medium lime (10.7%), medium calcium (15 ppm), and magnesium (6.2 ppm) content (Ulgen & Yurtsever, 1995). In addition, the field capacity of the trial site soils was measured as 26.0% and the wilting point as 9.1%. Helios, Sterk, and Ultra varieties and leaves, stems, and panicles of these varieties were used as plant material while irrigating and rainfed farming conditions were used as trial materials in the research.

Helios variety with light green leaves is a type of grain with high-fat content that belongs to *A. caudatus* (Yaroshko & Kuchuk, 2018). Sterk was developed as a variety resistant to high humidity and temperature stress as a result of mutation breeding in Russia. It is a variety developed in 1992 by applying chemical mutagens to hybrid seeds of *A. paniculatus* × *A. nutans* (Jafari et al., 2018). Ultra, on the other hand, is a variety belonging to *A. hybridus* species which is developed for short vegetation periods. Its leaves are light green and the seeds are white. It was registered in Ukraine in 1998 (Goptsiy et al., 2008).

The experiment was established on randomized complete block design with three replicates under irrigated and rainfed conditions. Area of each plot was set to 9.8 m^2 (3.5 m × 2.8 m) by leaving 1.2 m spaces between blocks. The sowings were made by hand into furrows of 1.5 cm sowing depth prepared by a marker, with 70 cm row spacing and 15 cm intra-row spacing (Svirskis, 2003). In the first year, sowings were carried out on April 14, 2017, and in the second year, sowings were carried out on March 25, 2018. Soil and climate conditions unsuitable for sowing were the reason for the difference in sowing dates. Fertilization was carried out during the seedbed preparations by applying 50 kg pure N (21% ammonium sulfate) and 100 kg pure P_2O_5 (46% triple superphosphate) per ha. Moreover, an additional 50 kg of pure N (21% ammonium sulfate) per ha was also applied when plants reached 30 cm of height (Myers, 1998). In addition to the existing rainfall in dry conditions, the development of the plant was achieved without any irrigation. In irrigation conditions, after determining the field capacity (26%) and the wilting point (9.1%) of the soil, irrigation was started when 50.0% (8.45%) of the available water holding capacity (16.9%) was consumed. The moisture content of the existing soil was followed by the soil moisture meter. Irrigation was started with the sprinkler irrigation system when the moisture content in the soil was seen as 17.55% in the soil moisture meter. Irrigation was terminated when the moisture content of the soil at a depth of 30 cm reached the field capacity (26.0%). During the growing period under irrigated conditions, the plants were irrigated four times in 2017 and five times in 2018. Moreover, weeds detected in the trial area were controlled by hand-picking and by hoeing. Harvests in all varieties were done by hand at the beginning of flowering at a 7.5 cm soil level (Fazaeli et al., 2011; Leukebandara et al., 2015). However, harvests were carried out on different dates as to variety, year, and growing conditions. In both years, Ultra was the first variety to reach harvest maturity under rainfed conditions (on July 1, 2017, in the first year and on June 20, 2018, in the second year) and was followed by Sterk and Helios, respectively, within 10-day intervals. In addition, varieties grown under irrigated conditions were harvested 1 week later, on average, than varieties grown under rainfed conditions in both years.

During the harvest period, 10 randomly selected plants in the harvest area were cut and separated from stems, leaves, and panicles. The separated parts were first dried in open air for 3–4 days and then in a drying oven set at 70°C until their weights were stabilized. After that, dried samples were prepared for chemical analyses by grinding in a mill with a sieve diameter set at 1 mm. Crude protein content of plant parts was found by multiplying the N% ratio determined by Micro Kjeldahl method by the coefficient of 6.25 (AOAC, 1997). Acid detergent fiber and neutral detergent fiber contents were determined by the method developed by Van Soest et al. (1991). Dry matter digestibility (DMD = (88.9-(0.779×ADF %)) and relative feed value (RFV=(DMD×DMC)/1.29) were determined by the method suggested by Boman (2003), while metabolic energy (ME Mcal/kg = (0.821×DE Mcal/kg)) content was determined by the equation developed by Khalil et al. (1986). In addition, dry matter consumption (DMC = (120/NDF%)) and digestible energy (DE Mcal/kg = (0.27+0.0428×(DMD%))) values used in the formulas were calculated by the equation suggested by Fonnesbeck et al. (1984).

Statistical Analysis

The results were subjected to variance analyses according to split plots in randomized block design by using JMP 5.0.1 statistical software package, and the grouping of the means which were found to be significant was conducted by the LSD (Least Significant Difference) test.

Results

The results obtained in the study conducted to determine the nutritional contents of plant parts of different *Amaranth* spp. varieties cultivated under irrigated and rainfed conditions for 2 years were subjected to statistical analysis, and the significance levels and LSD values of the parameters examined are presented in Table 1.

Table 1.
LSD Values and Significance Levels of the Examined Parameters

Variation Sources	Leaf CP	Panicle CP	Stem CP	Leaf NDF	Panicle NDF	Stem NDF	Leaf ADF	Panicle ADF	Stem ADF
Y	.65**	n.s.	.94**	1.73**	.95**	.70**	n.s.	.61**	1.60**
GC	.65**	.64**	.94**	n.s.	n.s.	.70**	.44**	.61*	1.60**
Y × GC	.91*	n.s.	n.s.	2.44**	1.35*	1.00**	n.s.	n.s.	n.s.
V	.62**	.65**	n.s.	2.14*	1.09**	1.69**	.38**	.60**	1.18**
Y × V	.87**	.92**	1.15**	3.02**	1.55**	2.39*	.54**	.84**	1.67**
GC × V	.87**	.92**	n.s.	3.02**	1.55*	2.39**	.54**	.84**	n.s.
Y × GC × V	1.23*	1.31**	1.62*	n.s.	n.s.	n.s.	.76**	n.s.	2.36**
Variation Sources	**Leaf DMD**	**Panicle DMD**	**Stem DMD**	**Leaf ME**	**Panicle ME**	**Stem ME**	**Leaf RFV**	**Panicle RFV**	**Stem RFV**
Y	n.s.	.47**	1.25**	n.s.	.02**	.04**	22.5**	5.0**	4.6**
GC	.35**	.47*	1.25**	.01**	.02*	.04**	n.s.	n.s.	n.s.
Y × GC	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	31.8*	n.s.	6.5**
V	.29**	.46**	.92**	.01**	.02**	.03**	20.7**	5.7**	6.7**
Y × V	.41**	.65**	1.30**	.01**	.03**	.04**	29.3**	8.1**	9.5**
GC × V	.41**	.65**	n.s.	.01**	.03**	n.s.	29.3**	8.1**	9.5*
Y × GC × V	.59**	n.s.	1.84**	.02**	n.s.	.06**	41.5*	n.s.	n.s.

Note: **p* < .05, ***p* < .01.

ns = non-significant; Y = Year; GC = growing condition; V = variety; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; DMD = dry matter digestibility; ME = metabolic energy; RFV = relative feed value.

Mean leaf, panicle, and stem CP contents of plant parts of *Amaranth* spp. varieties grown under irrigated and rainfed conditions are given in Table 2. When Table 2 was examined, it was seen that the leaf and stem CP contents of the plants were higher in 2018 compared to 2017, and the leaf, panicle, and stem CP contents of the plants were higher under irrigated conditions. This may have resulted from the fact that plants exposed to water stress (in 2017 and in the dry) reached form maturity at an earlier stage. Because maturation in plants is accelerated by drought stress, which results in decreased intra-cell material such as CP and feed quality (Buxton & Fales, 1994). It was also reported in other studies conducted on different fodder crops that drought causes a decrease in CP ratio (Kuchenmeister et al., 2013; Pecetti et al., 2016). When evaluated in terms of varieties, the highest leaf CP ratio was determined in Ultra, and the highest panicle CP content was determined in Helios variety. The different morphological and genetic structures of the varieties may have caused this.

As a matter of fact, it was reported by Svirskis (2003) that CP contents of the plant parts vary according to genetic characteristics in varieties of *A. cruentus* species grown under natural precipitation conditions, with the highest stem (7.1%), leaf (20.3%), and panicle (19.6%) CP ratios obtained from Raudonukai variety. In another study conducted by considering different plant densities, it was stated that CP ratios of leaves and stems in five genotypes belonging to two amaranth species varied between 15.3%–24.8% and 4.8%–9.5%, respectively (García-Pereyra, 2009).

It can be seen from Table 2 that, compared to other varieties, CP content of leaves, panicles, and stems of Helios variety grown in 2017 has shown a lower decrease under rainfed conditions in comparison with irrigated conditions. This may be the cause of the significance of triple interaction in terms of leaf, panicle, and stem CP. The highest leaf CP content was determined in Ultra variety (23.79%) grown under irrigated conditions in 2018, while the highest panicle (21.57%) and stem (13.73%) CP contents were determined in Helios variety grown under irrigated conditions in 2017 and 2018, respectively. These results showed that the leaf, panicle, and stem CP contents of the plants were higher under irrigated conditions compared to rainfed. As reported by Stordahl et al. (1999), different responses to agronomic conditions and annually changing climatic features by varieties with different genetic potential may be a reason for this result. In addition, the fact that 2017 was drier than 2018 and that plants grown under rainfed conditions mature at an earlier period compared to the irrigated conditions may have caused this situation.

