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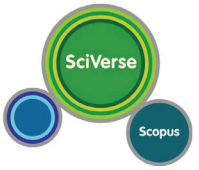

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Yönetim Yeri Adresi
Tarım Bilimleri Dergisi
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Yayın Ünitesi
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Telefon : +90 (312) 596 14 24
Belge geçer: +90 (312) 317 67 24
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İÇİNDEKİLER - CONTENTS

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Çok Kriterli Değerlendirme ile Ankara Güvenç Havzası'nda Erozyon Risk Tahminlenmesi

İnci DEMİRAĞ TURAN[a], Orhan DENGİZ[b]

[a]*Ondokuz Mayıs Üniversitesi, Fen Edebiyat Fakültesi, Coğrafya Bölümü, Samsun, TÜRKİYE*

[b]*Ondokuz Mayıs Üniversitesi, Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümü, Samsun, TÜRKİYE*

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Sorumlu Yazar: İnci DEMİRAĞ TURAN, E-posta: dmrginci@gmail.com, Tel: +90 (542) 804 15 27
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ÖZET

Bu çalışmanın amacı, Ankara Güvenç Havzası'nın coğrafi bilgi sistemi (CBS), uzaktan algılama (UA) ve istatistik yaklaşımlar kullanarak çok kriterli değerlendirme ile erozyon risk sınıflarının belirlenmesi ve haritalanmasıdır. Çalışma havzası yaklaşık 17.3 km²'lik bir alanı kapsamaktadır. Erozyon risk sınıflarının belirlenmesi amacıyla havzada toprak erozyonunun meydana gelmesinde etkili olan yedi adet parametre (bünye, toprak derinliği, yağış, arazi kullanımı, yükseklik, eğim ve bitki örtüsü) ve bu parametrelere ait alt kriterler dikkate alınmıştır. Parametrelere ait veriler için çalışma alanının 1:25000 ölçekli sayısal temel toprak haritası ve topografik harita kullanılmıştır. Arazi kullanımı-arazi örtüsünün ve bitki örtüsünün belirlenmesi amacıyla Landsat 7 uydu görüntüsünden yararlanılmıştır. Parametrelerin önceliklerinin belirlenmesinde analitik hiyerarşik süreç (AHS) tekniği, alt kriterlerin önceliklerinin belirlenmesinde ise Z-Skor istatistik analizi tekniğinden faydalanılmıştır. Nihai olarak ise dört sınıftan oluşan erozyon duyarlılık sınıflarının belirlenmesinde doğrusal kombinasyon tekniği kullanılmıştır. Elde edilen analiz sonuçlarına göre havzanın % 45.9'unun çok şiddetli erozyon riskini taşıdığı belirlenmiştir.

Anahtar Kelimeler: Analitik hiyerarşik süreç; Doğrusal kombinasyon tekniği; Erozyon risk belirleme; Z-Skor

Erosion Risk Prediction Using Multi-Criteria Assessment in Ankara Güvenç Basin

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ABSTRACT

The aim of this study is to determine erosion risk classes and to generate their map in Ankara Güvenç Basin using geographic information system (GIS), remote sensing (RS) and statistical approaches with method of multi-criteria decision-making. Basin covers about 17.3 km². In order to determine erosion risk classes, seven criteria (texture, soil depth, precipitation, land use, elevation, slope and vegetation) that influence the occurrence of soil erosion, and

sub-criteria of that seven criteria were taken into consideration. 1:25000 scale digital soil map and topographic map were used. In addition to that, Landsat 7 satellite images were used to generate the land use and vegetation cover map. Analytical hierarchy process (AHP) technique was used to determine the priorities of the each criteria while, the Z-score statistical analysis technique was used to determine the priorities of the sub-criteria. Finally, linear combination technique was used to determine classes of erosion risk. According to the obtained results, 45.9% of the basin area was identified as under high erosion risk.
Keywords: Analytical hierarchy process; Determining erosion risk; Linear combination technique; Z-Score

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1. Giriş

Toprak erozyonu bugün dünyada tarımı, doğal kaynakları ve çevreyi tehdit eden en önemli problemlerden birisidir. Aslında erozyon, doğal jeomorfolojik bir süreçtir. Ancak insan etkisi sonucu erozyon, hızlandırılmış hale dönüşmüştür. Hızlandırılmış erozyon da çevreye olan baskıyı artırarak, önemli bir çevresel problem haline gelmiştir. Eğer toprak erozyonunun mekânsal ve zamansal büyüklüğü bilinirse, yönetimsel uygulamalar bu problemi en aza indirmek için etkili bir şekilde gerçekleştirilebilir. Herhangi bir havzada erozyon süreçleri ve erozyon oranlarını belirlemek amacıyla toprak erozyon modelleri geliştirilmekte ve uygulanmaktadır. Toprak erozyonu tahmini ve değerlendirilmesi ile ilgili 1930'dan beri pek çok çalışma yapılmış ve birçok model geliştirilmiştir (Lal 2001). En yaygın olan modellerden bazıları evrensel toprak kaybı eşitliği (USLE) (Wischmeier & Smith 1978) ve revize edilmiş toprak kaybı eşitliği (RUSLE) (Renard et al 1991)'dir. Erozyon verimlilik etkisi hesaplaması (EPIC) (Williams et al 1990), Avrupa toprak erozyon modeli (EUROSEM) (Morgan et al 1992) ve su erozyonu tahmin projesi (WEPP) (Flanagan & Nearing 1995) gibi birçok model, toprak kaybı tahmininde kullanılmasının yanı sıra alanın erozyona karşı duyarlılık durumlarını belirlemek amacıyla da CORINE (1992), ICONA (1997), LEAM (Manrique 1988) gibi birçok erozyon risk değerlendirme modelleri de geliştirilmiştir. Bütün bu yöntemlerle ne kadar toprak kaybının olabileceği veya herhangi bir yönetim senaryosu altında erozyon riskine dair çıkarımlar yapılabilmesi söz konusudur. Arazi bozulmasını azaltmak ve toprak kaynaklarının sürdürülebilir bir şekilde kullanılmasını sağlamak amacıyla toprak koruma tedbirlerinin alınması gerekmektedir. Tedbirlerin alınması için öncelikle erozyon alanının erozyon risk dağılım haritalarının yapılması gerekir. Böylelikle toprak erozyonuna karşı gerekli yönetim planlamaları ve çalışmaları yapılabilmektedir.

Toprak erozyonunu hesaplamak veya risk dağılımlarının belirlemek için iklim, bitki örtüsü, arazi kullanımı, fiziki coğrafya özellikleri gibi çeşitli parametreler ele alınmıştır. Zhang et al (2013) tarafından yapılan çalışmada coğrafi bilgi sistemleri (CBS) ve uzaktan algılama (UA) teknolojileri kullanılarak yağış, toprak, topografya ve vejetasyon parametrelerinin erozyon üzerindeki etkileri değerlendirilmiştir. Wu & Wang (2007) analitik hiyerarşik süreç (AHS), uzaktan algılama ve coğrafi bilgi sistemlerini bir arada değerlendirmişler ve erozyona etki eden toprak tipi, yağmur yoğunluğu, arazi şekli, derin vadi yoğunluğu, arazi eğimi, bitki örtüsü, maden sahası, su ve toprak koruma seviyesi ve arazi kullanımı faktörlerini ele almışlardır. Aynı çalışmada toprak erozyonu risk derecesinin tematik katmanlarının CBS ile yapıldığı ve her tematik katmanın ağırlığına ise AHS ile karar verildiği belirtilmiştir.

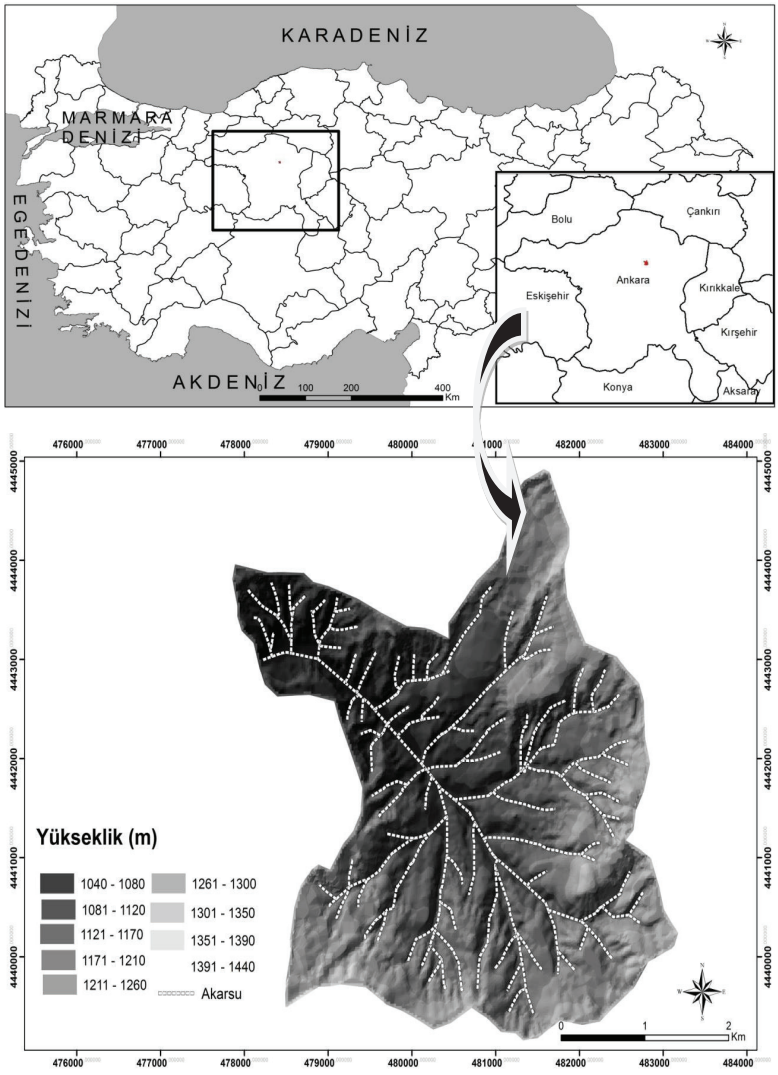
Bu çalışma ile Ankara Güvenç Havzası içerisinde dağılım gösteren arazilerin erozyon risk durumlarının belirlenmesi ve dağılım haritalarının oluşturulması amaçlanmıştır. Bu doğrultuda, toprak erozyonunu etkileyen toprak derinliği, toprak bünyesi, bitki örtüsü indeksi (NDVI), eğim, yağış, yükseklik ve arazi kullanımından oluşan yedi faktör ve bunlara ait alt faktörler

dikkate alınmıştır. Faktörler arasındaki ilişkilerin değerlendirmesinde çok kriterli yaklaşımlarından olan AHS uygulanmış ve alt faktörlerde ise Z-Skor analizi yapılarak kriterler aynı ölçeğe konulup artık birlikte toplanabilir, yani kombine edilebilir hale getirilmiştir. Böylece bu teknik ile erozyon riski değerlendirmesi çalışmalarına yönelik yeni bir yaklaşım geliştirilmiştir.

2. Materyal ve Yöntem

2.1. Çalışma alanı

Çalışma alanı Güvenç Göleti'ne ait su toplama havzasıdır. Güvenç Göleti Ankara-Yenimahalle-Güvenç Köyü'nde yer almaktadır. Çalışma alanının lokasyon haritası Şekil 1 olarak sunulmuştur. Havza yaklaşık 17.3 km² alana sahiptir (Şekil 1).



Şekil 1- Çalışma alanının lokasyon haritası

Figure 1- Location map of the study area

Güvenç Havzası yazları sıcak ve kurak, kışları soğuk ve yağışlıdır. Ankara Meteoroloji Müdürlüğü verilerine göre (1975-2013) yıllık ortalama yağış 399.5 mm, uzun yıllar ortalama sıcaklığı ise 12.04 °C'dir (MGM 2013). Havzanın deniz seviyesinden olan yükseltisi 1040 m ile 1440 m arasındadır. Özellikle Havza alanının yaklaşık % 50'si 1200-1350 m yükseklik arasında yer almaktadır. Ayrıca alanın yaklaşık % 46'sının 11°-30° arasında eğim değerlerine sahip olduğu belirlenmiştir.

Havzanın batı ve orta kesiminde Paleosen yaşlı kil ve kireçtaşı ara katmanları ile Sarıbeyler formasyonu dağılım göstermiştir. Bu birimler az geçirimli özelliğe sahiptir. Havzanın yukarı su toplama alanında kireç taşı ile marn kayaçlarından oluşan tabakalar bulunmaktadır. Buralarda yeraltı suyu verimliliğinin oldukça zayıf olduğu görülmüştür (DSİ 1969).

Havzanın güneybatısı ile kuzeydoğusu Orhaniye formasyonu ve Sarıbeyler formasyonu üzerinde yer almıştır. Orhaniye formasyonu orta derecede verimliliğe sahiptir. Havzanın güneydoğusunda siltli kumtaşı ile Dikmendere formasyonu yüzeylenmiştir. Formasyonların birbirlerine temas ettiği yerlerde yer yer su kaynakları bulunmaktadır (MTA 1994).

2.2. Yöntemler

Havzanın erozyon risk dağılımlarının belirlenmesinde, havzada öncelikli olarak erozyona etki edebilecek parametreler tanımlanmış ve alana ait detaylı toprak haritasında yer alan her bir haritalama ünitesi için erozyon duyarlılığının oranları hesaplanmıştır. Erozyon risk haritalarının oluşturulmasına yönelik çalışmalarda da çok kriterli karar verme yöntemi uygulanmış ve uygulanmaya da devam etmektedir. Buna yönelik birçok teknik olmasına karşın bu çalışmada çok kriterli erozyon risk değerlendirmesi tekniği olarak doğrusal kombinasyon tekniği kullanılmıştır (Patrono 1998).

Doğrusal kombinasyon tekniğinde, erozyona etki eden kriterlerin her birine bir ağırlık değeri aktarılmıştır. Bu ağırlık değerleri, kriterlerin göreceli önemine göre belirlenmiştir. Sonrasında bu kriterler alt kriterlere ayrılmış ve bu alt kriterler kendi içinde ayrı bir sayısal değerlendirmeye tabi tutularak alt kriter puanları saptanmıştır. Daha sonra bu alt kriter puanları, ait olduğu kriterin ağırlık değeri ile çarpılmıştır (Dengiz & Sarıoğlu 2013). Çalışmada, alt kriterlere ait değerler Z-Skor yöntemiyle, ait olduğu kriterin ağırlık değeri ise AHS yöntemi ile belirlenmiştir.

Böylece kriterler aynı ölçeğe konularak birlikte toplanabilir, yani kombine edilebilir hale getirilmiştir. Bu teknikteki erozyon riski değerlendirmesi yaklaşımına ait matematiksel ifade Eşitlik 1'de verilmiştir.

$$S = \sum_{i=1}^{n} \left(W_i . X_i \right) \quad (1)$$

Burada; S, erozyon risk puanı; W_i, i parametrenin ağırlık değeri; X_i, i parametresine ait Z-Skor alt kriter puanı; n, ele alınan parametrelerin toplam sayısıdır.

Ele alınan kriterler alt faktörlere ayrılarak 1 ile 4 arasında ağırlık değerleri verilmiştir. Erozyon risk sınıflamasına yönelik modelde kullanılan parametreler ve alt faktörlere ait ağırlık puanları Çizelge 1'de belirtilmiştir. Alt faktör, erozyonun risk ihtimalinin yüksek olması durumunda 1, erozyonun risk durumu az ise 4 değerini almıştır. 1 ile 4 arasındaki değerler ise erozyonun risk derecesine göre değişmektedir (Çizelge 1).

Erozyon risk değerlendirmesinde doğru ve karşılaştırılabilir sonuçlar elde etmek zordur. Bu nedenle toprak erozyon risk değerlendirmesinde belirlenen alt faktörler, CBS ile sayısal bir model olan Z-Skor birleştirilmiştir. Z-Skor'da dönüşüm kurallarında özel bir uygulama yapılmaktadır. Değişken alt parametreler için Z-Skor metodu kullanılarak standartlaştırma yapılmıştır. Z-Skor değeri bazen standart puanlar şeklinde de ifade edilmektedir.