Mean leaf, panicle, and stem NDF ratios of *Amaranth spp.* varieties planted under different growing conditions are included in Table 3. When Table 3 was examined, it was seen that the highest leaf, panicle, and stem NDF contents were determined in 2017. In terms of growing conditions, only the stem NDF ratio was found to be important and the highest ratio was determined in the rainfed. These differences may have been since 2017 was drier compared to 2018 and that the stress conditions were higher under rainfed conditions than the irrigated conditions. In addition, sowings were executed lately in 2017 in comparison to 2018. This resulted in more exposure of plants in 2017 to higher temperatures at earlier stages of development.

As a matter of fact, increasing temperature and drought accelerate the maturation of plants and this causes the formation of thick cell walls, thick cuticula, and highly lignified tissues within the plant (Buxton & Fales, 1994). Hence, it was reported by Svirskis (2003) that stem, leaf, and panicle (flower) NDF contents of varieties belonging to *A. cruentus* species vary and the highest stem (37.0%), leaf (14.0%), and panicle (26.9%) NDF ratios were obtained from Raudonukai variety. When evaluated in terms of varieties, the highest leaf (26.75%) and panicle (39.07%) NDF ratios were determined in Sterk, and the highest stem NDF ratio (46.64%) was determined in Ultra (Table 3). This may be due to the different genetic and morphological structures of the varieties. As a matter of fact, in previous studies, it was revealed that NDF contents of amaranths harvested as a whole plant vary between 13.8% and 47.0% according to growing conditions and varieties (Fazaeli et al., 2011; Písaríková et al., 2006; Pond & Lehmann, 1989; Sleugh et al., 2001). In the present study, it was observed that, except stem contents, leaf, and panicle NDF contents of amaranth varieties agreed with the literature and at the desired levels. As a matter of fact, it is desired to have NDF ratio below 40.0% in roughages (Rivera & Parish, 2010).

Effects of all binary interactions were found to be significant on the leaf, panicle, and stem NDF ratios (Figure 1).

Table 2.
The Changes in the Crude Protein (CP) Content of the Plant Parts According to Years, Growing Conditions, and Varieties (%)

Year	Variety	Leaf CP Ratio		Year Mean	Panicle CP Ratio		Year Mean	Stem CP Ratio		Year Mean
		Irrigated	Rainfed		Irrigated	Rainfed		Irrigated	Rainfed	
2017	Helios	17.97^{cd}	16.87^{d}	16.02^{b}	21.57^{a}	20.17^{b}	17.51	11.57^{cde}	10.67^{de}	10.05^{b}
	Sterk	17.23^{d}	12.43^{ef}		21.10^{ab}	13.70^{e}		11.43^{cde}	7.60^{g}	
	Ultra	18.03^{cd}	13.60^{e}		16.20^{d}	12.30^{f}		10.17^{ef}	8.87^{fg}	
2018	Helios	16.83^{d}	11.83^{f}	17.38^{a}	20.28^{ab}	16.91^{cd}	17.33	13.73^{a}	10.49^{de}	12.63^{a}
	Sterk	19.17^{bc}	13.29^{e}		16.12^{d}	11.76^{f}		13.52^{ab}	12.00^{bcd}	
	Ultra	23.79^{a}	19.38^{b}		21.37^{ab}	17.55^{c}		13.36^{ab}	12.66^{abc}	
GC mean		18.84^{a}	14.57^{b}		19.44^{a}	15.40^{b}		12.30^{a}	10.38^{b}	
Variety mean		Helios	15.87^{b}		Helios	19.73^{a}		Helios	11.62	
		Sterk	15.53^{b}		Sterk	15.67^{c}		Sterk	11.14	
		Ultra	18.70^{a}		Ultra	16.86^{b}		Ultra	11.26	

Note: a, b, c, d, e, f, g Values represented by the same letters do not differ statistically.
GC = growing condition.

Table 3.
The Changes in the Neutral Detergent Fiber (NDF) Contents of the Plant Parts According to Years, Growing Conditions, and Varieties (%)

Year	Variety	Leaf NDF Ratio		Year Mean	Panicle NDF Ratio		Year Mean	Stem NDF Ratio		Year Mean
		Irrigated	Rainfed		Irrigated	Rainfed		Irrigated	Rainfed	
2017	Helios	21.20	24.53	27.13^{a}	37.00	37.00	39.89^{a}	43.63	39.60	45.68^{a}
	Sterk	28.43	32.00		41.37	41.63		45.43	45.57	
	Ultra	24.73	31.87		39.80	42.53		47.76	52.10	
2018	Helios	25.69	22.85	23.20^{b}	39.13	35.51	35.42^{b}	38.17	41.39	40.93^{b}
	Sterk	26.13	20.42		36.97	36.30		36.29	43.03	
	Ultra	19.95	24.17		32.11	32.47		39.85	46.84	
GC mean		24.36	25.97		37.73	37.58		41.86^{b}	44.75^{a}	
Variety mean		Helios	23.57^{b}		Helios	37.16^{b}		Helios	40.70^{c}	
		Sterk	26.75^{a}		Sterk	39.07^{a}		Sterk	42.58^{b}	
		Ultra	25.18^{ab}		Ultra	36.73^{b}		Ultra	46.64^{a}	

Note: ^{a,b,c}Values represented by the same letters do not differ statistically.
GC = growing condition.

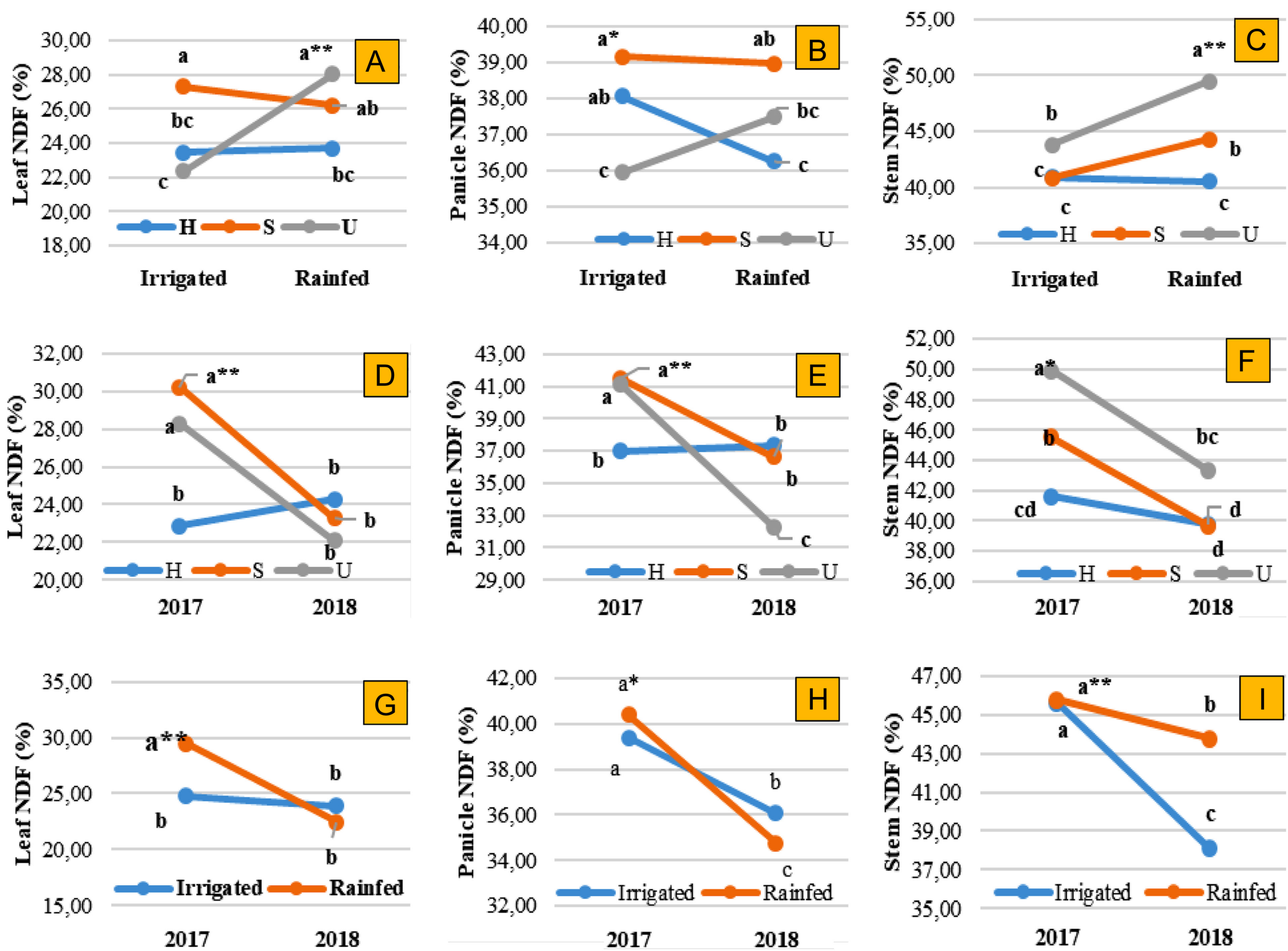

Figure 1.
*The Effect of Growing Condition × Variety (a, b, c), Year × Variety (d, e, f), and Year × Growing Condition (g, h, i) Interactions on the Leaf, Panicle, and Stem NDF. ** and * Plots Followed by Different Letters Are Significant at p ≤ .01 and p ≤ .05, respectively. H, Helios; S, Sterk; U, Ultra.*