Standartlaştırma her bir alt parametreden, ortalama farkının alınması ve elde edilen değerin standart sapmaya bölünmesi ile belirlenmiştir. Böylece, Z-Skor ham verileri standart hale dönüşmüş ve birim farklılıklarını ortadan kaldırmıştır. Z-Skor hesaplanması Eşitlik 2'de verilmiştir.

Çizelge 1- Erozyon risk sınıflamasına yönelik modelde kullanılan parametreler ve alt faktörlere ait ağırlık puanları

Table 1- Weighted values for parameters and sub factors which are used in model for determination of erosion risk class

Bünye		*Eğim (%)*		*Arazi kullanımı*		*Yağış (mm)*	
Sınıf	*Alt faktör ağırlık puanı*	*Sınıf*	*Alt faktör ağırlık puanı*	*Sınıf*	*Alt faktör ağırlık puanı*	*Sınıf*	*Alt faktör ağırlık puanı*
Kil	1	0-7	4	Kuru tarım	1	<60	4
Kil-tın	4	7-13	3	Mera	3	60-90	3
Kumlu-kil	3	13-20	2	Meyve ve fundalık	2	90 -120	2
Tın	2	20-46	1	Su yüzeyi	4	120 -160	1
				Zayıf mera	2	>160	1
				Zayıf orman	3		
Yükseklik (m)		*Toprak derinliği (cm)*		*Bitki yoğunluğu (%)*			
Sınıf	*Alt faktör ağırlık puanı*	*Sınıf*	*Alt faktör ağırlık puanı*	*Sınıf*		*Alt faktör ağırlık puanı*	
1340-1440	4	Derin (90 +)	4	0 -50		1	
1240-1340	3	Orta derin (90-50)	3	50-70		3	
1140-1240	2	Sığ (50-20)	2	70-100		4	
1040-1140	1	Çok sığ (20-0)	1				

$$Zij = \frac{xij - \mu i}{\sigma i} \quad (2)$$

Burada; *Zij*, faktörlerin skor değeri; *xij*, parametrelerin ağırlık değerleri; μij, ağırlık değerlerinin ortalaması; σi, ağırlık değerlerinin standart sapmasıdır.

Ana kriterlerin her birine ait ağırlık puanlarının belirlenmesinde değerlendirmeye alınan kriterlerin birbirlerine göre önemi dikkate alınarak Saaty (1980) tarafından geliştirilen AHS tekniği kullanılmıştır. Bu teknik ile parametreler ikili karşılaştırılıp öncelik değeri belirlenmiştir. Ayrıca bu teknik karar alternatifinin seçilmesinde, hem nicel hem de nitel faktörlerin dikkate alınmasına imkân vermektedir. İkili karşılaştırmalara dayalı göreceli önceliklendirme ölçeği Çizelge 2'de verilmiştir (Saaty 1980).

Çalışmada değerlendirmeye alınan kriterlerin ağırlık puanları AHS tekniği ile belirlenirken aşağıdaki adımlar izlenmiştir.

Birinci adımda kriterlerin etki durumu göz önünde bulundurularak ikili karşılaştırmaların yapıldığı matrisler oluşturulmuştur (Eşitlik 3).

$$A = \begin{bmatrix} a11 & a12... & a1n \\ a21 & a22... & a2n \\ an1 & an2... & ann \end{bmatrix} \quad (3)$$

Burada; *A*, karşılaştırma matrisi; a_{ij}, hiyerarşinin bir üst düzeydeki elemanına önemi (i, j= 1, 2,..., n); İkili karşılaştırma matrisinin özellikleri, $a_{ji}= 1/a_{ij}$, aij > 0 (i, j= 1, 2,..., n); karşılaştırmalar matrisinin tutarlılığı, $a_{ik}= a_{ji}a_{jk}$ (i, j, k= 1, 2,..., n).

Çizelge 2- AHS tekniğinde tercihler için kullanılan ikili karşılaştırmalar ölçeği (Saaty 1980)

Table 2- The pairwise comparisons scales used for the preferences in the AHP (Saaty 1980)

Sözel tercih hükmü	*Açıklama*	*Değer*
Eşit tercih edilme	İki faaliyet amaca eşit düzeyde katkıda bulunur	1
Kısmen tercih edilme	Tecrübe ve yargı bir faaliyeti diğerine göre kısmen tercih ettiriyor	3
Oldukça tercih edilme	Tecrübe ve yargı bir faaliyeti diğerine göre oldukça tercih ettiriyor	5
Kuvvetle tercih edilme	Bir faaliyet değerine göre kuvvetle tercih ediliyor ve baskınlığı uygulamada rahatlıkla görünüyor	7
Kesinlikle tercih edilme	Bir faaliyetin değerine göre tercih edilmesine ilişkin kanıtlar çok büyük bir güvenirliğe sahip	9
Orta değerler	Uzlaşma gerektiğinde kullanılmak üzere iki ardışık yargı arasına düşen değerler	2, 4, 6, 8
Ters (karşıt) değerler	Bir eleman başka bir elemanla karşılaştırıldığında yukarıdaki değerlerden birisi atanır. Bunlardan ikinci eleman birinci eleman ile karşılaştırıldığında ters değere sahip olur	

İkili karşılaştırma hükümleri kesin olarak tutarlı ise, A ikili karşılaştırmalar matrisinin girdileri hata içermez ve Eşitlik 4' te olduğu gibi ifade edilir.

$$a_{ij} = \frac{wi}{wj} \quad (4)$$

Burada; W_i, A ikili karşılaştırmalar matrisi vasıtasıyla hesaplanmış olan i elemanına ilişkin öncelik değer; W_j, A ikili karşılaştırmalar matrisi vasıtasıyla hesaplanmış olan j elemanına ilişkin öncelik değerdir.

Eşitlik 4'ten faydalanılarak Eşitlik 5 oluşturulmuştur.

$$a_{ik}a_{kj} = \frac{W_i}{W_k}\cdot\frac{W_k}{W_j} = \frac{W_i}{W_j} = a_{ij} \qquad (i, j, k= 1, 2,\ldots, n) \quad (5)$$

Burada; İkili karşılaştırmalar matrisinin köşegen elemanları değeri 1 olup (a_{ii}= 1 (i, j, k= 1, 2,…, n)) şeklinde ifade edilmiştir.

Matrisin oluşturulmasından sonra karşılaştırılan parametrelerin her birinin önceliğinin hesaplanmasında ilk önce ikili karşılaştırmalar matrisinin her sütunundaki değerler toplanmıştır. Daha sonra ikili karşılaştırmalar matrisindeki her bir eleman, bulunduğu sütunun toplam değerine bölünmüştür. Bunun sonucunda normalize edilmiş ikili karşılaştırmalar matrisi elde edilmiştir. Son aşamada da normalize edilmiş ikili karşılaştırmalar matrisinin her bir satırındaki elemanların aritmetik ortalaması hesap edilmiştir.

Yöntemin son aşamasında, elde edilen özvektörün tutarlılık kontrolünün yapılması işlemi gerçekleştirilmiştir. İkili karşılaştırmalar matrisi (A), öncelik vektörü (W) ile çarpılarak yeni bir vektör elde edilmiştir. Yeni vektörün her bir elemanını öncelik vektöründe buna karşılık gelen değere bölerek ikinci bir yeni vektör hesaplanmıştır. Son vektör değerlerinin aritmetik ortalaması alınarak maksimum özdeğere (λ_{max}) ulaşılmıştır. Kumar & Ganesh (1996) maksimum özdeğerin ikili karşılaştırmalar matrisindeki elemanların sayısına (n) yakın oldukça sonucun da o kadar tutarlı olacağını belirtmişlerdir.

Tutarlılık oranı Eşitlik 6'da verilen tutarlılık indeksi (Tİ)'ne göre hesaplanmıştır.

$$Tİ = \frac{\lambda max - n}{n-1} \quad (6)$$

Ayrıca tutarlılık oranını hesaplayabilmek için rastgele (tesadüfi) indeksi değeri belirlenmiştir. AHS tekniğindeki tutarlılık oranının hesaplanmasında kullanılan (Eşitlik 7) ve matris boyutlarına göre değişen rastgele indeks değerleri Çizelge 3'te verilmiştir.

$$TO = \frac{Tİ}{Rİ} \quad (7)$$

Tutarlılık kontrolü, yargılarda olabilecek hataların tanımlanmasına olanak sağlamıştır. Yöntemin geçerli olması için Saaty (1980) tutarlılık

Çizelge 3- AHS tekniğindeki tutarlılık oranının hesaplanmasında kullanılan ve matris boyutlarına göre değişen rastgele indeks değerleri (Saaty 1980)

Table 3- Random index used in measured consistency ratio and which varies functionally with size of matrix in the AHP (Saaty 1980)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Rİ	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

oranının 0.10 (% 10) veya daha küçük olması gerektiğini, eğer bu oran 0.10'dan büyük ise ikili karşılaştırma matrislerinin yeniden oluşturulması gerektiğini belirtmiştir.

Her bir haritalama ünitesi için doğrusal kombinasyon tekniği ile hesaplanan değerler Çizelge 4'e göre sınıflandırılarak alanın erozyon duyarlılık haritası oluşturulmuştur.

Çizelge 4- Erozyon duyarlılık sınıfları ve sınıflara ait değerleri

Table 4- The casses of erosion sensitivity and values of the classes

Tanımlama	*Sınıf*	*Değer*
Az veya hiç yok	E1	> 0.2567
Orta	E2	0.2566-0.1092
Şiddetli	E3	0.1091-0.000
Çok şiddetli	E4	< 0.0000

Yapılan erozyon riskini değerlendirme çalışmasında belirleyici olabilecek toplam yedi parametre dikkate alınmıştır. Bu parametrelerin dikkate alınmasında özellikle suyun toprak içerisinde depolanması, yüzey akışı ve toprak taşınımına etkisi olan arazi ve toprak özellikleri etkili olmuştur. Ayrıca bu parametreler, yaygın olarak CORINE, ICONA, LEAM, WEPP, EUROSEM, EPIC gibi birçok farklı modelsel çalışma içerisinde de kullanılmışlardır. Araştırmada kullanılan parametreler sırasıyla eğim, bünye, arazi kullanımı, yağış, toprak derinliği, yükseklik ve bitki örtüsü yüzey kaplama oranı şeklindedir. Kriterlere ait veriler için çalışma alanının 1:25000 ölçekli sayısal temel toprak haritası ve ANKARA H29d2 paftası içerisine giren 1:25000 ölçekli topografik haritası kullanılmıştır. Topografik haritaların sayısallaştırılmasının yanı sıra katman sorgulama ve analiz işlemlerinde ArcGIS 9.3v coğrafi bilgi sistemi programından yararlanılmıştır. Arazi kullanımı ve bitki örtüsü yoğunluğunun belirlenmesi amacıyla Landsat 7 uydu görüntüsü, yağış erozyon faktörünün belirlenmesinde fournier indeksi kullanılmıştır (CORINE 1992). Fournier indeksinin belirlenmesinde 1970-2013 yıllarına ait meteorolojik verilerden yararlanılmıştır (MGM 2013). İndeksin hesaplanmasında Eşitlik 8 kullanılmıştır.

$$FI = \sum_{i=1}^{12} \frac{Pi^2}{\overline{P}} \quad (8)$$

Burada; *Pi*, i ayındaki toplam yağış (mm); $\overline{P}$, yıllık ortalama yağış miktarı (mm)'dır.

Erozyon sürecinde önemli bir faktör olan eğim ve bünye alt sınıflarının belirlenmesinde Van Zuidam (1986) tarafından belirtilen sınıflandırmadan yararlanılmış ve eğim, alana ait sayısal yükselti modelinden üretilmiştir. Toprak derinlik sınıfları ise TÜGEM (2008) dikkate alınarak hazırlanmıştır. Toprak derinliği ve tekstür verileri Dengiz & Başkan (2005) tarafından yapılmış çalışmadan elde edilmiştir. Bitki örtüsü yoğunluk sınıflamasında ICONA (1997)'dan yararlanılmıştır. Yükseklik parametresinin ise bireysel olarak değil de ikili karşılaştırma matrisinde eğimin derecesi ile birlikte ele alındığında, erozyona olan etkisi bakımından özellikle suyun kinetik enerjisindeki artış veya azalışa neden olması dolaysıyla da toprağı taşıma kapasitesi üzerine etki etmesi yönünden önemli faktör olduğu düşünülmüştür. Bu nedenle havzanın kendine ait yükselti değişkenlikleri dört sınıfa ayrılmıştır.

3. Bulgular ve Tartışma

Analitik hiyerarşik süreç tekniği, çok kriterli problemlerin çözülmesinde kullanılan güçlü bir araçtır. Ayrıca ağırlıkların belirlenmesinde faydalanılan diğer yöntemlerle karşılaştırıldığında tutarsızlığın ölçümüne olanak sağlaması bakımından önemlidir. Karar verme süreçlerinde AHS'nin tek başına kullanımı, incelemeye konu olan alandaki mekânsal farklılıkları yansıtamadığı için yetersiz kalmaktadır (Carver 1991; Malczewski 1996). Bu eksiklik CBS ile giderilmiş böylece, sonuçlar haritalanma olanağı bulmuştur. Yapılan bu çalışmada da belirtilen hususlar göz önünde tutularak her parametrenin alt parametreleri belirlenmiş, Z-Skor ve CBS analizleri ile değerlendirmeleri yapılmıştır.

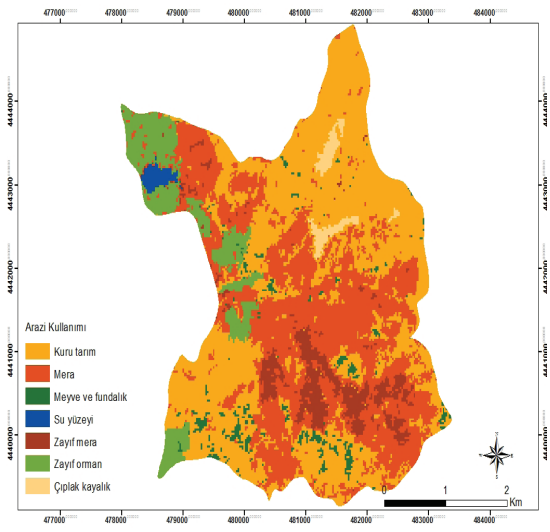
Çalışma alanında toprak erozyonuna neden olabilecek öncelikli parametreler dikkate alınarak CBS ile UA teknikleri yardımıyla matematiksel (AHS ve DKT) ve istatistiksel (Z-Skor) yaklaşımlar kullanılarak havzanın erozyon risk durumu değerlendirilmiştir. Araştırma sahasında Landsat 7 uydu görüntüleri yardımıyla bitki örtüsü yoğunluğu ve arazi kullanım desenine yönelik parametreler belirlenmiştir. Havzanın büyük bir kısmını kuru tarım (% 45) ve mera (% 35) oluştururken, geri kalan kısmını ise fundalık, zayıf orman ve çıplak kaya oluşturmaktadır (Şekil 2). Ayrıca % 74'ünün bitki örtüsü yoğunluğu bakımından % 0-50 arasında olduğu belirlenmiştir.

Çalışma alanında toplam alanın % 50'sinde eğimin % 10'dan az, % 10'unda ise eğimin % 20'den fazla olduğu belirlenmiştir (Şekil 3).

Toplam alanın yaklaşık % 63'ünde ise yükseltinin 1120 m ile 1300 m arasında olduğu belirlenmiştir.

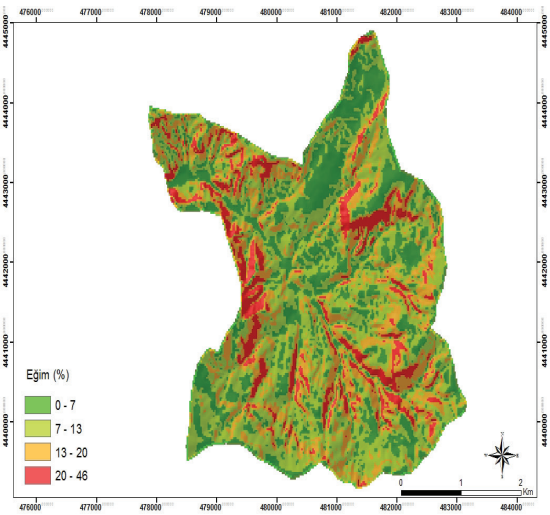
Toprak derinlik dağılım haritası Şekil 4'te verilmiştir. Buna göre toplam alanın yaklaşık % 60'ının çok sığ ve sığ, % 9.35'inin ise derin olduğu belirlenmiştir.