The highest NDF contents in terms of growing condition × variety interaction were determined in Ultra grown under rainfed conditions and Sterk grown under irrigated conditions (Figure 1a), while the highest panicle and stem NDF ratio were detected in Sterk grown under irrigated conditions and Ultra grown under rainfed conditions, respectively (Figure 1b and c). These differences may have resulted from the differences in anatomical and chemical composition structures of the feed tissues due to variety and environmental conditions and due to varieties reaching harvest maturity at different dates. When evaluated in terms of year × variety interaction, while the leaf NDF content of Helios variety increased 6.12% in 2018 compared to 2017, Sterk and Ultra varieties were decreased by 22.97% and 21.54%, respectively (Figure 1d). When examined in terms of panicle NDF ratios, no change as to years in the panicle NDF content of Helios variety was observed, however, significant decreases were observed in panicle NDF ratios of the other two varieties in 2018 (Figure 1e). Finally, looking at stem NDF ratios, while a lower percentage of decrease (4.42 %) was observed in the stem NDF content of Helios in 2018 when compared to 2017, higher decreases were seen in stem NDF contents of Sterk (12.84%) and Ultra (13.20%) varieties (Figure 1f). These differences caused the year × variety of interaction to be significant, which may be due to differences in genetic structures of the varieties and to the fact that 2017 was drier than 2018. When evaluated in terms of year × growing condition interaction, the highest leaf NDF ratio was determined under rainfed conditions in 2017 (Figure 1g), while the highest panicle and stem NDF content were determined under rainfed and irrigated conditions in 2017 (Figure 1h and i). These differences may have been due to the fact that 2017 was drier compared to 2018 and that the stress conditions were higher under rainfed conditions than the irrigated conditions.

Mean leaf, panicle, and stem ADF ratios of *Amaranth spp*. varieties grown under irrigated and rainfed conditions are presented in Table 4. When Table 4 was examined, it was determined that the panicle and stem ADF ratios were higher in 2017 and the ADF content of the leaf and panicle in rainfed conditions. This may have been due to more water scarcity in 2017 and dry conditions. Because increasing drought stress accelerates the maturation of plants and, consequently, the increase of structural carbohydrates such as cellulose and hemicelluloses (Buxton & Fales, 1994). When evaluated in terms of varieties, it was determined that late varieties have higher leaf and panicle ADF and lower stem ADF content than the early variety Ultra (Table 4). As a matter of fact, since late-maturing varieties are exposed to higher temperatures than the early ones, their fiber content increases (Collins & Fritz, 2003).

When Table 4 was examined, it was observed that the ADF ratios of the varieties in leaf, panicle, and stem differed, and these rates were at the levels (under 31%) that should be in quality roughages (Rivera & Parish, 2010). It was also reported in another study conducted on different amaranth species and varieties that leaf and stem ADF contents varied between 17.4%–25.2% and 48.8%–59.4%, respectively (García-Pereyra, 2009). Moreover, it was also reported by Sleugh et al. (2001) and Olorunnisomo (2010) that ADF ratios varied between 16.8% and 32.9% in varieties belonging to *A. cruentus* and *A. hybridus* harvested as a whole plant at different stages of development. However, these results were higher than the findings of our study. These differences are thought to be caused by the differences in investigated varieties, regional climate conditions, and agronomic applications.

While the panicle ADF content of the Helios variety decreased in dry conditions according to the irrigated conditions, the panicle ADF rate of the Ultra variety increased (Figure 2a). This may be caused by the fact that the varieties reacted differently to growing conditions and that the Helios variety was later than Ultra. This has resulted in the significance of growing condition × variety interaction (Figure 2a). When year × variety interaction was evaluated in terms of panicle ADF ratio, the highest panicle ADF content was observed in Sterk sown in 2017, while the lowest content was observed in Ultra grown in 2018 (Figure 2b). Possible reasons for these findings may be the fact that the varieties reached harvest maturity on different dates and that 2017 was drier than 2018. Hence, Sterk is a late variety and Ultra is the earliest variety among the studied varieties. The highest leaf ADF content, which is important in terms of year × growing condition × variety interaction, was determined in Helios (12.45%) grown in rainfed conditions in 2018, and the highest stem ADF content was measured in Ultra (40.77%) cultivated under irrigated conditions in 2017 (Table 4). The fact that the leaves and stems of the varieties have different tissue organization according to the years

Table 4.
The Changes in the Acid Detergent Fiber (ADF) Contents of The Plant Parts According to Years, Growing Conditions, and Varieties (%)

Year	Variety	Leaf ADF Ratio		Year Mean	Panicle ADF Ratio		Year Mean	Stem ADF Ratio		Year Mean
		Irrigated	Rainfed		Irrigated	Rainfed		Irrigated	Rainfed	
2017	Helios	10.33^{de}	10.93^{bcd}	10.53	22.50	21.80	22.51^{a}	32.23^{bcd}	26.57^{gh}	33.17^{a}
	Sterk	11.10^{bc}	10.47^{cde}		23.77	24.23		33.73^{bc}	31.63^{cd}	
	Ultra	9.50^{f}	10.87^{cd}		20.17	22.60		40.77^{a}	34.07^{b}	
2018	Helios	9.97^{ef}	12.45^{a}	10.11	23.01	21.45	19.27^{b}	28.99^{ef}	27.92^{fg}	28.25^{b}
	Sterk	10.75^{cd}	11.64^{b}		18.87	19.13		31.00^{de}	24.64^{h}	
	Ultra	7.67^{h}	8.19^{g}		14.46	18.67		28.81^{efg}	28.13^{fg}	
GC mean		9.89^{b}	10.76^{a}		20.46^{b}	21.31^{a}		32.59^{a}	28.83^{b}	
Variety mean		Helios	10.92^{a}		Helios	22.19^{a}		Helios	28.93^{c}	
		Sterk	10.99^{a}		Sterk	21.50^{b}		Sterk	30.25^{b}	
		Ultra	9.06^{b}		Ultra	18.97^{c}		Ultra	32.94^{a}	

Note: $^{a, b, c, d, e, f, g}$ Values represented by the same letters do not differ statistically.
GC = growing condition.

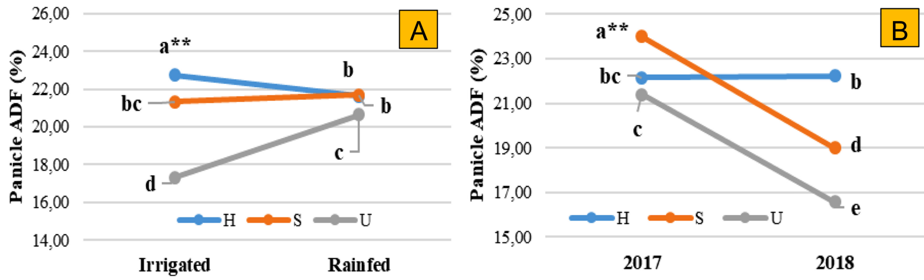

Figure 2
*The Effect of Growing Condition × Variety (a) and Year × Variety (b) İnteractions On The Panicle Acid Detergent Fiber (ADF). **Plots Followed by Different Letters Are Significant at p ≤ .01. H, Helios; S, Sterk; U, Ultra.*

and growing conditions (Önal Aşcı & Acar, 2018) may have caused this. In addition, it may be due to the fact that Helios is a late variety compared to other varieties and that there are more stress conditions under rainfed.

Dry matter digestibility and metabolic energy contents are calculated considering ADF ratios of the feed. According to this calculation, feeds with higher ADF content have lower DMD and ME values, and vice versa. It was also seen in this study that leaf, panicle, and stem DMD-ME contents were in compliance with the ADF values. As a matter of fact, when Table 4 was examined, it was determined that 2018, which has a lower panicle and stem ADF ratio, had a higher DMD (Table 5) and ME content (Table 6) compared to 2017.

Similarly, irrigated conditions with lower leaf and panicle ADF ratio had higher DMD (Table 5) and ME content (Table 6) than rainfed ones and dry conditions with lower stem ADF ratio than irrigated conditions. Because drought stress causes an increase in lowly digestible fractions such as cell walls and a decrease in easily digestible compounds such as non-structural carbohydrates and CP (Önal Aşcı and Acar, 2018). Hence, it was expressed that the forage plants grown in dry conditions had a thicker layer of cutin on the epidermis compared to those grown in the cool season and, therefore, their digestibility decreased (Hatfield et al., 2007).