Havzanın toprak bünyesi dağılımında ise toplam alanın yaklaşık % 58'inin killi-tın ve kumlu-kil, % 36'sının ise killi tekstüre sahip topraklar olduğu haritalandırılmıştır (Şekil 5). Kumlu-kil ve killi-tın bünyeli topraklar, kil bünyeli topraklara göre erozyona daha fazla duyarlıdır.



***Şekil 2- Çalışma* alanının arazi kullanım haritası**

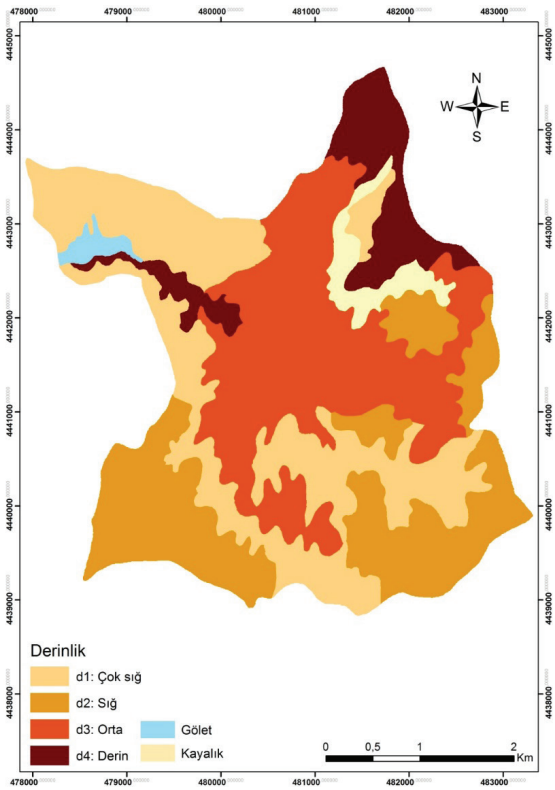
Figure 2- Land use map of the study area



Şekil 3- Çalışma alanının eğim haritası

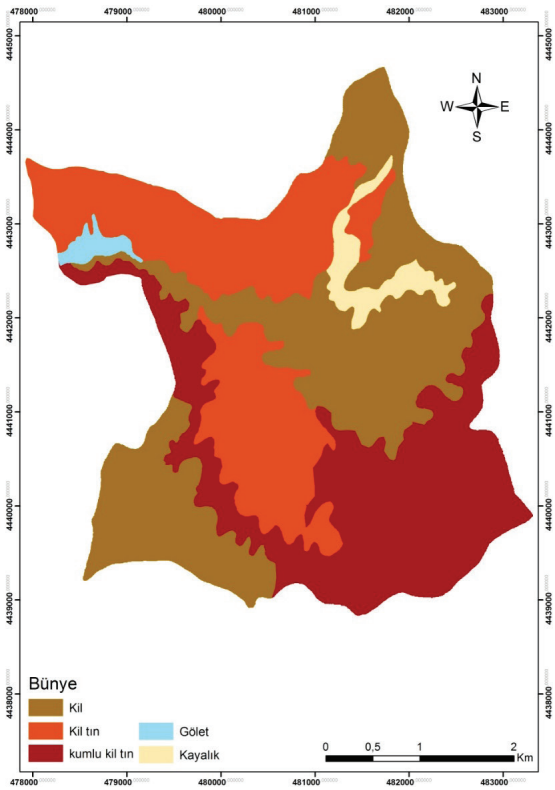
Figure 3- Slope map of the study area

Havzanın uzun yıllara ait yağış değerleri dikkate alındığında FI değeri 37.68 olarak bulunmuştur. Bu değer FI sınıflamasına göre 1. sınıfa girmektedir. Ayrıca alt faktör ağırlık puanı ise 4 olarak belirlenmiştir (Çizelge 2).



Şekil 4- Çalışma alanının toprak derinlik haritası

Figure 4- Soil depth map of the study area



Şekil 5- Çalışma alanının bünye haritası

Figure 5- Texture map of the study area

Tüm parametrelerin alt parametreleri belirlenirken Z-Skor analizi yönteminden yararlanılmış ve elde edilen sonuçlar Çizelge 5'te verilmiştir.

Çalışma alanının erozyon riskine yönelik duyarlılık sınıflarının belirlenmesinde seçilen kriterler için yapılan ikili karşılaştırmalara dayalı olarak elde edilen ağırlık değerleri Çizelge 6'da sunulmuştur.

Çizelge 6'dan görüleceği üzere, 0.358 ağırlık değeri ile bu uygunluk kriterlerinden eğim kriteri en yüksek ağırlığa sahip kriter olarak ortaya çıkmıştır. Bu kriteri sırasıyla arazi kullanımı (0.179), toprak bünyesi (0.156), yağış faktörü (0.116), yükseklik (0.092), toprak derinliği (0.060) ile bitki örtüsü kriterlerinin (0.033) izlediği belirlenmiştir. Bu kriterlerin ikili karşılaştırmalarına ait ortalama tutarlılık oranının ise 0.09 olduğu belirlenmiştir.

Yapılan AHS analizi sonucu kriterlerin ağırlıklandırmasında eğimin en yüksek değeri almasının önemli nedeni, şüphesiz ki toprak erozyonunun oluşmasında önemli belirleyicilerden biri olmasıdır. Özellikle toprak yüzeyinde herhangi bir koruyucu örtü bulunmaması durumunda, eğim artışına bağlı olarak yüzey akışı, dolayısıyla toprak taşınımında artış meydana gelmektedir (Dengiz & Akgül 2005). Bu nedenle toprak-su muhafazası tedbirleri alınmadan veya çok az tedbirler alınarak işlemeli tarımın yapılabilmesi için kritik eğim olan % 10-12'yi geçmemesi gerekmektedir (Sönmez 1994).

Çizelge 5- Seçilen alt faktörlerin Z-Skor değerleri

Table 5- Z-Score map of the selected subfactors

Arazi kullanım		*Eğim*		*Erozivite*		*Bünye*	
Sınıf	*Z-Skor değeri*	*Sınıf (%)*	*Z-Skor değeri*	*Sınıf*	*Z-Skor değeri*	*Sınıf*	*Z-Skor değeri*
Kuru tarım	-1.1554	0-7	1.1619	<60	1.3805	Kil	-1.1619
Mera	0.6419	7-13	0.3873	60-90	0.6135	Kil-tın	1.1619
Meyve ve fundalık	-0.2567	13-20	-0.3873	90-120	-0.1533	Kumlu-kil Tın	0.3873
Zayıf mera	-0.2567	20+	-1.1619	120-160	-0.9203		
Zayıf orman	0.6419			>160	-0.9203		
Su yüzeyi	1.5406						
Çıplak kaya	-1.1554						

Yükseklik Sınıf (m)	*Z-Skor değeri*	*Toprak derinliği Sınıf (cm)*	*Z-Skor değeri*	*Bitki yoğunluğu Sınıf (%)*	*Z-Skor değeri*
1340-1440	1.1619	Derin -0.3873 (90+)	1.1619	0-50	-1.0910
1240-1340	0.3873	Orta derin (90-50)	0.3873	50-70	0.2182
1140-1240	-0.3873	Sığ (50-20)	-0.3873	70-	0.8728
1040-1140	-1.1619	Çok sığ (20-0)	-1.1619		

Çizelge 6- Parametrelere ait ağırlık değerlerinin belirlenmesine yönelik AHS tekniği hesaplamaları

Table 6- Calculations of AHS technique to determine weighted values for parameters

İkili karşılaştırmalar matrisi

	Eğim (%)	*Bünye (%)*	*Arazi kullanım*	*Yağış (mm)*	*Yükseklik (m)*	*Toprak derinliği (cm)*	*Bitki örtüsü (%)*
Eğim (%)	1.000	4.000	6.000	7.000	2.000	3.000	7.000
Bünye (%)	0.250	1.000	2.000	3.000	2.000	5.000	2.000
Arazi kullanım	0.166	0.500	1.000	7.000	2.000	5.000	7.000
Yağış (mm)	0.142	0.333	0.142	1.000	2.000	5.000	7.000
Yükseklik (m)	0.500	0.500	0.500	0.500	1.000	3.000	2.000
Toprak derinliği (cm)	0.333	0.200	0.200	0.200	0.333	1.000	5.000
Bitki örtüsü (%)	0.142	0.500	0.142	0.142	0.500	0.200	1.000
Toplam	2.5	7.0	9.9	18.8	9.8	22.2	31

Normalize edilmiş ikili karşılaştırmalar matrisi

	Eğim (%)	*Bünye (%)*	*Arazi kullanım*	*Yağış (mm)*	*Yükseklik (m)*	*Toprak derinliği (cm)*	*Bitki örtüsü (%)*
Eğim (%)	0.400	0.570	0.606	0.372	0.204	0.135	0.222
Bünye (%)	0.100	0.142	0.202	0.159	0.204	0.222	0.060
Arazi kullanım	0.060	0.071	0.101	0.372	0.204	0.222	0.222
Yağış (mm)	0.050	0.047	0.014	0.053	0.204	0.222	0.222
Yükseklik (m)	0.200	0.071	0.050	0.026	0.102	0.135	0.060
Toprak derinliği (cm)	0.133	0.028	0.020	0.010	0.030	0.040	0.161
Bitki örtüsü (%)	0.050	0.071	0.014	0.007	0.051	0.009	0.032

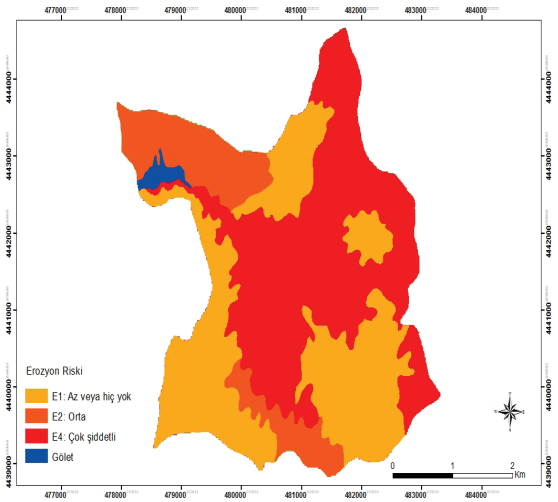
Öncelik vektör

	Normalize edilmiş satırlar toplamı	*Normalize edilmiş satırlar ortalaması*	*Öncelik vektörü*
Eğim (%)	2.509	2.509/7	0.358
Bünye (%)	1.089	1.089/7	0.156
Arazi kullanım	1.252	1.252/7	0.179
Yağış (mm)	0.812	0.812/7	0.116
Yükseklik (m)	0.644	0.644/7	0.092
Toprak derinliği (cm)	0.422	0.422/7	0.060
Bitki örtüsü (%)	0.234	0.234/7	0.033

Maksimum özdeğer $(\lambda)_{max}$ = 7.8, Tutarlılık indeksi (Tİ)= 0.13, Tutarlılık oranı (TO)= 0.09

Eğimin hemen ardından ikinci en yüksek ağırlık değerini arazi kullanımının alınması da yaklaşımın doğruluğunu göstermektedir. Çünkü doğal süreçler içerisinde genellikle yüksek eğimli arazilerden taban arazilere sürekli toprak taşınımının meydana gelmesi olağan bir işlem olarak görülmekte ve toprak oluşum süreci içerisinde telafi olabilmektedir. Fakat günümüzde toprak erozyonu ve arazi bozulumu kavramı özellikle arazilerin plansız, amaç dışı ve yanlış kullanımlarından dolayı oluşmaktadır.

Doğrusal kombinasyon tekniği dikkate alınarak oluşturulan çalışma alanına ait erozyon risk haritası Şekil 6'da ve her bir erozyon risk sınıflarının alansal ve oransal dağılımları ise Çizelge 7'de verilmiştir.



Şekil 6- Çalışma alanının erozyon risk haritası

Figure 6- Erosion risk map of the study area

Çizelge 7- Erozyon risk sınıflarının alansal ve oransal dağılımı

Table 7- Spatial and proportional distribution of erosion risk classes

Erozyon risk sınıfı	*Alan (ha)*	*Oran (%)*
E1	650	37.5
E2	259	15.0
E4	795	45.9
Gölet	28	1.6
Toplam	1732	100

Buna göre havzanın yaklaşık % 45.9'u çok şiddetli erozyon riski ile karşı karşıya kalırken alanın % 37.5'inde ise erozyon riski bulunmadığı belirlenmiştir. Aynı havzada Dengiz et al (2009) farklı modelsel yaklaşımla yaptıkları erozyon risk çalışmasında, alanın % 44.4'ünün yüksek erozyonun riski altında olduğunu buna karşın toplam havzanın % 42.0'sinin ise çok az risk taşıdığını veya hiç risk taşımadığını belirlemişlerdir. Çalışmaların sonuçları karşılaştırıldığında, birbirleri ile oldukça yakın paralellik gösterdiği görülmektedir.

Havzada erozyon riskinin yüksek olduğu yerler, eğimi fazla yamaç araziler üzerinde ve koruyucu bir bitki örtüsünün olmadığı veya çok zayıf olduğu, hatta yer yer kuru tarım olarak kullanılan alanlar olduğu belirlenmiştir.

4. Sonuçlar

Bu çalışma ile Güvenç Havzası'nda erozyona etki eden parametrelerin değerlendirilmesinde çok kriterli karar verme yöntemlerinden biri olan AHS ve doğrusal kombinasyon tekniğinden yararlanılmıştır. Yapılan çalışma sonucunda; havzanın % 45.9'unun şiddetli ve çok şiddetli erozyon riski altında olduğu, alanın % 15'inin orta düzeyde ve % 37.5'inin ise erozyon tehlikesine yönelik risk taşımadığı belirlenmiştir. Şiddetli erozyon riski altında olan alanlar genellikle eğimi yüksek, sığ toprak derinliğine sahip, bitki örtüsünce zayıf ve özelikle yer yer kuru tarım olarak kullanılan alanlardır. Buna karşılık erozyon riski çok az veya hiç olmayan alanları ise genellikle yüksek düzlük araziler ile havzanın kot seviyesi en düşük yeri olan gölet etrafında yer alan, hafif eğimli bitki örtüsünce kaplı alanlar oluşturmaktadır.

Bu çalışma UA, CBS, AHS ve Z-Skor teknikleri tarafından erozyon risk durumunun ortaya konulabileceğini göstermektedir. Bu yaklaşımla nicel olarak bir alanda erozyon tehlikesi belirlenmiştir. Elde edilen sonuçlar farklı yeni bilimsel çalışmalara ve yerel yöneticilere bilimsel veri sağlayacaktır. Modelden elde edilen sonuçlara göre, çalışma alanının geniş alanlarda şiddetli erozyon tehlikesi ile karşı karşıya olduğu belirlenmiştir. Böylece

şiddetli erozyon alanları, acil müdahale gerektiren yerler olarak belirlenmiştir. Diğer alanların ise acil koruma çalışmalarına öncelik verilmelidir.

Havzada özellikle eğimin fazla olması nedeniyle, erozyona en fazla etki eden faktör eğim olarak belirlenmiştir. Etkili olan diğer önemli faktörler ise arazi kullanımı/arazi örtüsü, toprak tekstürü, yağış, yükseklik, toprak derinliği ve bitki örtüsü olmuştur. Erozyona hassas olan alanlarda bu faktörlerin de göz önünde bulundurularak toprakların taşınımını engelleyici tedbirlerin alınması gerekmektedir.

CBS ve UA teknikleri, yeni yöntem ve modellerle gün geçtikçe artan bir öneme sahip olmuştur. Erozyona etki eden faktörlerin çoğunda CBS ve UA tekniklerinin kullanılması, analizlerin yapılmasında ve haritaların oluşturulmasında kolaylıklar sağlamıştır. Bu tekniğin kullanılması verilere daha kısa sürede ulaşılmasına, analiz ve sorgulama işlemi ile haritaların üretilmesine olanak tanımıştır. Bu tekniklerin kullanımlarının yaygın hale getirilmesi, yerel yöneticilerin ve bilim adamlarının daha hızlı ve doğru olarak sonuçlara ulaşmasına imkân sağlayacaktır.

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Borçka Barajı Rezervuarında Yeni Oluşmuş Bir Sediment Birikim Sahasındaki Penetrasyon Direnç Değerlerinin Uzaysal Dağılımı

Bülent TURGUT[a], Mehmet ÖZALP[a], Taşkın ÖZTAŞ[b]

[a]*Artvin Çoruh Üniversitesi, Orman Fakültesi, Orman Mühendisliği Bölümü, 08000, Artvin, TÜRKİYE*

[b]*Atatürk Üniversitesi, Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümü, 25240, Erzurum, TÜRKİYE*

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Bülent TURGUT, E-posta: bturgut@artvin.edu.tr, Tel: +90 (533) 648 71 88
Geliş Tarihi: 31 Aralık 2014, Düzeltmelerin Gelişi: 25 Aralık 2015, Kabul: 28 Aralık 2015

ÖZET

Bu çalışma, Borçka Barajı rezervuarında yeni oluşmuş sediment birikim sahalarından birindeki penetrasyon direnci (PD) değerlerinin yatay ve düşey doğrultudaki uzaysal değişkenliğinin belirlenmesi amacıyla yürütülmüştür. Araştırma sahasında 50 m x 10 m aralıklarla 91 grid oluşturulmuş ve her bir gridde 80 cm'lik derinlik boyunca 10 cm'lik artışlarla belirlenen 8 katmanın PD değerleri ölçülmüştür. Tüm katmanlarda PD'nin uzaysal değişkenliği jeoistatistiksel yöntemlerle belirlenmiştir. Her bir katman için PD'ne ait semivaryogramlar oluşturulmuş ve buna bağlı olarak krigleme haritaları üretilmiştir. Çalışma sonunda PD'nin yüzey katmanında (0-10 cm) en yüksek değeri aldığı (0.75 MPa) ve derinlikle beraber kademeli olarak azaldığı ortaya konulmuştur. Tanımlayıcı istatistikler ve jeoistatistiksel analiz sonuçları, çevresel faktörlerden önemli seviyede etkilenen ve ölçüm zamanında daha kuru olan yüzey katmanındaki PD değerlerinin diğer katmanlara nazaran daha değişken olduğunu göstermiştir. PD'nin uzaysal değişkenliği, ilgili semivaryogramların sill, nugget ve range değerleri ile krigleme yoluyla üretilen yüzey haritaları tüm katmanlarda farklılık göstermiştir. Jeoistatistiksel range değerlerinin en kısası (40.8 m) yüzey katmanında (0-10 cm) ve en uzunu (173.3 m) ise ikinci katmanda (21-30 cm) hesaplanmıştır. Bunun yanında en yüksek nugget etki (% 44) üçüncü katmanda (21-30 cm) ve en düşüğü ise (% 13) ikinci katmanda gerçekleşmiştir. Benzer çalışmaların farklı birikim sahalarında ve daha fazla değişkenle tekrar edilmesinin, bu alanlardaki uzaysal değişkenliğin gelişiminde ve derecesinde etkili olan mekanizmaların anlaşılmasında yararlı olacağı düşünülmektedir.

Anahtar Kelimeler: Jeoistatistik; Krigleme; Sediment; Semivaryogram; Sıkışma

Spatial Distribution of Penetration Resistance in a Recently Deposited Sediment Area within the Borçka Dam Reservoir

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Corresponding Author: Bülent TURGUT, E-mail: bturgut@artvin.edu.tr, Tel: +90 (533) 648 71 88
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ABSTRACT

This study was conducted to analyze vertical and horizontal spatial variability of penetration resistance (PR) in recently deposited sediments at Borçka Dam reservoir. Ninety-one grids with 50 m by 10 m were located and PR was measured

to a depth 80 cm by 10 cm increment (8 layers) within each grid. Spatial variation of PR was assessed by geostatistical techniques in all 8 layers. Semivariograms of PR were constructed for all the layers and corresponding kriging maps were built. The PR values were greater in surface layer (0-10 cm) and gradually decreased by depth. Mean PR was greatest (0.747 MPa) in surface layer and lowest (0.413 MPa) in 61-70 cm (layer 7). Results from exploratory statistics and geostatistical analyses showed that the PR values were more variable in surface layer compared to those in deeper layers due to that the surface layer was drier at the sampling and that affected by environmental factors in a greater extent. All the studied layers exhibited differences in spatial variation of PR as sill, nugget, and range values of corresponding semivariograms and kriging-predicted surface maps showed. The shortest geostatistical range (40.8 m) occurred of surface layer while longest (173.3 m) occurred for second layer (11-20 cm). The nugget effect was greatest (44%) in third layer (21-30 cm) while lowest (13%) in the surface layer. The same study may be repeated with more variables to understand mechanisms behind development and extent of spatial variation in these newly deposited sediments.

Keywords: Compaction; Geostatistics; Kriging; Sediment; Semivariogram

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1. Giriş

İnsan müdahalelerinin söz konusu olmadığı nehirlerde sediment giriş ve çıkışı dengededir (Morris & Fan 1998). Ancak barajlar gibi nehrin doğal akış rejimini değiştiren yapılar nedeniyle denge bozulmakta, suyun akış hızının ve taşıma gücünün azaldığı rezervuar sahalarında kademeli olarak sediment birikimi gerçekleşmektedir (Bravard et al 2014). Baraj rezervuar sahalarında biriken sedimentler genellikle kum, silt ve kil iriliğindeki parçacıklardan oluşmaktadır (Kamarudin et al 2009).

Sediment birikim sahalarındaki penetrasyon direnci (PD) ölçümleri birikim süresine göre farklılık göstermektedir. Sediment birikiminin ilk aşamasında kil ve silt tanecikleri parçacıklar arası köprü marifetiyle gevşek bir matriks içinde yerleşmektedirler (Morris & Fan 1998). Fakat zamanla ortama dâhil olan yeni sedimentlerin kendi ağırlıkları nedeniyle oluşturdukları basınç, poroziteyi ve boşluk oranını azaltıp hacim ağırlığını arttırarak PD'nin yükselmesine neden olmaktadır (Arega & Hayter 2008; Narantsetseg et al 2014).

Rezervuar sahalarında biriken sedimentlerin orijinleri farklı olduğundan sediment özellikleri önemli derecede değişkenlik göstermektedir (Walling & Moorehead 1989; Morris & Fan 1998; Xu 2000). Bu nedenle sediment özelliklerinin istatistiksel anlamda değerlendirilmesinde, bir parametrenin uzaysal dağılımını ve uzaysal davranışını karakterize eden, bu bilgileri kullanarak incelenen değişkenin örneklenen noktalar arasındaki değerini tahmin eden ve tahminleme hatasını en aza indirgemede kullanılabilen jeoistatistiksel analizler tercih edilmektedir (Webster & Oliver 1992; Cabezas et al 2010; de Groot et al 2011).

Deriner Barajı'nın 2012 yılından itibaren su tutmaya başlaması ile Borçka Barajı rezervuarına ulaşan su miktarında önemli düzeyde azalma meydana gelmiş ve buna bağlı olarak rezervuar sahasının önemli bir kısmında sediment birikim alanları belirgin bir şekilde ortaya çıkmıştır. Bu birikim sahalarından biri de Çoruh Nehri'nin membaına doğru ve Borçka Barajı'na yaklaşık 20 km mesafede oluşmuş ve bu durum şimdiye kadar üzerinde çalışılmamış olan yeni sediment birikim sahalarında araştırma yapma fırsatı sunmuştur.

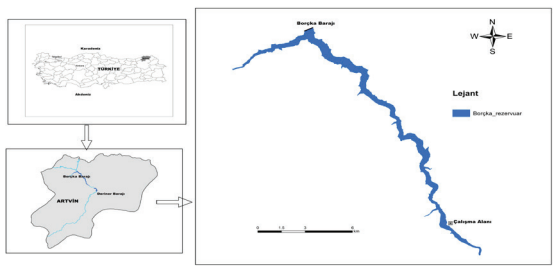
Bu çalışmanın amacı, Borçka Barajı rezervuar sahasında oluşmuş yeni sediment birikim sahalarında PD'nin (i) derinliğe bağlı olarak değişimini incelemek, (ii) uzaysal bağımlılık derecelerini belirlemek ve (iii) dağılım haritalarını oluşturmaktır. Böylece yeni biriken sedimentlerdeki sıkışma süreci hakkında şimdiye kadar literatürde yer almayan bilgilere ulaşılması amaçlanmıştır.

2. Materyal ve Yöntem

2.1. Çalışma alanının genel özellikleri

Çalışma Çoruh Nehri üzerinde kurulmuş olan Borçka Barajı rezervuar alanında oluşan sediment birikim alanlarından birinde yürütülmüştür (Şekil 1). Söz konusu alan Borçka Barajının 20 km güneyinde ve Artvin şehir merkezi çıkışının 3 km kuzeyindedir. Çalışma alanının denizden yüksekliği ise yaklaşık 190 m'dir. Çoruh havzası, yılda taşınan yaklaşık 5.8 milyon m^3 sediment miktarı ile toprak erozyonunun

en yoğun olduğu havzalardan birisidir (Sucu & Dinç 2008). Borçka Barajı'nın 2006 yılından itibaren su tutmaya başlaması ile beraber yaklaşık 10.84 km^2'lik bir rezervuar alanı oluşmuştur. Rezervuar sahasındaki sedimentin kaynağını Çoruh havzası boyunca erozyonla taşınan materyal ile yol yapımı ve baraj inşaatı esnasında nehre atılan hafriyat oluşturmaktadır. Çoruh havzasının ortalama eğimi % 30'un üzerinde olup (Zengin et al 2009; Akıncı et al 2013; Yavuz Özalp et al 2013) havza sınırları içerisinde oldukça yüksek oranlarda bozuk ormanlar ve çıplak alanlar mevcuttur (Pekal & Tilki 2010). Çalışma alanındaki sedimentlere ait bazı fiziksel ve kimyasal özellikler incelendiğinde alandaki yaygın tekstür sınıfının killi tın olduğu, pH değerleri bakımından hafif alkalin, organik madde içeriği bakımından düşük ve agregat stabilitesi bakımından ise zayıf sınıfında yer aldığı belirlenmiştir (Çizelge 1).



Şekil 1- Borçka Barajı rezervuar sahası ve çalışma alanı

Figure 1- Location of Borcka Dam reservoir and the experimental field

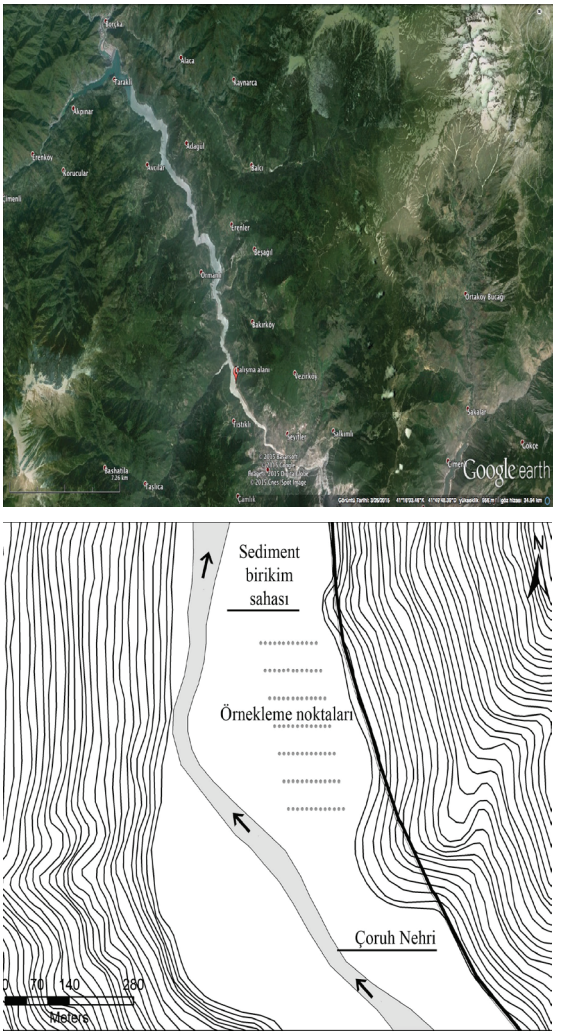
Çizelge 1- Çalışma alanına ait sediment özellikleri (n= 182)

Table 1- Sediment properties of the study site (n= 182)

Sediment özelliği	*Ortalama*	*Değişkenlik katsayısı (%)*
Kil (%)	35.12	44.14
Kum (%)	23.53	106.16
Silt (%)	41.34	31.35
pH	7.71	2.00
Organik madde (%)	1.06	36.11
Agregat stabilitesi (%)	17.47	67.34

2.2. Örnekleme yöntemi ve penetrasyon direnç değerlerinin ölçülmesi

Yaklaşık 300 m uzunluğunda ve 120 m genişliğindeki 3.6 ha'lık çalışma alanı Doğu-Batı ve Kuzey-Güney doğrultularında 50 m x 10 m'lik gridlere bölünmüş ve gridlerin kesiştiği 91 noktada penetrasyon direnci (PD) ölçülmüştür (Şekil 2). PD'nin belirlenmesinde her 1 cm'lik derinlikten ölçüm değeri alabilen bir



Şekil 2- Çalışma alanının topoğrafyası ve örnekleme noktaları

Figure 2- Topography of the experimental field and location of sampled points

dijital penetrometre (Eijelkamp Penetrologger) kullanılmıştır. Elde edilen ölçümlerden her bir örnekleme noktası için 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm ve 70-80 cm'lik katmanlar için ortalama PD hesaplanmıştır. Örneklerin tane büyüklük dağılımlarının belirlenmesinde Bouyoucos hidrometre yöntemi (Gee & Bauder 1986), organik madde içeriğinin belirlenmesinde ıslak yakma yöntemi (Mulvaney 1996), suya dayanıklı agregatların belirlenmesinde Yoder ıslak eleme yöntemi (Dane et al 2002) ve pH'ların belirlenmesinde ise 1:2.5 sediment:su süspansiyonu kullanılmıştır (Conklin 2005).

2.3. Tanımlayıcı istatistikler ve jeoistatistiksel yöntemler

Veri setinde yer alan tüm değerlere tanımlayıcı istatistiksel analizler uygulanmıştır. Bu amaçla, her bir katman için en düşük ve en yüksek değer, ortalama, standart sapma, çarpıklık ve basıklık değerleri hesaplanmıştır. Bunun yanında verilerin normal dağılıma uygunluklarının belirlenmesinde Shapiro-Wilk W Testi uygulanmıştır. Normal dağılıma uygunluk analizinde artık (residual) değerler kullanılmıştır (Montgomery et al 2012). PD bakımından katmanlar arasındaki farklılığın belirlenmesinde tek yönlü varyans analizi (ANOVA) ve ortalamaların karşılaştırılmasında asgari önem derecesi (LSD) çoklu karşılaştırma testi kullanılmıştır. Uygulanan istatistiksel analizlerde JMP 5.0 yazılımından yararlanılmıştır.

PD'nin her katmandaki uzaysal bağımlılığı, semivaryogram analizi yardımıyla belirlenmiştir. Semivaryogram belli bir h mesafesi ile birbirlerinden ayrılan örnek çiftleri arasındaki varyansın mesafeyle olan ilişkisini göstermektedir. Diğer bir ifade ile semivaryogram, örnekleme çiftleri arasındaki mesafenin bir fonksiyonu olarak uzaysal bağımlılığı tanımlamakta ve matematiksel olarak Eşitlik 1 ile ifade edilmektedir (Journel & Huijbregts 1978).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N} [Z(x_i) - Z(x_i + h)]^2 \qquad (1)$$

Burada; γ(h), semivaryans; *N(h)*, *h*, mesafesi ile ayrılan örnek çiftlerinin sayısı; *Z(xi)*, incelenen özelliğin *i* noktasındaki ölçüm değeri ve *Z(xi+h)* ise incelenen özelliğin (i+h) noktasındaki ölçüm değeridir.