When evaluated in terms of varieties, the highest leaf and panicle DMD-ME content was determined in Ultra, which is the early variety, and the stem DMD-ME value was determined in Helios, which is a late variety. This might be caused by Ultra being an early variety, compared to other varieties in the research, which reached harvesting maturity at an earlier date. Early maturing varieties will have lower fiber content and higher amount of structural carbohydrates compared to late varieties since they are exposed shorter to higher temperatures (Collins & Fritz, 2003). In a study conducted with amaranth species under rainfed conditions, stem, leaf, and panicle (flower) DMD contents of varieties were reported to vary between 57.5%–62.2%, 70.4%–71.0%, and 58.5%–60.9%, respectively (Svirskis, 2003). It was reported in another study that *A. hypochondriacus*, which was harvested as a whole plant at the beginning of flowering under irrigated conditions, had a content of 2.82 Mcal/kg ME (Fazaeli et al., 2011). In this study, it was also observed that ME and DMD of the varieties of amaranth species varied according to plant parts. Metabolic energy and dry matter digestibility contents were found to be sufficient and the findings were in agreement with the literature.

In the present study, panicle DMD and ME contents were found to be significant in terms of growing condition × variety interaction (Figure 3a and b). While panicle DMD and ME contents of Ultra and Sterk varieties were decreased under rainfed conditions compared to irrigated conditions, the DMD and ME contents of Helios variety also increased, which resulted in the significance of growing condition × variety interaction. This may be caused by Helios being a late variety and due to existence of more stress factors under rainfed conditions.

When examined in terms of year × variety interaction, panicle DMD and ME contents of Helios did not show a significant difference as to years, however, a significant increase was observed in

Table 5.
The Changes in the Dry Matter Digestibility (DMD) of the Plant Parts According to Years, Growing Conditions, and Varieties (%)

Year	Variety	Leaf DMD		Year Mean	Panicle DMD		Year Mean	Stem DMD		Year Mean
		Irrigated	Rainfed		Irrigated	Rainfed		Irrigated	Rainfed	
2017	Helios	80.87^{cd}	80.40^{def}	80.70	71.36	71.93	71.37^{b}	63.78^{efg}	68.20^{ab}	63.06^{b}
	Sterk	80.24^{ef}	80.76^{cde}		70.39	70.02		62.65^{fg}	64.26^{ef}	
	Ultra	81.49^{b}	80.43^{de}		73.19	71.31		57.14^{h}	62.35^{g}	
2018	Helios	81.13^{bc}	79.20^{g}	81.02	70.98	72.19	73.89^{a}	66.31^{cd}	67.15^{bc}	66.89^{a}
	Sterk	80.53^{de}	79.83^{f}		74.20	74.00		64.75^{de}	69.71^{a}	
	Ultra	82.92^{a}	82.26^{ab}		77.64	74.36		66.46^{bcd}	66.98^{bc}	
GC mean		81.20^{a}	80.52^{b}		72.96^{a}	72.30^{b}		63.52^{b}	66.44^{a}	
Variety mean		Helios	80.40^{b}		Helios	71.62^{c}		Helios	66.36^{a}	
		Sterk	80.34^{b}		Sterk	72.15^{b}		Sterk	65.34^{b}	
		Ultra	81.84^{a}		Ultra	74.12^{a}		Ultra	63.23^{c}	

Note: $^{a, b, c, d, e, f, g, h}$ Values represented by the same letters do not differ statistically.
GC = growing condition.

Table 6.
The Changes in the Metabolic Energy (ME) Contents of the Plant Parts According to Years, Growing Conditions, and Varieties (Mcal/kg)

Year	Variety	Leaf ME			Panicle ME		Year Mean	Stem ME		Year Mean
		Irrigated	Rainfed	Year Mean	Irrigated	Rainfed		Irrigated	Rainfed	
2017	Helios	3.06^{cd}	3.05^{de}	3.06	2.73	2.75	2.73^{b}	2.46^{efg}	2.62^{ab}	2.44^{b}
	Sterk	3.04^{ef}	3.06^{cd}		2.69	2.68		2.42^{fg}	2.48^{ef}	
	Ultra	3.09^{b}	3.05^{de}		2.79	2.73		2.23^{g}	2.42^{fg}	
2018	Helios	3.07^{bc}	3.00^{g}	3.07	2.71	2.76	2.82^{a}	2.55^{cd}	2.58^{bc}	2.57^{a}
	Sterk	3.05^{de}	3.03^{f}		2.83	2.82		2.50^{de}	2.67^{a}	
	Ultra	3.13^{a}	3.11^{ab}		2.95	2.83		2.56^{cd}	2.58^{bc}	
GC mean		3.08^{a}	3.05^{b}		2.79^{a}	2.76^{b}		2.45^{b}	2.56^{a}	
Variety mean		Helios	3.05^{b}		Helios	2.74^{c}		Helios	2.55^{a}	
		Sterk	3.04^{b}		Sterk	2.76^{b}		Sterk	2.52^{b}	
		Ultra	3.10^{a}		Ultra	2.83^{a}		Ultra	2.45^{c}	

Note: $^{a, b, c, d, e, f, g}$ Values represented by the same letters do not differ statistically.
GC = growing condition.

DMD and ME contents of Sterk and Ultra in 2018 (Figure 3c and d), which resulted in the significance of year × variety interaction. The fact that 2018 was a cooler year than 2017 and Ultra being an early variety compared to others may be accounted for as other causes behind this finding. The highest leaf DMD (82.92%) and ME (3.13 Mcal/kg) content, which are important in terms of year × growing condition × cultivar interaction, were determined in the Ultra variety grown under irrigated in 2018, and the highest stem DMD (69.71%) and ME (2.67 Mcal/kg) content in the Sterk variety grown under rainfed conditions in 2018 (Tables 5 and 6). The fact that leaf and stems have different tissue organization as to years and growing conditions may be a cause of this situation. Hence Stordahl et al. (1999) reported that vegetable-type amaranths had a more succulent body and leaf structure, and thus a higher digestibility than the grain-type amaranths harvested during the same period. In addition, DMD of the amaranths harvested as whole plants was reported to vary between 59.0% and 79.0% according to the growing conditions, development periods, species, and varieties (Fazaeli et al., 2011; Olorunnisomo, 2010; Rahnama & Safaeie, 2017; Sleugh et al., 2001).

Mean relative feed values of plant parts (leaf, panicle, and stem) according to years, growing conditions, and varieties are presented in Table 7. When Table 7 was examined, RFV of leaves, panicles, and stems was found higher in 2018 compared to 2017.

This may be due to the lower NDF and ADF ratios in 2018 compared to 2017 (Tables 3 and 4). When evaluated in terms of varieties, the highest leaf RFV was found in Helios (319.1) and Ultra