Standart bir varyogramın tanımlanmasında üç temel parametre kullanılmaktadır, bunlar; nugget varyans (c_0), sill (c_0+c) ve range (r)'dir. Nugget varyans, örnekleme ölçeğinde açıklanamayan varyasyonu temsil etmektedir. Bu varyans sadece ölçüm hatalarından ve mikro ölçekli varyasyondan kaynaklanmaktadır. Sill, varyogram ile elde edilebilen en yüksek varyans değeridir ve şansa bağlı sürecin varyansını tahmin etmektedir. Range ise örnek çiftlerinin birbirleriyle ilişkili olabilecekleri en yüksek mesafe ya da uzaysal ilişkinin sınırı olarak tanımlanmaktadır.

İncelenen yapının en önemli uzaysal özelliklerini elde etmek için varyogram modellerinden küresel ve üssel modeller deneysel varyogram olarak belirlenmiştir. Bu modeller Eşitlik 2 ve Eşitlik 3'te tanımlanmıştır (Oliver & Webster 2014).

Küresel model için;

$$\begin{aligned} \gamma_m(h) &= c_0 + c\left[\frac{3h}{2} - \frac{1}{2}\left(\frac{h}{r}\right)^3\right] && h \le r \\ \gamma_m(h) &= c_0 + c && h > r \end{aligned} \qquad (2)$$

Eksponansiyel model için;

$$\gamma_m(h) = c_0 + c\left[1 - \exp\left(\frac{-3h}{a}\right)\right] \qquad (3)$$

Burada; h=|h|, örnek çiftleri arasındaki mesafeyi (lag); c_0, nuget varyansı; c, uzaysal olarak ilişkilendirilen varyansı ve r ise range değerini ifade etmektedir.

Her bir katman için PD'nin uzaysal dağılımlarının haritalandırılmasında, yakın örnek değerlerinin ağırlıklı ortalamasını esas alarak örneklenmeyen noktaların değerlerini tahmin eden Kriging interpolasyon yöntemi kullanılmıştır (Goovaerts 1999). Bu yöntem Eşitlik 4 ile ifade edilmiştir.

$$\hat{Z}(S_0) = \sum_{i=1}^{N} \lambda_i Z(S_i) \qquad (4)$$

Burada; $Z(S_i)$, incelenen özelliğin *i* noktasındaki ölçüm değerini; λ_i, *i* noktasındaki ölçülen değere

verilmesi gereken ağırlığı; S_0, tahmini yapılan noktayı ve N ise $\hat{Z}(S_0)$'nun tahmininde kullanılan komşu veri sayısıdır. Jeoistatistiksel analizlerin uygulanmasında GS+10 yazılımı kullanılmıştır (Gamma Design Software 2014).

3. Bulgular ve Tartışma

3.1. Tanımlayıcı istatistikler

Veri setinde yer alan değerlere ait ortalama, standart sapma, en düşük ve en yüksek değer ile değişim genişliği değerlerini içeren tanımlayıcı istatistik sonuçları Çizelge 2'de verilmiştir.

Penetrasyon direnci (PD) değerlerine ait en yüksek ortalama (0.75 MPa) ve standart sapma değeri (0.12) yüzey katmanında (0-10 cm) hesaplanmıştır. Standart sapma değerinin yüksek olması, PD'nin bu katmanda heterojen bir dağılım gösterdiğinin bir ölçüsüdür. Bunun yanında 31-40 cm'lik katmandan itibaren standart sapma değerlerinde kademeli olarak bir azalma görülmüştür. Üst sediment katmanındaki PD değerlerinin diğer katmanlara nazaran daha geniş bir aralıkta yer aldığı (0.62), derinlik artışına bağlı olarak bu aralığın daraldığı ve en alt katmanda en düşük seviyeye indiği (0.22) belirlenmiştir. Ölçüm hatası veya uç değerlerin dağılım histogramı yardımıyla belirlenip veri setinden çıkarılmasından sonra (32 değer) yapılan normal dağılım uygunluk analizinde, tüm katmanlardaki PD değerleri normal dağılım göstermiştir (Çizelge 2).

PD değerlerinin yüzey sediment katmanında (0-10 cm) daha heterojen bir dağılım göstermesine başta sıcaklık olmak üzere rüzgâr ve su seviyesindeki değişimler gibi çevresel faktörlerin neden olduğu düşünülmektedir. Üst katmanda farklı derecelerde meydana gelen kurumalar, PD'nin bu katmanda daha heterojen bir dağılım göstermesiyle sonuçlanmıştır. Birikim sahasının mikro topografik yapısındaki farklılıklar, yüzey sediment katmanındaki heterojenliğin diğer bir nedeni olabilir. Mikro topoğrafyadaki değişikliklerin suyun ve rüzgârın taşıma gücünü etkileyerek taneciklerin farklı yerlerde ve farklı oranlarda birikmesine ve PD'nin de çalışma alanında önemli seviyede değişkenlik göstermesine neden olduğu düşünülmektedir. Araştırmacılar su seviyesindeki değişimlerin (Powell et al 2001; Lu et al 2010) ve rüzgârın (Zhang et al 2011), sediment birikim sahalarındaki tane büyüklük dağılımını ve bunun doğrudan bir sonucu olarak ta PD'ni (Buchanan et al 2010) etkilediğini bildirmektedirler.

3.2. Varyans analiz sonuçları

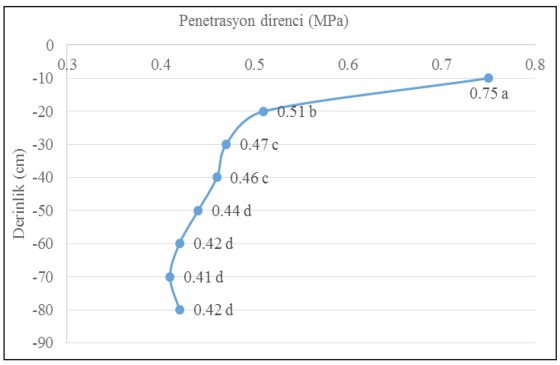
Çalışma alanındaki PD değerlerinin birikim katmanlarına göre önemli seviyede farklılık gösterdiği belirlenmiştir ($f= 110$; $P<0.01$). Birikim katmanları arasındaki bu farklılığın derecesini belirlemek amacıyla yapılan çoklu karşılaştırma testinde, üst sediment katmanındaki (0-10 cm) PD'nin en yüksek seviyede olduğu (0.75 MPa) ve derinliğe bağlı olarak bu değerin düşme eğiliminde olduğu belirlenmiştir (Şekil 3).

Çizelge 2- Her bir sediment katmanındaki penetrasyon direnci değerlerine ait istatistiksel parametreler

Table 2- Statistical parameters of penetration resistance values for each sediment layer

Katman (cm)	*Ortalama*	*Standart sapma*	*En düşük*	*En yüksek*	*Değişim genişliği*	*Çarpıklık*	*Basıklık*	*Shapiro-Wilk W-test*
0-10	0.75	0.12	0.45	1.07	0.62	-0.41	-0.19	0.98[öd]
11-20	0.51	0.09	0.34	0.76	0.42	0.07	1.71	0.97[öd]
21-30	0.47	0.10	0.32	0.73	0.41	0.48	0.15	0.97[öd]
31-40	0.46	0.11	0.30	0.82	0.52	0.48	0.55	0.96[öd]
41-50	0.44	0.09	0.31	0.68	0.37	0.18	1.12	0.96[öd]
51-60	0.42	0.07	0.32	0.64	0.32	0.24	1.78	0.97[öd]
61-70	0.41	0.07	0.32	0.65	0.33	0.14	1.97	0.96[öd]
71-80	0.42	0.06	0.33	0.55	0.22	0.14	1.78	0.97[öd]

[öd], önemli değil



Şekil 3- LSD çoklu karşılaştırma testi sonucuna göre penetrasyon direnci değerleri bakımından katmanlar arasındaki farklılıklar (Asgari Önem Derecesi-LSD, 0.029)

Figure 3- The differences between layers in respect to the penetration resistance values according to the LSD test (Least Significance Difference-LSD, 0.029)

Oluşumu uzun yıllar alan rezervuar sedimentleri, kendi ağırlığı ve yıllar itibariyle eklenen sediment miktarından dolayı zaman içerisinde sıkışma eğilimi göstermektedirler (Morris & Fan 1998). Ancak çalışma alanındaki sediment birikim sahası yeni oluştuğundan dolayı tane dizilişleri derinlik boyunca ilk birikim koşullarını yansıtmaktadır. Morris & Fan (1998), kil ve silt içeriği yüksek olan sedimentlerin geniş boşluk oranlarına sahip gevşek bir matris oluşturma eğiliminde olduğunu bildirmektedir. Bu nedenle özellikle sıcaklık gibi çevresel faktörlerin etkisinde kalmayan alt katmanların bu gevşek dizilişten dolayı düşük PD'ne sahip olması beklenen bir sonuçtur. Üst sediment katmanında PD değerlerinin yüksek çıkmasının temel nedeninin doğrudan güneş ışığı ve rüzgâra maruz kalmasından dolayı meydana gelen nem kayıpları olduğu düşünülmektedir. Bu konuda yapılan çalışmalarda araştırmacılar nem içeriğindeki azalmaya bağlı olarak PD değerlerinde bir artış olduğunu bildirmektedirler (Kılıç et al 2004; Vaz et al 2011; Turgut & Oztas 2012). Bunun yanında ıslanma-kuruma süreçlerinin üst katmanda daha etkili olması taneciklerin daha sıkı bir şekilde paketlenmesine (Dexter et al 1984; Hadas 1990) ve buna bağlı olarak PD'nin bu katmanda daha yüksek değerler almasına neden olmuştur.

3.3. Jeoistatistiksel analiz sonuçları

3.3.1. Semivaryogram ve uzaysal otokorelasyonlar

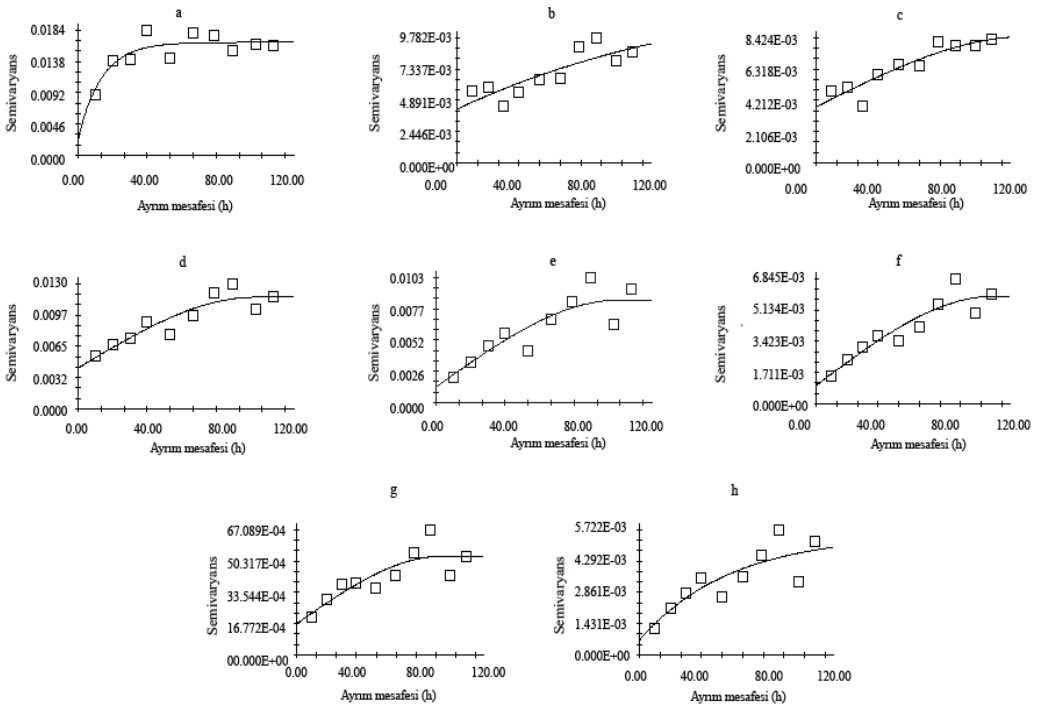
Sediment birikim katmanlarındaki PD değerleri için oluşturulan izotropik semivaryogramların jeoistatistiksel parametreleri Çizelge 3'te verilmiştir. Örnek sayısının 150'nin altında olması, PD'nin yöne bağlı olarak değişiminin (anisotropy) belirlenmesine engel olmuştur (Goovaerts 1999). Bu nedenle değişimin mesafeyle ilişkilendirildiği izotropik modeller kullanılmıştır (Şekil 4).

Çizelge 3- Her bir sediment katmanındaki penetrasyon direnci değerlerine ait semivariygram modelleri ve model parametreleri

Table 3- The semivariogram models and model parameters of penetration resistance values in each sediment layer

Sediment katmanı (cm)	*Teorik model*	C_0	C_0+C	*Range (m)*	C_0/C_0+C	r^2
0-10 cm	Üssel	0.00220	0.01660	40.80	0.13	0.753
11-20 cm	Üssel	0.00420	0.01417	173.30	0.30	0.693
21-30 cm	Küresel	0.00377	0.00852	136.10	0.44	0.842
31-40 cm	Küresel	0.00424	0.01158	102.70	0.37	0.837
41-50 cm	Küresel	0.00129	0.00848	106.40	0.15	0.778
51-60 cm	Küresel	0.00101	0.00590	114.90	0.17	0.829
61-70 cm	Küresel	0.00140	0.00756	96.20	0.19	0.717
71-80 cm	Küresel	0.00088	0.00462	100.40	0.19	0.719

C_0, nugget varyans; C, yapı bileşeni; r^2; modele ait regresyon katsayısı



Şekil 4- Sediment katmanlarındaki (a, 0-10 cm; b, 10-20 cm; c, 20-30 cm; d, 30-40 cm; e, 40-50 cm; f, 50-60 cm; g, 60-70 cm; h, 70-80 cm) penetrasyon direnci değerlerine ait semivaryogram modelleri

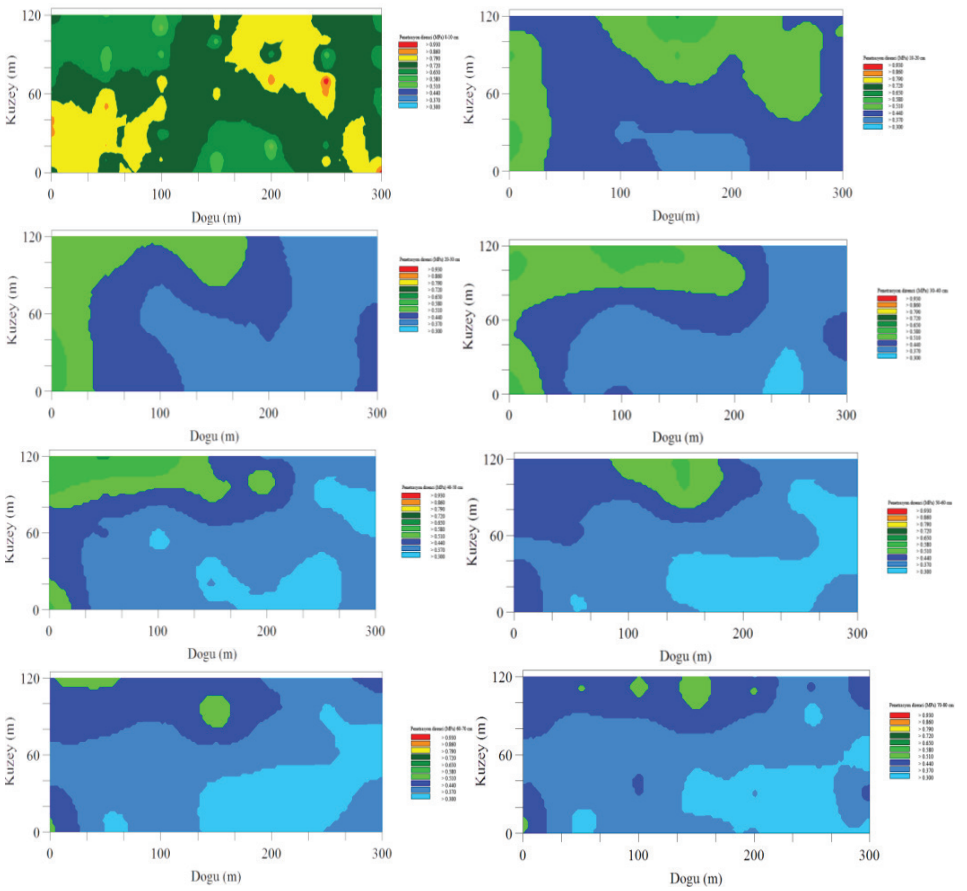
Figure 4- The semivariogram models of penetration resistance values in the sediment layers (a, 0-10 cm; b, 10-20 cm; c, 20-30 cm; d, 30-40 cm; e, 40-50 cm; f, 50-60 cm; g, 60-70 cm; h, 70-80 cm)