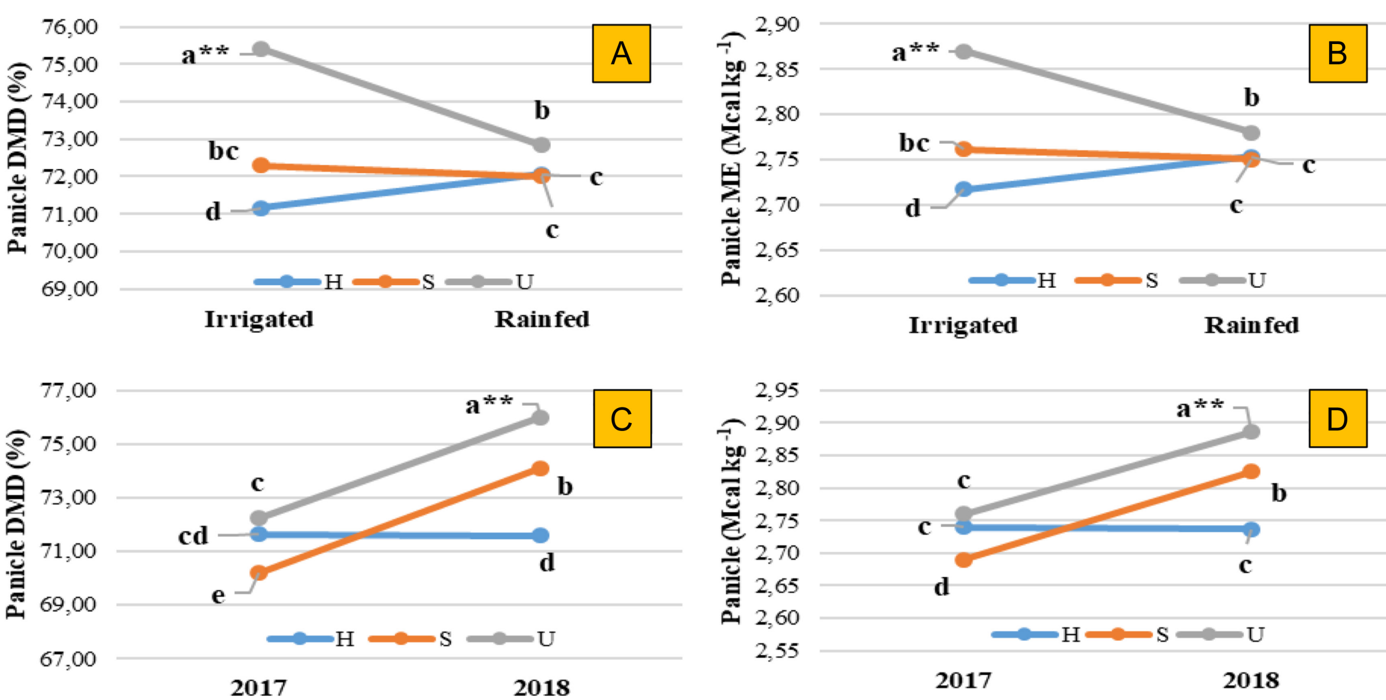

Figure 3
*The Effect of Growing Condition × Variety (a-b) and Year × Variety (c-d) Interactions on Panicle Dry Matter Digestibility (DMD) and Metabolic Energy (ME). **Plots Followed by Different Letters Are Significant at p ≤ .01. H, Helios; S, Sterk; U, Ultra.*

Table 7.
The Changes in the Relative Feed Values (RFV) of the Plant Parts According to Years, Growing Conditions, and Varieties

Year	Variety	Leaf RFV Irrigated	Leaf RFV Rainfed	Year Mean	Panicle RFV Irrigated	Panicle RFV Rainfed	Year Mean	Stem RFV Irrigated	Stem RFV Rainfed	Year Mean
2017	Helios	355.2^{ab}	304.9^{c}	284.5^{b}	179.6	180.9	167.1^{b}	136.0	160.2	129.7^{b}
	Sterk	262.9^{de}	235.5^{e}		158.3	156.4		128.3	131.2	
	Ultra	306.4^{c}	242.2^{e}		171.0	156.4		111.3	111.4	
2018	Helios	293.9^{cd}	322.7^{bc}	329.4^{a}	169.0	189.3	195.5^{a}	161.7	150.9	153.3^{a}
	Sterk	286.8^{cd}	364.2^{a}		186.8	189.9		167.9	150.7	
	Ultra	386.8^{a}	322.1b^{c}		225.1	213.1		155.4	133.2	
GC mean		315.3	298.6		181.6	181.0		143.4	139.6	
Variety mean		Helios	319.1^{a}		Helios	179.7^{b}		Helios	152.2^{a}	
		Sterk	287.3^{b}		Sterk	172.8^{c}		Sterk	144.5^{b}	
		Ultra	314.4^{a}		Ultra	191.4^{a}		Ultra	127.8^{c}	

Note: [a,b,c]Values represented by the same letters do not differ statistically.
GC = growing condition.

(314.4) and the highest panicle (191.4) and stem (152.2) RFV in Ultra and Helios varieties, respectively (Table 7). Differences in leaf, panicle, and stem tissue organization of the cultivars may have caused this. As a matter of fact, the chemical structure of the intracellular and cell walls (NDF and ADF) differs significantly depending on the tissue type and plant species (Zeng et al., 2017). These results obtained in the present study were found to be higher than the RFV (157.1–171.5) determined for amaranth species and varieties harvested as whole plants reported by Rahnama and Safaeie (2017). It is thought that this is caused by the differences in investigated varieties, regional climate conditions, and agronomic applications. As a result, these differences between years and varieties are thought to be caused by the NDF and ADF contents of the plant parts. Because RFV is calculated by using ADF and NDF values of the feed (Moore & Undersander, 2002). Therefore, the high NDF and ADF ratios decrease the RFV of the feed and vice versa.

Looking at Figure 4a, while panicle RFV of Sterk variety was found to be not differ according to irrigated and rainfed conditions, panicle RFV of Helios decreased under irrigated conditions in comparison to rainfed conditions and the panicle RFV of Ultra variety increased.

When evaluated in terms of stem RFV, while the stem RFVs of Sterk and Ultra varieties were decreased under rainfed conditions compared to the irrigated conditions, the stem RFV of the Helios cultivar increased (Figure 4b). This caused the panicle and stem RFV to be important in terms of growing condition × cultivar interaction. When analyzed in terms of year × variety interaction, it was seen that the panicle and stem RFV of Helios variety

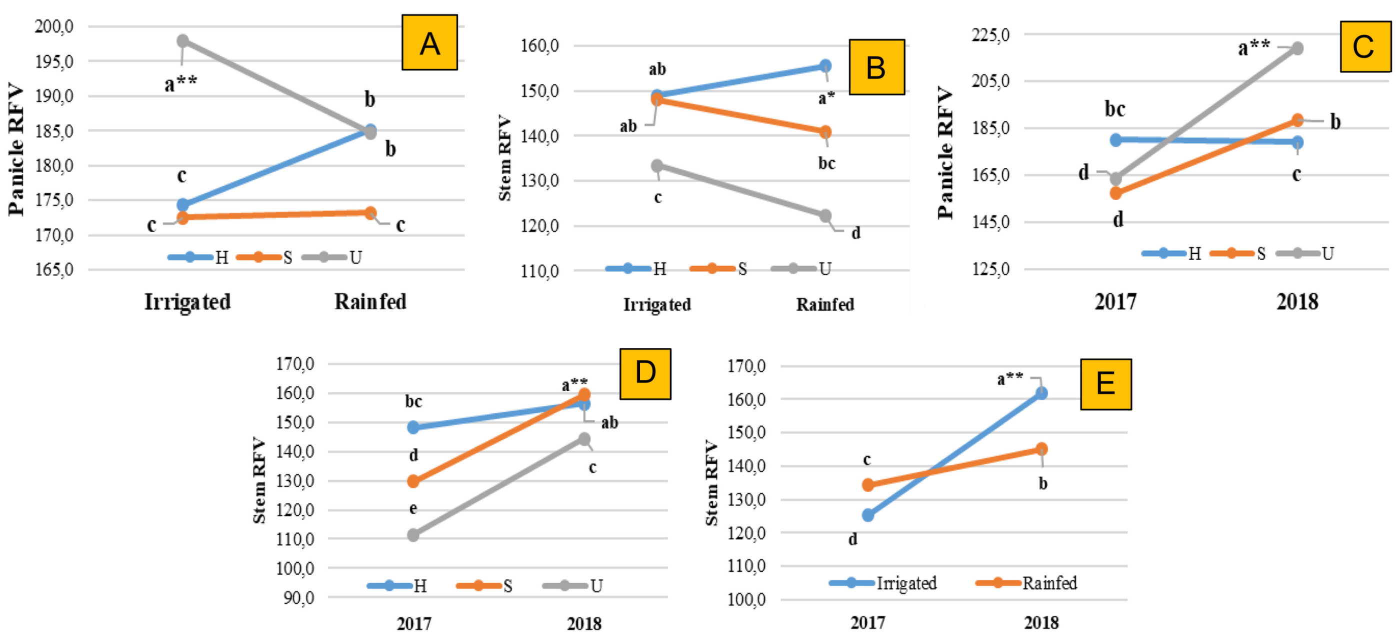

Figure 4
*The Effect of Growing Condition × Variety (a, b), Year × Variety (c, d), and Year × Growing Condition (e) Interactions on the Panicle and Stem Relative Feed Value. ** and *Plots Followed by Different Letters Are Significant at p ≤ .01 and p ≤ .05, respectively. H, Helios; S, Sterk; U, Ultra.*

does not vary as to years, while the panicle RFVs of Sterk and Ultra varieties increased significantly in 2018 (Figure 4c and d). Besides the varieties reacting differently to the growing conditions and climatic conditions that change according to years, the fact that 2017 was drier compared to 2018 and the existence of more stress factors under rainfed conditions may have caused this outcome. Because the late varieties will be exposed to higher temperatures longer than the early ones, their fiber content (NDF and ADF ratios) increases (Collins & Fritz, 2003). Similarly, increasing drought stress (under rainfed and in 2017) causes an increase in less digestible fibrous compounds (NDF and ADF), such as the cell wall in plants (Önal Aşcı & Acar, 2018). As a result, RFV of the panicle and stem decreases because of increasing NDF and ADF contents. In addition, the fact that 2018 was cooler compared to 2017 and the stress conditions were less in irrigated conditions than in dry conditions caused the year × growing condition interaction to be significant in terms of stem RFV (Figure 4e). As a matter of fact, plants in cool conditions with less stress factors have thinner cell walls and more intracellular substances (Hatfield et al., 2007; Önal Aşcı & Acar, 2018). Thus, the quality of the feed, and therefore the stem RFV, increases under such conditions. The leaf RFV was found to be significant in terms of year × growing condition × variety interaction, and the highest leaf RFV was determined in the Ultra (386.8) cultivated under irrigated conditions and Sterk (364.2) cultivated under rainfed conditions in 2018, whereas the lowest leaf RFV was detected in Sterk (235.5) and Ultra (242.2) varieties grown under rainfed conditions in 2017 (Table 7). This may be a result of 2017 being a drier year compared to 2018 and the existence of more stress factors under rainfed conditions. In addition, carrying out sowings at a later date in 2017 compared to 2018 caused plants to be exposed to higher temperatures during their early development stages.