Model parametreleri incelendiğinde nugget değerlerinin 11-20 cm (0.00420), 21-30 cm (0.00377) ve 31-40 cm (0.00424) derinliğindeki katmanlarda daha yüksek olduğu görülmüştür. Diğer bir ifadeyle bu katmanlarda iki nokta arasındaki mesafenin sıfır olduğu durumda bile bir değişkenlik ortaya çıkmıştır. Bu değişkenliğin kaynakları ölçüm ya da örnekleme hatası (Jemo et al 2014; Oliver & Webster 2014), incelenen özelliğin örnekleme aralığından daha kısa mesafelerde değişkenlik göstermesi ve çalışma alanının doğasında var olan değişkenliktir (Jemo et al 2014). Söz konusu katmanlarda açıklanamayan değişkenliğin nedeninin, sıkışma anlamında henüz dengeye ulaşmamış sedimentlerin kendisini meydana getiren materyallerin farklı orijinlere sahip olmasından kaynaklanan doğal değişkenlik olduğu düşünülmektedir. Değişkenliğin uzaysal bağımlılığının (otokorelasyon) bir göstergesi olan nugget/sill oranının (C_0/C_0+C), % 25'in altında olması uzaysal bağımlılığın kuvvetli, % 25-75 arasında olması orta ve % 75'den büyük olması ise zayıf olduğunu göstermektedir (Li & Reynolds 1995; Chien et al 1997). Çalışma sahasının 11-20 cm, 21-30 cm ve 31-40 cm'lik katmanlarındaki C_0/C_0+C değerlerinin sırasıyla 0.30, 0.44 ve 0.37 olduğu, bu nedenle söz konusu katmanlarda ölçülen PD'ndeki değişimin orta düzeyde uzaysal bağımlılık gösterdiği belirlenmiştir. Diğer yandan 41-50 cm derinliğindeki katmandan itibaren, ölçülen özellik yüksek düzeyde uzaysal bağımlılık göstermiştir. Semivaryogramlarda belirlenen diğer bir model parametresi ise range değeridir. Oliver & Webster (2014) range değeri içerisinde kalan noktaların birbirleriyle ilişkili

olduğu, bu değerin dışındaki mesafelerde kalan noktaların ise uzaysal olarak bağımsız olduğunu bildirmektedirler. Bu çalışmada sediment katmanları içerisinde en düşük range değeri (40.80 m), standart sapma değerinin en yüksek olduğu yüzey katmanında (0-10 cm) hesaplanmıştır. Cambardella et al (1994) range değerinin aktif lag mesafesinden büyük olması durumunda örnek sayısının uzaysal bağımlılığın tahmin edilmesi için yetersiz olduğunu bildirmektedir. Çalışmada 21-30 cm ve 31-40 cm'lik katmanlar için hesaplanan range değerlerinin (sırasıyla 173.30 m ve 136.10 m) aktif lag mesafesinden (120 m) yüksek olması nedeniyle söz konusu katmanlardaki örnekleme sayısının (91) yetersiz olduğu sonucuna varılmıştır.

3.3.2. Krigleme ve penetrasyon direnç değerlerinin uzaysal dağılımı

Çalışma alanındaki sediment birikim katmanlarının daha iyi karşılaştırılabilmesi için dağılım haritalarında sınıf aralıkları her katmanda aynı alınmıştır. Kriging interpolasyon yöntemi ile oluşturulan PD değerlerine ait tahmin haritaları incelendiğinde yüzey katmanının (0-10 cm) diğer katmanlardan farklı bir dağılım gösterdiği görülmüştür. PD yüzey katmanında 0.510 MPa'nın altına düşmezken alt katmanlarda ise 0.650 MPa'nın üzerine çıkmamıştır (Şekil 5). PD yüzey katmanında daha yüksek değerlerler alsa da range değerinin daha düşük olmasının bir sonucu olarak,



Şekil 5- Sediment katmanlarındaki penetrasyon direnci değerlerinin uzaysal dağılım haritaları

Figure 5- The spatial distribution maps of penetratin resistance values in the sediment layers

dağılım haritasında alt katmanlardaki gibi kademeli değişimler yerine ani yükselmeler ve düşmeler görülmüştür.

Her ne kadar örnek sayısının yetersizliğinden dolayı değişimin yönle ilişkisi (anisotropy) incelenememiş olsa da alt katmanlarda PD'nin kuzey-güney ve doğu-batı yönlerinde bir artış eğiliminde olduğu fakat yüzey katmanında bu eğilimin net olarak görülmediği belirlenmiştir. Deriner barajının su tutmaya başlamasına kadar geçen süre içerisinde sediment birikimi rezervuar gölü tabanında meydana gelmiştir, ancak rezervuar sahasındaki su seviyesinin düşmesiyle beraber birikim sahaları yüzeye çıkarak çevresel faktörlerin etkisi altında kalmış ve bu durumdan en fazla etkilenen kısım ise yüzey katmanı olmuştur. Bu nedenle yüzey katmanındaki sedimentler birikim koşullarını yansıtan özelliklerini kaybetmiş, ancak çevresel faktörlerden daha az etkilenen alt katmanlar bu özelliklerini yansıtmaya devam etmişlerdir. Sediment birikim sahalarında nehir yatağına doğru gidildikçe biriken materyalin ortalama çap değerlerinin (Morris & Fan 1998) ve buna bağlı olarak PD değerlerinin arttığı (Buchanan et al 2010; Ecemis & Karaman 2014) bilinmektedir. Çalışma alanının güney ve batı kısımları nehir yatağına daha yakın olmasından dolayı bu alanlarda biriken materyalin daha iri parçacıklardan oluşması, alt katmanlarda PD değerlerinin bu alanlarda yüksek çıkmasını açıklamaktadır.

PD değerlerine ait ölçüm değerleri ile krigleme sonucunda elde edilen tahmin değerlerinin ortalama ve standart sapma değerleri Çizelge 4'te verilmiştir. Her bir katmandaki ortalama PD'nin farklılık göstermediği, ancak krigleme sonucunda elde edilen verilerin standart sapma değerlerinin daha düşük olduğu belirlenmiştir. Tahmin edilen değerler ile ölçüm değerleri arasındaki korelasyon katsayısı bu değerlerin 45° hat boyunca birbirlerinden ne ölçüde farklılık gösterdiğinin iyi bir göstergesidir (Ersahin & Brohi 2006). Bu amaçla yapılan değerlendirmelerde korelasyon katsayısının 0-10 cm derinliğindeki katmanda 0.47 ve 11-20 cm'lik katmanda ise 0.54 olarak hesaplanmıştır, ancak 21-30 cm'lik katmandan itibaren korelasyon katsayısının 0.70'in üzerinde olduğu belirlenmiştir. Elde edilen bulgular, yeni birikmiş sedimentlere ait PD'nin uzaysal dağılımlarının belirlenmesinde mevcut örnekleme mesafelerinin (50 m x 10 m) ilk iki katman için yetersiz olduğunu yani örnekleme mesafesinin daha kısa tutulması gerektiğini, üçüncü katmandan itibaren ise söz konusu örnekleme mesafesinin yeterli olduğunu göstermektedir.

Çizelge 4- Ölçülen ve modelde tahmin edilen değerlerin karşılaştırmaları

Table 4- Comparison of actual and estimated values

Değişken	*Ortalama*		*Standart sapma*		r^a
(cm)	*Ölçülen*	*Tahmin edilen*	*Ölçülen*	*Tahmin edilen*	
0-10	0.75	0.75	0.12	0.04	0.47
11-20	0.51	0.51	0.09	0.05	0.54
21-30	0.47	0.47	0.10	0.06	0.73
31-40	0.46	0.46	0.11	0.07	0.75
41-50	0.44	0.44	0.09	0.07	0.82
51-60	0.42	0.42	0.07	0.05	0.86
61-70	0.41	0.41	0.07	0.05	0.80
71-80	0.42	0.42	0.06	0.05	0.86

[a], çapraz doğrulama korelasyon katsayısı

4. Sonuçlar

Mevcut enerji yatırımları programı kapsamında Çoruh nehri üzerinde on adet baraj ve hidroelektrik santrali planlanmaktadır. Bunlardan ilk üç tanesi (Muratlı, Borçka ve Deriner Barajları) tamamlanarak enerji üretimine başlamıştır. Ancak, barajların

ekonomik ömrünü önemli ölçüde etkileyen sediment özelliklerinin belirlenmesi ile ilgili şu ana kadar herhangi bir çalışma yapılmamıştır. Bu çalışma söz konusu alanda sediment birikimi ile ilgili ilk çalışma olma niteliğindedir. Su tutmaya başladığı 2007 yılından beri Borçka Barajı Rezervuar sahasında önemli seviyede sediment birikimi gerçekleşmiştir. Özellikle mevsime bağlı su seviyesindeki düşmelerle bu birikintiler rezervuar sahası boyunca kendini göstermektedir. Biriken sedimentin büyük bir kısmının ince yapılı olduğu ve yılın belirli dönemlerinde bu birikim sahalarının su altında kaldığı gözlemlenmiştir.

Sediment katmanlarındaki penetrasyon direnci (PD) değerlerine ait tanımlayıcı istatistikler incelendiğinde, yüzey sediment katmanının hem en yüksek ortalama PD değerine sahip olduğu hem de incelenen özellik bakımından en heterojen katman olduğu görülmüştür.

PD bakımından sediment katmanları arasındaki farklılığın belirlenmesinde varyans analizi kullanılmıştır. Analiz sonuçları PD'nin yüzey katmanında en yüksek değer aldığını, beklenenin aksine derinliğe bağlı olarak önemli seviyede düşme eğiliminde olduğunu göstermiştir.

PD değerlerinin uzaysal değişimi jeoistatistiksel yöntemler kullanılarak belirlenmiştir. Semivaryogram analizleri sonucunda model parametrelerinin her bir katmanda farklı olduğu, örnekleme noktaları arasındaki varyansın mesafeye bağlı olarak değişkenlik sergilediği ve PD değerlerinin yüzey sediment katmanı dışındaki tüm katmanlarda nehre dik doğrultuda artış gösterdiği belirlenmiştir. Modellemelerin güvenilirliklerinin sorgulandığı çapraz doğrulama testlerinde ise uygulanan krigleme yönteminin (blok kriging) ilk iki katmanda (0-10 cm ve 11-20 cm) güvenilir sonuçlar vermediği ancak üçüncü katmandan (21-30 cm) itibaren modelin güvenilirliğinin arttığı görülmüştür.

Benzer çalışmaların daha fazla değişkenle rezervuar sahasındaki diğer sediment birikim sahalarında yürütülmesi ile hem rezervuar sahasının geneli hakkında hem de bu alanlardaki uzaysal değişkenliğin gelişim derecesinde etkili mekanizmaların anlaşılması noktasında yararlı olacağı düşünülmektedir.

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Contact Toxicity of Six Plant Extracts to Different Larval Stages of Colorado Potato Beetle (*Leptinotarsa decemlineata* SAY (Col: Chrysomelidae))

Mustafa ALKAN[a], Ayhan GÖKÇE[b], Kenan KARA[c]

[a]*Plant Protection Central Research Institute, Ankara, TURKEY*

[b]*Niğde Ömer Halisdemir University, Faculty of Agricultural Sciences and Technologies, Department of Plant Production and Technologies, Nigde, TURKEY*

[c]*Gaziosmanpasa University, Faculty of Agriculture, Department of Plant Protection, Tokat, TURKEY*

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Corresponding Author: Mustafa ALKAN, E-mail: mustafa_alkan@ziraimucadele.gov.tr, Tel: +90 (312) 344 59 93
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ABSTRACT

Discovery of new eco-friendly methods for insect pest management is very important in integrated pest management program. Contact toxicity of six plant extracts i.e. *Acanthus dioscoridis* L. (Acanthaceae), *Achillea millefolium* L. (Asteraceae), *Bifora radians* Bieb. (Apiaceae), *Heracleum platytaenium* Boiss (Apiaceae), *Humulus lupulus* L. (Cannabaceae) and *Phlomoides tuberosa* (L.) Moench (Lamiaceae), were tested on the 1st to 4th instar larvae of Colorado potato beetle (*Leptinotarsa decemlineata* Say. (Coleoptera: Chrysomelidae)). The *H. platytaenium* and *H. lupulus* extracts were the most effective among the tested extracts, so dose-response bioassay was carried out only with *H. lupulus* and *H. platytaenium* against larval stages of Colorado potato beetle. The *H. platytaenium* extract was the most effective extract with calculated LD_{50} values 0.126, 0.204, 0.206 and 0.458 µL insect^{-1}, LD_{90} values were calculated as 0.345, 0.342, 0.402, 0.566 µL insect^{-1} for 1st, 2nd, 3rd and 4th instars larvae respectively. These results indicate that *H. platytaenium* and *H. lupulus* extracts have great potentials as insecticides in the management of larvae of *L. decemlineata*.

Keywords: Colorado potato beetle; Plant extracts; *Heracleum platytaenium*; *Humulus lupulus*; Contact toxicity

Altı Bitki Ekstraktının Patates Böceğinin (*Leptinotarsa decemlineata* SAY (Col: Chrysomelidae)) Farklı Dönemlerdeki Larvaları Üzerine Kontakt Etkileri

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Mustafa ALKAN, E-posta: mustafa_alkan@ziraimucadele.gov.tr, Tel: +90 (312) 344 59 93
Geliş Tarihi: 04 Haziran 2015, Düzeltmelerin Gelişi: 31 Aralık 2015, Kabul: 31 Aralık 2015

ÖZET

Zararlı böcekler ile mücadelede yeni çevre dostu metodların keşfi entegre zararlı yönetiminde çok önemlidir. Farklı familyalara ait altı bitki ekstraktının (*Acanthus dioscoridis* L. (Acanthaceae), *Achillea millefolium* L. (Asteraceae), *Bifora radians* Bieb. (Apiaceae), *Heracleum platytaenium* Boiss (Apiaceae), *Humulus lupulus* L. (Cannabaceae) and *Phlomoides tuberosa* (L.) Moench (Lamiaceae)) kontakt toksisiteleri patates böceğinin (*Leptinotarsa decemlineata* (Coleoptera:Chysomelidae)) 1-4 dönem larvalarına karşı laboratuvar koşullarında test edilmiştir. *H. platytaenium* ve *H. lupulus* ekstraktları test edilen ekstraktlar arasında tüm larval dönemler için en yüksek toksik etkiye sahip olmuştur. Çalışmanın ikinci kısmında, *H. lupulus* ve *H. platytaenium* ekstraktların ile Patates böceğinin farklı larva dönemlerinde doz-etki ile denemeleri yürütülmüştür. *H. platytaenium* ekstraktı en yüksek toksik etkiye sahip olmuş ve bu bitki ekstraktı için LD_{50} değerleri birinci, ikinci, üçüncü ve dördüncü dönem larvalar için sırasıyla 0.126, 0.204, 0.206 ve 0.458 µL böcek^{-1} olarak, LD_{90} değerleri ise 0.345, 0.342, 0.402, 0.566 µL böcek^{-1} olarak hesaplanmıştır. Bu sonuçlar *H. platytaenium*'un patates böceği ile mücadele de potansiyele sahip olduğunu göstermektedir.