Conclusion and Recommendation

As a result, the feed quality characteristics of the plant parts (leaf, panicle, and stem) of the amaranth varieties that were studied differed significantly according to the climatic and growing conditions. According to the 2-year means, the leaves of Helios and Sterk varieties, panicle of Sterk variety, and the stem quality values of Ultra and Helios varieties were the least varied according to growing conditions. In addition, considering the RFV, which is the indicator of feed quality, Ultra variety was observed to react more to changing climate conditions, with respect to other types. In addition, it was revealed that the leaves and panicles of the examined varieties produced a higher quality feed material under irrigated conditions but their stems (except CP) under rainfed conditions. As a result, it has been revealed that plant parts of Amaranth varieties can be a good alternative protein and fiber source in animal nutrition.

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Evaluation of Interactions Among Aphids, Endosymbionts, and Host Plants: A Foresight for the Future

Afitler, Endosimbiyontlar ve Konukçu Bitkiler Arasındaki İlişkilerin Değerlendirilmesi: Gelecek için Bir Öngörü

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ABSTRACT

Insects, the most common and most successful animals on earth, establish long-term and stable ecological relationships with bacteria. Aphids (Hemiptera: Aphididae) are an insect group of agricultural importance that can feed on many herbaceous, shrubs, and woody plants as hosts and are also in close relationship with endosymbiont bacteria. It is seen that aphid is going to further increase their current pest potential in the near future due to their high adaptability and rapid reproduction ability. In order to be effective and successful in the biological control of aphids, many features of aphids are required to be known and clarified. Therefore, determining the interactions among aphid, host plant, and endosymbiont in this relationship might make biological control of aphids more effective. In this review, what is known about the relationship among aphids, the primary endosymbiotic bacterium *Buchnera aphidicola,* and the host plant is examined, and the possibilities of using symbiont bacteria in the biological control of aphids are discussed.

Keywords: Aphid, biological control, *Buchnera aphidicola*, stress

ÖZ

Yeryüzündeki en yaygın ve en başarılı hayvanlar olan böcekler, bakterilerle uzun vadeli ve istikrarlı ekolojik ilişkiler kurarlar. Afitler (Yaprak bitleri), konak olarak birçok otsu bitki, çalı ve odunsu bitki ile beslenen, aynı zamanda endosimbiyont bakterilerle de yakın ilişki içinde olan, tarımsal öneme sahip bir böcek grubudur. Yaprak bitlerinin yüksek adaptasyon ve hızlı üreme yetenekleri nedeniyle yakın gelecekte mevcut zararlı potansiyellerini daha da artıracağı görülmektedir. Yaprak bitlerinin biyolojik mücadelesinde etkili ve başarılı olabilmek için yaprak bitlerinin birçok özelliğinin bilinmesi ve netleştirilmesi gerekmektedir. Bu nedenle, bu ilişkide yaprak biti, konak bitki ve endosimbiyont arasındaki etkileşimlerin belirlenmesi, yaprak bitleri ile biyolojik mücadeleyi daha etkin kılabilir. Bu derlemede, yaprak biti, birincil endosimbiyotik bakteri *Buchnera aphidicola* ve konak bitki arasındaki ilişki hakkında bilinenler incelenmekte ve yaprak bitlerinin bisyolojik kontrolünde simbiyotik bakterilerin kullanım olanakları tartışılmaktadır.

Anahtar Kelimeler: Afit, biyolojik mücadele, *Buchnera aphidicola*, stres

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Introduction

Aphids (Hemiptera: Aphididae) are insects of agricultural importance that feed on plant sap and can choose many plants as hosts. Since 2012, the studies about Turkey aphid fauna gradually increased and the number of aphid species in Turkey aphid fauna reached 604 species (Görür et al., 2022; Kök, 2021; Kök & Özdemir, 2021). Aphids seem to have the potential to become one of the most important pests of plants in the near future, due to their rapid growth characteristics and their high adaptability to survive in any environment where environmental conditions are suitable. For this reason, in order to be effective in the biological control against aphids, the physiological characteristics of aphids should be clarified in more detail. In addition, since knowing only the characteristics of aphids may be insufficient in effective control, it is necessary to know the effect on the food chain with the change of all living relationships and ecological characteristics related to aphids on the food chain. Most aphids harbor primary and secondary symbionts in specialized cells or body cavities. It has been reported by many studies that the basis of this association is nutrition, increasing the quality of host life under stress conditions and providing protection against predators and parasites (Dale & Moran, 2006; Dunbar et al., 2007; Tsuchida et al., 2011). Recent research, which will bridge the gap between mechanical and ecological approaches, shows that herbivores and their natural enemies interact with the environment and other living things (Coppola et al., 2018; Smith & Chuang, 2014). In such interactions, human intervention and genetic changes can result in the production of certain traits (such as nutritional quality and physical structure) and defense-related products in plants, such as primary, secondary chemicals, and plant volatiles. Therefore, it is possible for pests to be affected by changes in host plants in various ways and levels.

Aphid Endosymbiont Relationship

Almost all aphid species engage in mutualistic relationships with endosymbiotic bacteria. These symbiotic relationships may be obligatory or facultative, depending on the evolutionary process. Commonly, it has been reported that in these relationships, symbionts provide some amino acids and vitamins to their hosts, protect them against predators and parasites, and increase their host's quality of life under stress conditions. Most of the bacterial endosymbionts cannot be cultured independently and can be found in the host as obligate endosymbionts (Oliver et al., 2010). Culturing endosymbionts can be difficult due to their slow growth, lifestyle, and requirement for certain host metabolites (Pontes & Dale, 2006). Although some bacteria are parasitic and reduce their host's quality of life, most symbiotic bacteria benefit their host in different ways. In general, it is effective for the host's development, nutrition, reproduction, thermal tolerance, defense, and immune behavior (Dale & Moran, 2006; Dunbar et al., 2007; Tsuchida et al., 2011). It is stated that bacterial symbionts can increase the chance of survival of their host, as well as manipulate the reproduction of their host to benefit its own transmission (Skaljac, 2016). The most popular and known endosymbiont of the aphids is *Buchnera aphidicola*.

Aphid–*Buchnera* Relationship

Most of the aphids are in a mutualistic relationship with the primary-obligate endosymbiont bacterium *B. aphidicola* (Oliver et al., 2010). Douglas (1996), in one of their studies, expressed that endosymbionts in aphids are not related to nitrogen fixation; however, *Buchnera* contributes to the reproduction of the host by synthesizing some essential amino acids and vitamins that the aphids cannot adequately provide from the plant sap. It is thought that aphids provide a safe environment and food for endosymbiont bacteria (Güz et al., 2015). Aphids overcome amino acid deficiency with the help of the endosymbiont *Buchnera*, which can produce riboflavin with some amino acids (Nakabachi & Ishikawa 1999, Shigenobu et al., 2000). It is pointed out that *Buchnera* uses some non-essential amino acids which were taken from the sap by the aphid and converts them into essential amino acids that its host needs, and for this reason, it is of vital importance for its host (Douglas, 1996). Various studies have been conducted on what type of function endosymbionts have for their hosts. In one of these studies, when the amino acid profiles of aposymbiotic (symbiont free) *Acyrthosiphon pisum Harris,* 1776 obtained by the application of rifampicin were examined, it was stated that the concentrations of aromatic amino acids phenylalanine and tryptophan in the embryos of aposymbiotics were very low and that these amino acid amounts could limit the embryo development of aposymbiotics (Douglas, 1996). According to Douglas and Prosser (1992), aposymbiotic aphids cannot synthesize many amino acids such as tryptophan. It has also been shown that aphids fed on a diet that does not contain tryptophan are unable to sustain their growth. It has been determined that the riboflavin (vitamin B2) synthase complex of *Buchnera* works actively only when the symbiotic relationship is continuous and this relationship is well established in the young host. It has been reported that dietary riboflavin increases the performance of aposymbiotics. According to these results, it was stated that young aphids containing endosymbionts met their riboflavin needs from *Buchnera* (Güz et al., 2015; Nakabachi & Ishikawa, 1999). Machado-Assefh et al. (2015), in their study with aposymbiotic *Myzus persicae Sulzer,* 1776 individuals, tried to determine the effect of antibiotic administration on the feeding behavior of aphids and the expression of genes in salivary secretion. They reported that besides synthesizing essential amino acids and vitamins, *B. aphidicola* also contributes to plant–insect interaction. In addition, some bacterial proteins involved in the metabolism of the host plant were found in the saliva of *M. persicae*. Differences in the feeding behavior of aposymbiotic aphids, some problems during the penetration of the stylets of the aphids into the host plant, and delays in the recognition of the host plant by the aphids were observed (Machado-Assefh et al., 2015).

B. aphidicola, known to be related to *Enterobacteriaceae*, is a bacterium with a gram-negative cell wall of 2.5–4 μm in diameter. However, unlike most other gram-negative bacteria, *Buchnera* lacks the genes responsible for the production of lipopolysaccharides found in the outer membrane structure. During this symbiotic relationship dating back 160–280 million years, *Buchnera* lost some genes required for anaerobic respiration and genes responsible for the synthesis of amino sugars, fatty acids, phospholipids, and complex carbohydrates. It has also lost some regulatory factors that allow the continuous overproduction of certain amino acids, such as tryptophan (Skaljac, 2016). It has been stated that *Buchnera* has a 641 kb long genome rich in Adenin-Timin nucleotide pairs of genes responsible for the biosynthesis of many essential amino acids but lacks genes responsible for the biosynthesis of cell surface components of its genome and genes involved in cellular defense and regulatory genes (Shigenobu et al., 2000). The genome of *Buchnera*, the endosymbiont of the *A. pisum*, has been characterized as a 657 kb circular DNA molecule. In addition, when the genome map of *Buchnera* was compared with the genome map of *Escherichia coli* and *Haemophilus influenzae*, it was stated that *Buchnera* was more similar to *E. coli* (Charles & Ishikawa, 1999). The genome size varies in *Buchnera* species and even decreases to 450 kb in some species (Gill et al., 2002). Genome studies with insects indicate that during the evolutionary process, the host organism lost these genes by establishing symbiotic relationships with the bacteria responsible for arginine biosynthesis (Luan et al., 2015). It has been reported that aphids and endosymbionts evolve in parallel and endosymbionts are transferred vertically from female adult aphids to offspring (Martinez-Torres et al., 2001).

The primary symbiont *Buchnera* is typically found in specialized cell groups called mycetocytes or bacteriocytes in the body cavity of its host (Sasaki & Ishikawa, 1995). An adult aphid may carry an estimated 5.6×10^6 *Buchnera* cells (Baumann & Baumann, 1994). However, the number of endosymbiont bacteria can be affected by many factors such as the performance of the host, seasonal changes, temperature changes, and the quality of the host plant on which the aphid feeds (Yao, 2019). Numerous studies have been conducted to determine the effect of temperature on this symbiotic relationship. For example, it was determined that the bacterial density of aphids increased from 1.3×10^7 to 2.0×10^7 at temperatures between 15°C and 25°C, and the endosymbiotic relationship was disrupted at 37°C and −10°C. It has also been stated that the density of endosymbiotic bacteria in aphids may vary according to the developmental stage of the insect (Humphreys & Douglas, 1997). There are many studies on the role of endosymbionts in the nutrition of aphids. These studies have been facilitated by the development of synthetic media, the use of antibiotics, and the application of heat shock to produce aposymbiotic aphids (Dixon, 1998). In order to study the effect of bacteria on the aphid-endosymbiont relationship, it is tried to make aphids aposymbiotic by applying antibiotics at different doses and in different ways. It is known that antibiotic application has different effects on the amount and structure of honeydew in aphids. It was concluded that the honeydew particle size of aposymbiotic *A. pisum* is smaller than that of symbionts (Wilkinson & Douglas, 1995).

There are also many studies investigating the effects of *Buchnera* presence on aphid morphology. It has been observed that there are limitations in the growth and development of aphids treated with chlortetracycline, and their fertility decreased. In addition, it was observed that *A. pisum* and *Megoura viciae* Buckton, 1876, had similar effects on their size and fertility but did not affect wing development (Hardie & Leckstein, 2007). In the study examining the effects of starvation and symbiont *Buchnera* on the wing dimorphism of the *Sitobion avenae Fabricius,* 1775 aphid species, it was determined that the fertility, body weight, and the number of winged individuals decreased in the aposymbiotics and that starvation also reduced the winged individual percentage and the survival rate (Zhang et al., 2015). They discussed the potential importance of reduced winged formation in integrated management of aphids.

Besides primary symbionts, aphids can also contain facultative symbionts known as secondary symbionts (Guo et al., 2022; Sharma et al., 2021). As facultative symbionts may be non-essential for aphid species survival, aphids obtain some ecological benefits, such as host plant use, defense against natural enemies, body color modifications, temperature tolerance, and manipulation of their reproduction (Guo et al., 2017). Particular attention should be given to facultative symbionts' effect on natural enemies in aphid management applications. Secondary symbiotic bacteria associated with aphids are *Hamiltonella defensa*, *Regiella insecticola*, *Erwinia aphidicola*, *Serratia symbiotica*, *Pseudomonas aeruginosa*, *Wolbachia pipientis*, *Rickettsiella* sp., *Rickettsia* sp., *Spiroplasma* sp., *Arsenophonus* sp., *Photorhabdus* sp., *Xenorhabdus* sp., and X-type (Oliver et al., 2010, Zepeda-Paulo & Lavandero, 2021). Jousselin et al. (2016) stated that *S. symbiotica* is the most common endosymbiont bacteria after *B. aphidicola* in *Cinara* aphid species. They reported that *H. defensa* contains a lysogenic bacteriophage that protects its host against parasitic *Aphidius ervi*, while *R. insecticola* provides resistance against the fungal pathogen (Jousselin et al., 2016). Secondary symbionts are not found in specialized cell groups like primary symbionts. Instead, they are usually localized in secondary bacteriocyte cells, sheath cells, which are small flat cells found around primary bacteriocyte cells and hemolymph (Moran et al., 2005). For example, while *H. defensa*, *S. symbiotica*, *R. insecticola,* and *Rickettsiella* are located in the cytoplasm of secondary bacteriocytes and sheath cells, they are also found in the hemolymph of *A. pisum* (Fukatsu et al., 2000; Moran et al., 2005; Tsuchida et al., 2005). Secondary symbionts can be transmitted vertically between individuals and between species, as well as horizontally (Guo et al., 2022; Russell et al., 2003, Sharma et al., 2021). Facultative symbionts are not obligatory, but they are reported to take on very important tasks. It is stated that secondary symbionts have important roles such as protecting their host against predators, improving host resistance against biotic and abiotic factors, nutrition, and differentiation of body color (Brinza et al., 2009; Koga et al., 2003; Sharma et al., 2021; Zepeda-Paulo & Lavandero, 2021; Zhang et al., 2015). It is also reported that some secondary symbionts provide the necessary cofactors for the synthesis of some amino acids (Gosalbes et al., 2008). Koga et al. (2003) studied the interactions of *Buchnera* and pea aphid secondary symbiont (PASS) with each other and their effect on aphid reproduction–development in members of *A. pisum*. As a result of the elimination of *Buchnera*, it was determined that PASS replaced *Buchnera*, allowing its host to survive and reproduce. On the other hand, it has been reported that PASS suppresses *Buchnera* and adversely affects the performance of aphid. In the symbiotic relationship of *Regiella insecticola* and *A. pisum*, it is stated that *Regiella* reduces the amount of spores produced by entomopathogenic fungi such as *Pandora neoaphidis* and *Zoophthora occidentalis* (Parker et al., 2013; Scarborough et al., 2005). Some secondary symbionts such as X-type bacterium (Heyworth & Ferrari, 2015) protected aphids against the fungal pathogens (e.g., *Pandora neoaphidis),* increased the resistance to the parasitoids (e.g., *Aphidius ervi* (Haliday, 1834), and also affected the response of aphid to heat stress (Guo et al., 2022; Heyworth & Ferrari, 2015). In general, phylogenetic analyses in *S. symbiotica* show that there are some differences in the distribution, morphology, and functions of symbionts, which potentially play a role in aphid feeding (Burke et al., 2009), and such secondary symbionts provide benefits by supporting their host under different conditions such as heat stress (Koga et al., 2003, Montllor et al., 2002; Zepeda-Paulo & Lavandero, 2021). It was stated that the number of PASS in aphids increased in hot weather, aphids without PASS could not reproduce under heat stress, and 80%–100% of aphids containing PASS gave offspring. It has been reported that temperature changes affect some vital parameters of aphids such as survival rate, offspring development, development time, and age-related fertility rate (Morgan et al., 2001).

Aphid–Host Plant Relationship

Insect–plant interaction is a complex relationship influenced by biotic and abiotic factors. Plants produce a range of chemical compounds to cope with insect infestations (Sharma et al., 2021). Structural chemicals are produced even when the plant is under no stress (Wittstock & Gershenzon, 2002). Herbivorous insects use these chemicals as a cue to recognize host plants (Ali & Agrawal, 2012; Karban et al., 2014). Most herbivorous insects have developed various mechanisms to overcome these changes in the host plant. Thus, both parties develop different mechanisms to overcome the defense response of the other and enter the process of co-evolution (Sharma et al., 2021). However, both insects and plants are associated with many organisms and determine the outcome of insect feeding on a plant. Microbiome studies associated with plants and insects provide a new perspective on this issue and show that these interactions are more complex than they seem (Bultman & Bell, 2003; Frago et al., 2012; Sharma et al., 2021).