Anahtar Kelimeler: Patates böceği; Bitki ekstraktı; *Heracleum platytaenium*; *Humulus lupulus*; Kontakt toksisite

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1. Introduction

Colorado potato beetle (*Leptinotarsa decemlineata* SAY) (CPB) is a polyphagous insect-pest causing damage to various Solanaceae plants including potato, tomato and eggplant (Hsiao 1978; Hare 1990). In absence of control tactics, yield loss can rise to even 100% (Christie et al 1991). This cosmopolitan insect is spread over an area of 12 million km^2 in the world including North America, Asia and Europe (Alyokhin 2009). It feeds on different sections of the host plants and is also vectors of certain viral plant diseases e.g. potato spindle tuber viroid (PTSVD) (Borror & DeLong 1966; Kısmalı 1973; Jolivet et al 1988; Booth et al 1990).

A variety of insecticides are registered for the management of CPB. Extensive use of insecticides against this pest has led to serious problems like resistance, phytotoxicity and environmental contamination problems (Ioannidis et al 1991; Stewart et al 1997; Mota-Sanchez et al 2000). CPB has developed resistance to 54 insecticides belonging to different chemical classes with various modes of actions (Whalon et al 2013). These problems have led to exploration of different control methods like bio-pesticides including plant-based compounds against this pest. Although promising outcomes were reported with plant extracts especially acute toxicity and also behavioral effects (Hough-Goldstein 1990; Scott et al 2003; 2004; Gökçe et al 2005; 2006; 2012), however limited numbers of commercialized natural products are available for use (Hassan & Gökçe 2014).

In previous studies, *H. lupulus* and *B. radinas* were tested against CPB using total methanol extracts (Gökçe et al 2006; 2007). However, in the current study, these plants species were treated with solvent using maceration technique. This technique allows to obtain all available secondary plant metabolites using a larger amount of solvent (Hassan & Gökçe 2014) comparing with the previous studies. The other plant species (*Acanthus dioscoridis*, *Achillea millefolium*, *Heracleum platytaenium* and *Phlomoides tuberosa*) used in this study have not been not tested against CPB yet. The objectives of the current study were to evaluate the contact toxicities of six different plant extracts on various larval stages of CPB and to calculate LD_{50} and LD_{90} values for the most promising extracts.

2. Material and Methods

2.1. Materials

Plant species, extracted parts and places of collection are presented in the Table 1. As described in Gökçe et al (2005), the plants were collected in the summer or spring months of 2009. After the

separation of leafs, stems and cones from other parts, they were placed over blotting paper and kept under room temperature (25 ˚C) in dark conditions for two weeks. Subsequent to drying process, the plant materials were grounded into small pieces using a mill (M 20 IKA Universal Mill, IKA Group, Wilmington, NC, USA) and then they were put into 5 liter glass jars and protected in a dark room at 15±5 ˚C until they were used.

2.2. Preparation of plant extracts

Plant extracts were obtained through the maceration method as described in Alkan & Gökçe (2012). Two hundred grams of each plant species were put into a 5 liter glass jar and hexane, ethyl acetate, and methanol were separately added into the jar in an order according to their polarity range. Plant materials were firstly treated with hexane for 48 hours; and then the plant suspension was filtered through Whatman™ No 4 filter paper to obtain hexane fraction. After this process, ethyl acetate was added to the jars, and the plant materials were left again in this solvent for 48 hours at room conditions. Ethyl acetate fraction was filtered through the filter paper followed by separation from plant materials. Lastly, methanol was added to the plant materials and incubated as described above and then the filtration of the suspension was also repeated for methanol fraction. Excess solvents in the suspensions were evaporated using a rotary evaporator (RV 05 Basic 1-B, IKA® werke GmbH & Co. KG, Germany) and plant residues of *A. dioscoridis*, *H. platytaenium* and *P. tuberosa* were obtained. The *H. lupulus*, *B. radians* and *A. millefolium* extracts were prepared using the same technique but only methanol was used as a solvent. All plant extracts were diluted with 70% acetone solution to give the concentration of 15% plant extract/acetone (w v^{-1}). Plant extracts prepared were transferred to glass tubes and then stored at 4 ˚C in the refrigerator.

2.3. Rearing of potato beetles

Larvae of CPB were reared at Gaziosmanpasa University, Faculty of Agriculture, Plant Protection Department. CPB colony was continuously reared on potato plants (*Solanum tuberosum* L. cultivar Granola) which were planted at Gaziosmanpasa University Research Station in Tasliciftlik, Tokat, Turkey. The field was designated for the organic potato production and there was no pesticide application for 3 years prior to the initiation of this project and no pesticide was applied during the study. Granola cultivar was planted in a 0.2 ha potato field. When the potato plants reached to 3 to 5 leaves stage adults of test pest were released into the field and all required stages for the studies were collected from the field.

2.4. Single dose contact toxicity screening tests

Single dose contact toxicity of plant extracts were separately tested on 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} instars larvae of CPB. Identification of larval stage was carried out using Boiteau & Le Blancthe (1992)' key. An extract suspension (15% w v^{-1}) was applied at a 2 µL $insect^{-1}$ ratio to the dorsal of larva using a micro-syringe 25 µL microsyringe connected to a microapplicator (Hamilton® Company, Reno, NV). Ten larvae were treated in each replication. After the treatment, 10 larvae were transferred into a 90 mm in diameter glass petri dish in which potato leaflets

Table 1- Plant species and their parts used in the study

Çizelge 1- Çalışmada kullanılan bitkiler ve kısımları

Botanical name	*Family*	*Part used*	*Place collected*
Humulus lupulus	Cannabaceae	Cone	Tokat
Heracleum platytaenium	Apiaceae	Leaf, stem	Trabzon
Achillea millefolium	Asteraceae	Leaf, stem, flower	Tokat
Acanthus dioscoridis	Acanthaceae	Leaf, stem, flower	Erzincan
Phlomoides tuberosa	Lamiaceae	Leaf, stem, flower	Erzincan
Bifora radians	Apiaceae	Leaf, stem	Tokat

were provided. In the control group, the larvae were treated with 70% acetone at 2 µL insect^{-1} dose. An insecticide with spinosad active ingredient was used as a positive control, which was applied at 2 µL insect^{-1} dose as described above. Spinosad (Laser™, Dow Agro Sciences®) was prepared with water at recommended dose for larvae (0.1 mL L^{-1}). After the application, the larvae were incubated at 25±2 ˚C, 60±5% relative humidity (RH) and a 16:8 (Light: Dark) photo period. Mortality of larvae was recorded after 24 hours after treatment (HAT). Bioassays were set up in the randomized complete block design. Experiment was repeated on three different days (blocks) and in each replication all treatment contained three subset groups.

2.5. Dose-response bio-assay

Based on the single-dose screening test results, dose-response bioassays were carried out with *H. platytaenium* and *H. lupulus* extracts that showed high contact toxicity to CPB larvae. These plant extracts were tested against various stages on potato beetle larvae (1st, 2nd, 3rd and 4th instars larvae) in 6 different doses. The doses ranging from 10 to 200 g L^{-1} (10, 25, 50, 75, 100 and 150 g L^{-1} for the 1st , 2nd and 3rd instar larvae, 50, 75, 100, 150, 175 and 200 g L^{-1} for the 4th instars larvae) for *H. lupulus* and from 5 to 250 g L^{-1} (5, 10, 25, 50, 100 and 150 g L^{-1} for the 1st instar lavae, 25, 50, 75, 100, 125 and 150 g L^{-1} for the 2nd and 3rd instar larvae, 125, 150, 175, 200, 225 and 250 g L^{-1} for the 4th instars larvae) for *H. platytaenium* were prepared with 70% acetone and applied to the larvae at 2 µL insect^{-1} dose as stated above. In the control group, the larvae were treated with 70% acetone at 2 µL insect^{-1} dose. Randomized complete block experimental design was used in this study and each block comprised all tested doses and control. Whole treatments were repeated three times. Each trial consisted of 7 treatments i.e. six doses and control group that contained three subset groups.

2.6. Statistical analysis

Single-dose contact toxicity screening test results were firstly converted into percent mortality and then were subjected to arcsine transformation. Variance analysis was carried out with transformed data, and additionally, the differences among treatments were analyzed by means of Tukey multiple comparison test ($P<0.05$). All statistical analyses were conducted with MINITAB® Release 16 package program. Dose-response bioassay results were analyzed using Polo-PC probit package program (LeOra 2002), and confidence intervals were determined with LD_{50} and LD_{90} values.

3. Results and Discussion

3.1. Single dose contact toxicity screening tests

All tested plant extracts caused some contact toxicity to larvae of *L. decemlineata*, ranging from 1.5% to 100%. Among the tested plant extracts, *H. lupulus* showed the greatest contact toxicity to 1st instar larvae with 97.8% mortality 24 HAT. *Heracleum platytaenium* was the second most effective extract with 94.0% mortality rate. Mortality rates significantly between the treatments ($F= 86.87$; $df= 7, 16$; $P<0.05$). Unlike 1st instar larvae in 2nd instar larvae, the greatest mortality was observed when treated with *H. platytaenium* followed by *H. lupulus*. After 24 hours, mortality rate was 100% in case of *H. platytaenium* extract followed by 89.8% mortality recorded in case of *H. lupulus* extract (Table 2).

Insecticidal activities of the plants belonging to *Heracleum* genus against important insect pest species were previously reported by other researchers. Metspalu et al (2001) tested *Heracleum sosnowskyi* and *A. millefolium* against different stages of *L. decemlineata* larvae under laboratory conditions. They reported that the greatest contact toxicity was seen in *H. sosnowskyi* extract with 80% mortality. However their findings were not comparable to our studies possibly due to variation in way of extraction of plant extracts and polarity of solvents used for extractions (Ghosh et al 2012).

Chemical analysis of plants belonging to *H. platytaenium* genus showed that the leaves contained intensive secondary metabolite compounds such as octyl acetate, octyl butyrate, (z)-4-octenyl

Table 2- Contact toxicity of the plant extracts (15% w v^{-1}) on various development stages of *Leptinotarsa decemlineata* larvae after 24 hours

Çizelge 2- Bitki ekstraktlarının (% 15 w v^{-1}) Leptinotarsa decemlineata'nın farklı gelişme dönemleri üzerine 24 saat sonundaki kontakt toksisiteleri

	% Mortality±SD*			
Treatment	*1.instar*	*2. instar*	*3. instar*	*4. instar*
Control	0.00±0.00 b[1]	0.00±0.00 c	0.00±0.00 c	0.00±0.00 c
Acanthus dioscoridis	1.49±1.12 b	1.49±1.12 c	0.00±0.00 c	1.49±1.12 c
Achillea millefolium	2.18±1.79 b	4.32±0.20 c	1.49±1.12 c	0.00±0.00 c
Bifora radians	1.49±1.12 b	1.49±1.12 c	0.00±0.00 c	0.00±0.00 c
Heracleum platytaenium	94.00±4.76 a	100.00±0.00 a	100.00±0.00 a	3.33±0.00 c
Humulus lupulus	97.82±1.79 a	89.74±1.57 b	95.68±0.20 b	48.90±0.93 b
Phlomoides tuberosa	1.49±1.12 b	1.49±1.12 c	1.49±1.12 c	0.00±0.00 c
Spinosad	99.63±1.12 a	94.82±0.63 ab	87.10±0.84 b	90.77±1.41 a

[1], different letters following means in the same column indicate statistical significance from each other (Anova P<0.05, Tukey test); *, standard deviation

acetate**,** (z)-4-octenyl butyrate**,** octyl 3-methyl butyrate (=octyl isovalerate)**,** octyl hexanoate**,** octyl octanoate**,** hexyl 2-methylbutyrate**,** hexyl 3-methylbutyrate (=hexyl isovalerate)**,** decyl acetate and many others. Among these elements, octyl acetate and octyl butyrate have a major share (Iscan et al 2004) and both are very important essential oils (Carroll et al 2000) thus playing role in insect-pests' management (Koul et al 2008). In *H. lupulus*; humulene, caryophyllene and myrcene are the major constituents which are terpenes in nature thus playing significant role in insect-pests' management (Bernotienë et al 2004; Koul et al 2008). These chemicals could play an important role in toxicity of this plant species to CPB larvae.

Contact toxicity of *H. lupulus* extract was also very high and the mortality rate of 3rd instar larvae was treated with this extract was 95.7% 24 HAT. Similar activity with *H. lupulus* extract on the 3rd instar larvae was also reported by Gökçe et al (2007) who observed 91% mortality on their study.

The 4th instar larvae are the most destructive stages of CPB and cause serious damages on green parts of the plant (Wale et al 2008). The chemical standard spinosad as expected was the most effective treatment against this larval stage. Among the plant extracts, the most effective was *H. lupulus* with 48.9% mortality 24 HAT but this rate was lower than the mortality rates seen in the first three stages. Similarly, Gökçe et al (2006) reported that the first three larval stages were more sensitive than 4th instar larvae and adult insects. Scott et al (2003) tested plant extracts belonging to *Piperaceae* on CPB adults and larvae and they concluded that last stage larvae, pupae and adults were less sensitive than early stage larvae were. The results of the above studies are in accordance with our results. Varying contact toxicity effects of the plant extracts to CPB larvae could be related with physiological changes in developing larvae (Karakoç & Gökçe 2012).

3.2. Dose-response bioassay

Treatment of larval stages of CPB with various concentrations of *H. platytaenium* and *H. lupulus* extracts produced different LD_{50} and LD_{90} values. For 1st instar larvae, 0.126 µL insect^{-1} LD_{50} was calculated in case of *H. platytaenium* extract while that obtained with *H. lupulus* extract was 0.150 µL insect^{-1} (Table 3). There was no significant difference among the treatments (P<0.05). The LD_{90} values were 0.274 and 0.345 µL insect^{-1} for *H. lupulus* and *H. platytaenium* extracts, respectively. For the 2nd instar larvae, similar results were observed among treatments i.e. LD_{50} values were i.e. 0.168 µL insect^{-1} and 0.204 µL insect^{-1} for *H. lupulus* and *H. platytaenium* (P<0.05).

Additionally, no significant difference was also observed among LD_{90} values of these plant extracts. In the 3rd instar larvae, calculated LD_{50} was 0.206 µL insect^{-1} for *H. platytaenium* extract and 0.149 µL insect^{-1} for *H. lupulus* extracts with no significant difference among the treatments (Table 3). These results showed that LD_{50} and LD_{90} values increased according to developmental stages of larvae as expected. This could be related to morphological and physiological changes in the beetle larvae as there is a considerable size difference especially between 1st and 3rd instars. Therefore, more plant extract is required to produce 50% or 90% mortality in the tested larvae, which leads to bigger LD_{50} or LD_{90} values. Similarly, Gökçe et al (2006) stated that LD_{50} and LD_{90} values increased according to larval stages of CPB. Dose-response bioassay with *H. platytaenium* extract on 4th stage larvae showed that LD_{50} and LD_{90} values were 0.458 and 0.566 µL insect^{-1}, respectively.

Table 3- Results of dose-response bioassays of *Heracleum platytaenium* and *Humulus lupulus* extracts on various development stages of *Leptinotarsa decemlineata* larvae after 24 hours

Çizelge 3- Heracleum platytaenium ve Humulus lupulus ekstraktlarının 24 saat sonunda Leptinotarsa decemlineata'nın farklı gelişim dönemleri üzerindeki doz-etki denemeleri sonuçları

Plant	*Larval term*	*Slope±SD**	*LD_{50} (µL insect^{-1}) (Fudicial limit)*	*LD_{90} (µL insect^{-1}) (Fudicial limit)*
H. platytaenium	1st instar larvae	2.927±0.234	0.126 (0.087-0.190)	0.345 (0.220-0.928)
	2nd instar larvae	5.710±0.460	0.204 (0.154-0.285)	0.342 (0.256-1.073)
	3rd instar larvae	7.443±0.578	0.206 (0.189-0.226)	0.402 (0.358-0.461)
	4th instar larvae	14.034±1.733	0.458 (0.438-0.485)	0.566 (0.524-0.660)
H. lupulus	1st instar larvae	4.901±0.405	0.150 (0.137-0.164)	0.274 (0.242-0.324)
	2nd instar larvae	4.853±0.426	0.168 (0.152-0.185)	0.308 (0.267-0.378)
	3rd instar larvae	2.767±0.243	0.149 (0.118-0.189)	0.433 (0.311-0.776)

*, standard deviation

4. Conclusions

Evaluation of the plant extracts contact toxicities against the most destructive larval stages of CPB showed that especially *H. platytaenium* and *H. lupulus* were as effective as the chemical standard, spinosad, up to 4th instar larvae, and that the extracts obtained from those plants could be used in the control of Colorado potato beetle. This research is a core study; therefore it is considered that the study will become more significant with the help of other disciplines, which enable the purification and characterization of the active compound(s). That will definitely help further development of these plant extracts by the industry.