Aphids are insects with different adaptation mechanisms that can adapt to changing environmental conditions in a short time. Some factors such as crowding, host plant quality, and temperature may cause stress in aphids. The nutritional quality of the host plant is a very important factor in determining the size, distribution, survival, and reproduction rate of aphids. Some factors, such as the aging of the plant, can lower the plant's nutrient content. These changes in host plant quality trigger the formation of winged individuals in aphids. In addition, they can increase the number of winged individuals very quickly in a short time on the host plant they live on. The increase in the number of individuals causes the aphids to not benefit enough from the host plant. For example, while *A. pisum* reacts to crowding during the feeding process from mature leaves, *Dysaphis devecta* (Walker, 1849) only increases the number of winged individuals in response to changes in host plant quality (Dixon, 1998). Not only endosymbionts activate the resistance and adaptation of aphids to the environment but also aphids activate the resistance mechanisms of their host plant against stress conditions. A wide variety of biotic and abiotic environmental factors in nature cause stress in plants. Plants have many defense mechanisms to protect themselves from pathogen attacks. Although these defense mechanisms play a deterrent role for some pathogens, they are ineffective for some pathogens (Koç & Üstün, 2008).

Plants, which are food sources for many organisms, cannot be isolated from pathogens, but they have evolved appropriate defense strategies to detect and counter the inevitable pathogen attacks. In order to prevent pathogen invasion, plants use inducible defense responses activated by pathogen attack as well as physical and chemical barriers existing in their structures (Koç & Üstün, 2008). In some studies, it has been determined that aphid infestation increases the insect resistance of the plant and creates a vaccine effect on the plant (Coppola et al., 2018; Smith & Chuang, 2014). Plants can either cope with stress or move away from that stress factor. Various studies have shown that some aphids can stimulate plant resistance, as well as plants resistant to aphid attack. It has been determined that aphid infestation increases the plant's defense against secondary invasions by creating various metabolic changes such as triggering the synthesis of stress hormones salicylic acid and jasmonic acid in plants (Coppola et al., 2018; Jaouannet et al., 2014; Smith & Chuang, 2014). It has been stated that insect and pathogen invasion increases the production of various secondary metabolites in plants as well as stress hormones and these secondary metabolites are associated with the plant's defense system. On the other hand, it has been demonstrated in different studies that aphids try to attenuate the defense responses of plants with various chemicals and enzymes found in their salivary glands (Cheynier et al., 2013; Mugford et al., 2016; Thorpe et al., 2016; Wang et al., 2016).

Aphid Endosymbiont–Host Plant Tritrophic Interaction

The relationship between aphid endosymbiont–host plants is quite complex. Insects choose hosts according to the nutrient biosynthesis capacity of their endosymbionts. Endosymbiont bacteria synthesize essential amino acids and vitamins to their host by using some non-essential amino acids found in the plant sap of their host. Endosymbiont bacteria have a very important role in the synthesis of these compounds and in choosing the right host for aphids. However, some endosymbionts have lost the ability to produce different compounds in the evolutionary process. For example, it has been reported in various studies that *B. aphidicola* lost genes responsible for tryptophan and riboflavin synthesis in *Cinara cedri* Mimeur,1936 biotin biosynthesis in *A. pisum* and arginine biosynthesis in *Baizongia pistaceae Linnaeus,* 1767 (Pérez-Brocal et al., 2006; Shigenobu et al., 2000; van Ham et al., 2003). Such loss of biosynthetic capacity may put pressure on the selection of the right host that can provide the insect with the food it needs (Clark et al., 2010; Sharma et al., 2021). In addition, there is information that some symbionts change the behavior of their hosts for their own evolutionary benefit (Giordanengo et al., 2010; Thomas et al., 2005).

Understanding how and why the host plant–aphid-endosymbiont relationship is affected by the environment and other factors are important not only for effective biological control against aphids but also for the continuity of plant productivity. Therefore, examining the relationship between aphid-*Buchnera* and aphid-host plant alone will not be sufficient to clarify these relations from all aspects. At the same time, all the parameters of the tritrophic relationship should be examined without overlooking as there are contrast findings (McLean et al., 2010). Such interactions also raise the following questions. Why are the plant species used as hosts by aphid species different? What are the effective parameters on the host plant and feeding preferences in aphids? What is the importance of *Buchnera* in the aphid–host relationship? In order to answer these and similar questions, the internal (characteristics of the living thing) and external (such as the temperature, water, humidity, and CO_2 ratio of the living thing's environment) variables in the food chain and their interactions with each other should be investigated in more detail. In terrestrial environments, strong trophic interactions are modified by the chemistry, morphology, and behavior of the organisms in question. It has been observed that plants attract the natural enemies of herbivores by using volatile substances (Agrawal, 2000; Birch et al., 1999). Examining such tri-trophic interactions is important to understand the interactions of natural species and to be able to use these interactions in pest control. It is seen that the common denominator in the plant–*Buchnera*–aphid relationship is nitrogen compounds and nutritional needs. Therefore, the host plant is very important in the evolution and ecology of phytophages such as aphids. As it is known, nitrogen is a limiting element for living things. It has been determined that changes in nitrogen availability affect the nutritional and defense properties of the plant (Mattson, 1980), the quality of host plant components (such as C, N, and defense metabolites), herbivore productivity and reproductive strategies (Awmack & Leather, 2002). Since host selection also causes various mating preferences, it has been argued that the mechanisms underlying these preferences will contribute directly to the understanding of speciation, and the functions of chemosensory genes that have an effect on smell and taste in speciation and host selection are sought to be investigated (Eyres et al., 2017). Many herbivorous insects change the quality of the host plant by affecting its internal and external relations. It has been observed that the quality of the host plant affects the higher trophic relationships of predators and parasites and that it affects insect productivity at both individual and population scales (Awmack & Leather, 2002). In addition, the salivary secretion of aphids has a key role in aphid–plant relationship. Saliva content is affected by the environment the stylet tip encounters. Enzymes and proteins such as various pectinases and cellulases in saliva break plant defenses and increase the availability of organic nitrogenous compounds. It has been suggested that some enzymes detoxify plant phenols and that some salivary proteins may act as effectors, suppressing or promoting plant defense (Giordanengo et al., 2010). It has also been pointed out that some salivary proteins such as GroEL are produced from *Buchnera* origin and that this protein is an excretory product that induces defense reactions of the plant. It has also been suggested that chitin fragments in saliva may trigger the plant's defense reactions (van Bel & Will, 2016). In various studies in which endosymbionts were removed from aphids, it was clearly determined that the growth of aphids decreased. It is stated that the associations formed by microorganisms living in common with plants and insects affect plant and insect relationship. It has been shown that insect–microorganism associations suppress the plant's defenses and support the development of insects in the plant by detoxifying protective phytochemicals. Phytopathogens can change the effectiveness and behavior of insects by changing plant quality and defense. The plant–beneficial microorganism relationship can promote plant growth by affecting the plant nutrient and phytochemical composition and may positively or negatively affect the effectiveness of insects. From the results obtained, it was stated that the protein contents of the aphids were affected by the host plant and the symbionts contributed to the adaptation of the aphids (Francis et al., 2006, 2010).

Conclusion and Recommendations

Since it is predicted that insects such as aphids, which are plant pests, will feel their negative effects more with the increase in global warming, some unknowns need to be revealed in the biological control of these pests. In order to carry out an effective biological control, it is necessary to determine exactly what the functions of the obligate endosymbiont bacteria *Buchnera* will play a very important role in the metabolism of aphids and other facultative endosymbionts. In the studies carried out so far, different parameters have been studied in aposymbiont aphids. However, in these studies, the aphid–*Buchnera* relationship was generally considered, while the host plant effect was ignored. For this reason, in order to be more effective in the biological control of aphids, it is necessary to consider not only the aphid–*Buchnera* relationship but also the aphid–*Buchnera*–host plant relationship together. In many studies, it is stated that the presence of plant pest herbivores such as aphids causes stress in the plant and triggers the production of some special chemicals in the plant. It was concluded that aphids fed with plant sap may also undergo some morphological and physiological changes by being affected by the plant composition, and therefore, differences may be observed in *Buchnera* function. Based on this, it was emphasized in the aphid–*Buchnera* relationship that host plant can cause various changes in the metabolism of both aphids and endosymbionts and host plant metabolism should not be ignored in these relationships. It is thought that revealing the aphid–*Buchnera*–host plant relationship will lead to significant progress in the biological control of aphids in the long term. It has also been observed that there are important trends in this field recently. In this review, it was emphasized that aphids can be controlled more effectively by considering the aphid–*Buchnera*–host plant tritrophic interaction together, and it was revealed that more studies should be done on this subject. In this context, researchers should focus on finding out the answers to the following questions which are: How did aphid obtain *Buchnera*? Why was *Buchnera* compelled into the aphid? How *Buchnera* became an endosymbiont?

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