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Effect of Cup Size, Seed Characteristics and Angular Speed on the Performance of an Automatic Potato Planter under Laboratory Conditions

Mustafa Gökalp BOYDAŞ[a]

[a]*Atatürk Universiy, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, 25240, Erzurum, TURKEY*

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Corresponding Author: Mustafa Gökalp BOYDAŞ, E-mail: mboydas@atauni.edu.tr, Tel: +90 (442) 231 25 49
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ABSTRACT

The seed metering mechanism is the most important unit of potato planters. Accuracy of row plant spacing depends on the ability of the seed metering mechanism. The ability of the seed metering mechanism is directly associated with the constructive and operational variables of the planter. This study was conducted to evaluate the effects of different cups sizes (C1<C2<C3), different seed sizes (25 to 45 and 45 to 65 mm), different shapes (oblong and spherical), and angular speeds (0.9, 2.04 and 3.18 rad s^{-1}) on the seed metering mechanism in a full automatic potato planter. The cup, angular speed, seed size and shape have an important role on the efficiency of the seed metering mechanism. The seed spacing uniformity was determined including doubles and skips. The coefficient of variation (CV%) was used to determine the seed spacing uniformity. The values of CV% for cups were 29.24, 23.76 and 26.11% for C1, C2 and C3, respectively. C3 has the highest percent value of doubles and the lowest percent value of skips. The seed spacing uniformity of oblong potato seeds was better than that of spherical potato seeds. The percent value of doubles increased and percent value of skips decreased for oblong potato seeds, opposite to the spherical potato seeds. The seed size of 45-65 mm gave a better seed spacing uniformity than the other seed size. It was observed that the seed size of 25-45 mm had higher percent value of doubles. The seed spacing uniformity tended to increase as the angular speed reduced. The CV% values of angular speed were 22.83, 24.90 and 31.39% for 0.9, 2.04, 3.18 rad s^{-1}, respectively. As the angular speed increased, percent value of doubles decreased and percent value of skips increased.

Keywords: Seed metering mechanism; Seed spacing uniformity; Laser measurement system; Doubles; Skips

Laboratuvar Koşullarında Otomatik Bir Patates Dikim Makinasının Performansına Kepçe Büyüklüğünün, Tohum Karakteristiklerinin ve Açısal Hızın Etkisi

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Mustafa Gökalp BOYDAŞ, E-posta: mboydas@atauni.edu.tr, Tel: +90 (442) 231 25 49
Geliş Tarihi: 12 Haziran 2015, Düzeltmelerin Gelişi: 14 Aralık 2015, Kabul: 17 Aralık 2015

ÖZET

Tohum dağıtma düzeni patates dikim makinalarının en temel kısmını oluşturmaktadır. Sıra üzeri tohum dağılım düzgünlüğündeki doğruluk, tohum dağıtma düzeninin kabiliyetine bağlıdır. Tohum dağıtma düzeninin bu kabiliyeti yapısal ve çalışma şartlarına direkt olarak bağlıdır. Bu çalışma, tam otomatik bir patates dikim makinasında farklı büyüklükte kepçelerin (C1<C2<C3), farklı büyüklükteki tohumların (25 ile 45 mm ve 45 ile 65 mm arası), farklı şekildeki tohumların (uzun ve küresel) ve farklı açısal hızların (0.9, 2.04 ve 3.18 rad s^{-1}) tohum dağıtma düzeni üzerine etkisini belirlemek için yürütülmüştür. Kepçelerin, açısal hızın, tohum büyüklüğünün ve şeklinin tohum dağıtma düzeni üzerine önemli bir etkiye sahip olduğu görülmüştür. Denemede, tohum dağılım düzgünlüğü, ikili atma ve boş bırakma belirlenmiştir. Tohum dağılım düzgünlüğünü belirlemede varyasyon katsayısı (% CV) kullanılmıştır. C1, C2 ve C3 kepçeleri için en büyük % CV değerleri sırayla % 29.24, 23.76 ve 26.11 olarak bulunmuştur. C3 kepçesiyle en büyük ikili atma ve en küçük boş bırakma değerleri elde edilmiştir. Uzun tohumlardan elde edilen tohum dağılım düzgünlüğünün küresel tohumlara göre daha iyi olduğu belirlenmiştir. Uzun tohumlarda ikili atmanın arttığı ve boş bırakmanın azaldığı görülmüştür. Küresel tohumlarda ise bunun tam aksi görülmüştür. 45-65 mm aralığındaki tohumlardan elde edilen % CV değerlerinin 25-45 mm aralığındaki tohumlardan elde edilen % CV değerinden daha düşük olduğu belirlenmiştir. 25-45 mm aralığındaki tohumların ikili atmayı artırdığı görülmüştür. Açısal hızdaki azalma tohum dağılım düzgünlüğünde iyileşmeye neden olmuştur. Farklı açısal hızlardan elde edilen % CV değerleri; 0.9, 2.04, 3.18 rad s^{-1} için sırasıyla % 22.83, 24.90 ve 31.39 olarak bulunmuştur. Açısal hızdaki artış ikili atmada azalışa ve boş bırakmada artışa neden olmuştur.

Anahtar Kelimeler: Tohum dağıtma düzeni; Tohum dağılım düzgünlüğü; Lazer ölçüm sistemi; İkizlenme; Boş bırakma

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1. Introduction

Potato is an important food crop for humans and animals due to its desirable starch, protein and vitamins contents. The potato is used as a versatile vegetable and in the industry. The potato is grown in many countries around the world and in different climates (Taheri & Shamabadi 2013; Potato 2015). The potato acreage in Turkey is 125030 ha resulting in a harvest of 3.9 million tonnes of tubers and yield is 31.6 tons per ha for the year 2013 (FAO 2015). The most common potato varieties in Turkey have yellow flesh are Marabel, Marfona, Granola, Latona, Adora, Atlas, Fabula, Lady Rosetta, Lady Claire, Russet Burbank, Shepody, Agria and Van Gogh. According to regional conditions in Turkey, traditional and modern methods are used in the potato production. Traditional potato production is difficult, time consuming and labor intensive. Therefore, most of the farming operation for this crop has been mechanized to reduce the cost of production. There are three main stages in potato production: planting, cultivating, and harvesting. Planting has an important effect on the potato yield. Planting is performed by hand, semi-automatic planters, and fully automatic planters. Planting done by hand is time-consuming and requires a great deal of labor. Semi-automatic potato planters have a suitable performance and low labor and less time-consuming compared to planting by hand. Labor and time-consuming in fully automatic potato planters are the lowest level. Results achieved in potato planting by machine depend on complex relationships between the technical quality of machine performance and the ability to work fast with a minimum demand for labour (Culpin 1992; Steele et al 2010). The fully automatic potato planters release potato seeds in furrows at desired certain spacing and depth. A potato planting machine has many different parts such as frame, wheels, seed metering mechanism, furrow openers, covering discs, and the seed spacing adjustment gear. Among these parts, the seed metering mechanism is a crucial one. Accuracy of in-row seed spacing is the main parameter of the seed metering mechanism. Because, improvement of plant spacing uniformity leads to high yield, and to facilitate harvesting and post-harvest operations (McPhee et al 1996; Pavek & Thornton 2003). The plant uniformity affects development, yield and seed quality of plant (Bussan et al 2007; Güllüoglu & Arioglu 2009). Seed spacing uniformity has very important role for evaluating a

potato planter performance (Zoraki & Acar 2000; Seyedbagheri 2006). To increase yield and quality of potato, uniform seed spacing is required (Klassen 1974; Klassen 1975). Rupp & Thornton (1992) found that a 10% decrease or increase in the optimum plant number leads to reduce yield from 2% to 12%. Furthermore, they said that increasing skips and doubles reduced economic return compared with uniform seed spacing. Deep planting and diseased seed can cause skips to increase (Cross & Ohms 1967; James at al 1973). However, James et al (1975) determined that 88% of skips were due to the lack of seed. Some researchers found that the skips were mainly caused by mechanical deficiencies of the potato planter (Misener 1979). James et al (1973) found that 10, 20 and 30% of skips led to 0, 5.6 and 11.1% average yield loss, respectively. However, potato yield is a good criterion along with the market value of tubers in the proto production. Therefore, the physical properties of potato tubers also have an important role in appearance at markets. Tuber size is more important indication of marketable yield than the total tuber yield. Some researchers have showed that seed spacing uniformity plays a major impact on marketable yield (Schotzko et al 1983; Thornton et al 1983; Rex et al 1987; Rupp & Thornton 1992; Creamer et al 1999; Love & Thompson-Johns 1999). Getachew et al (2012) determined the effect of seed spacing on total yield and marketable yield of potato in Ethiopia. They found the highest total tuber yield at seed spacing of 10 cm whereas marketable tuber yield at seed spacing of 10 cm had the lowest value. Similarly, Love & Thompson-Johns (1999) determined that seed planted at seed spacing of 8 cm resulted in more potato yields than those of seed planted at spacing from 15 to 91 cm. But, they said that the market value decreased due to increasing percent of small potatoes. Naturally, accuracy of seed spacing changes depending on the size and shape of cups. However, although many works were done on potato planters, studies on the effect of cups on seed spacing uniformity are limited. Buitenwerf et al (2006) studied on cup-belt planter and stated that the geometry of cups should be focused. In addition, previous research (Khairy 1997; Altuntas 2005; Al-Gaadi & Marey 2011) showed that there was an effect of ground speed, and different seed sizes and shapes on seed spacing uniformity. Altuntas (2005) reported that in-row spacing uniformity decreased as ground speed increased. Khairy (1997) found that when the ground speed was higher than 3.6 km h^{-1}, seed spacing uniformity became worse. Similarly, Al-Gaadi & Marey (2011) determined that the lowest and the highest mean values of CV% were 28.73 and 54.53% for ground speed of 1.80 and 3 km h^{-1}, respectively. Sieczka et al (1986) stated that high planting speeds reduced performance of potato planter. Buitenwerf et al (2006) determined that potato shape had an important effect on seed spacing uniformity.

The objective of this study was to determine the effect of three various size cups, three different angular speeds, and two several seed size and shape on the seed spacing uniformity, skips and doubles; and then to develop a measurement system suitable for laboratory and field studies.

2. Material and Methods

2.1. Potato planter, cups, and angular speeds

The experiments were conducted at the laboratory of Agricultural Farm Machinery Department, Ataturk University, Erzurum, Turkey. The laboratory temperature and relative humidity were measured as 9 ^{0}C and 25%, respectively. A full automatic potato planter (Model: YN-08 Kenan Ertugrul, Nevsehir, Turkey) (Figure 1) was used in the experiments.

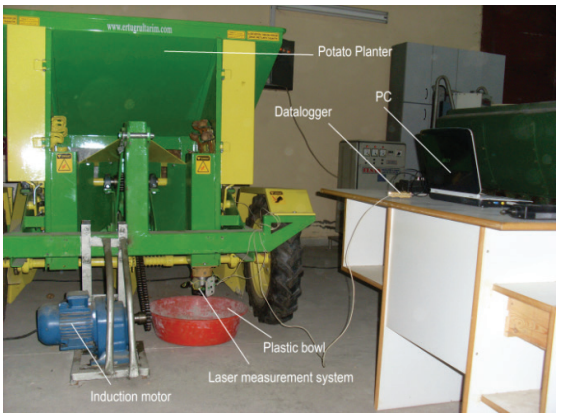

Figure 1- Potato planter and test rig

Şekil 1- Patates dikim makinası ve deney düzeneği

The potato planter consists of two rows. The seed metering mechanisms are placed under the hopper, and driven by ground wheels. The seed metering mechanism consists of a vertical disc, cups, holding pins, and torsion springs. The 14 cups, 14 holding pins, and 14 torsion springs are attached with equal angles to the vertical disc.

The seed metering mechanism works like a water mill. The cups, attached to vertical disc, clutch potato seeds in the bottom of seed hopper while the vertical disc rotates. Then, seed entering into the cup is kept by the holding pin, and transferred out of the seed hopper. After vertical disc revolves 190^0, the holding pin is opened by the pin-position cam. So, potato seed drops into furrow (Figure 4). The force exerted by helical spring was 11.96±0.96 N. The cups with three different sizes (Figure 2) (small, middle and big is C1, C2 and C3, respectively) were used in the experiment. All cups were made of cast iron. The dimensions of these cups are presented in Table 1 and Figure 3. Three angular speeds for the seed metering mechanism were determined by taking into account the maximum and minimum forward speeds and seed rates of the potato planter, because while the ground speed and seed rates change, the angular speeds of the seed metering mechanism change. So, the angular speeds of the seed metering mechanism were selected as 0.9, 2.04 and 3.18 rad s^{-1}. The seed rates were 120, 273 and 425 seed min^{-1} for these angular speeds, respectively. These angular speeds were provided by an AC three phase inverter which changed the rpm of the three-phase electric motor attached by a roller chain to the axle of the vertical disc.

Figure 2- Cups used in the experiment

Şekil 2- Denemede kullanılan kepçeler

Table 1- Selected dimensions of the cups

Çizelge 1- Kepçelerin seçilmiş boyutları

Cups	*A, mm*	*B, mm*	*C, mm*	*D, mm*	*E, mm*
C1	50	40	50	45	15
C2	64	54	64	54	21
C3	76	65	76	65	25

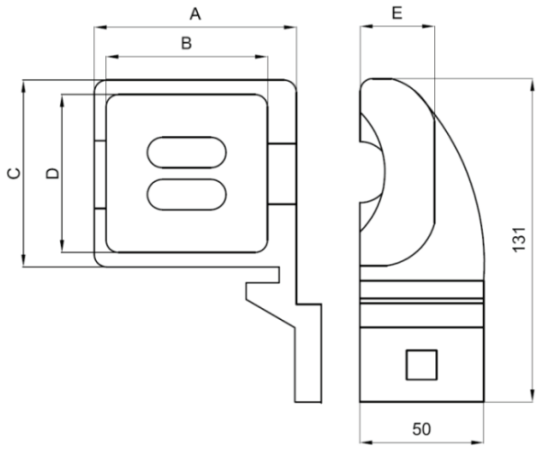

Figure 3- Dimensions of the cups

Şekil 3- Kepçelerin boyutları

2.2. Seed material

Agria and Marfona cultivars were used as seed materials in the experiments. These cultivars had different shapes from each other. Until the experiments were conducted, the potato seeds were stored in a warehouse under appropriate conditions. The potato seeds were separated into two groups. The first group was between 25-45 mm seed size, and the second group was between 45-65 mm seed size. Some physical properties of seeds were presented in Table 2.

Shape factor (*Sf*) was determined with Equation 1 (Buitenwerf et al 2006).

$$S_f = \frac{a^2}{bc} x100\% \quad (1)$$

Where; *a*, *b* and *c*, length, width and height of the seed as mm, respectively. The *a*, *b* and *c* dimensions have a relationship of c<b<a (Mohsenin 1986).

Table 2- Some physical properties of Marfona and Agria*

*Çizelge 2- Marfona ve Agria'nın bazı fiziksel özellikleri**

	Agria		*Marfona*	
	25-45 mm	*45-65 mm*	*25-45 mm*	*45-65 mm*
a, mm	60.97±4.02	70.88±3.53	50.18±3.43	56.94±5.68
b, mm	43.10±1.56	49.42±3.42	43.89±3.51	51.65±2.61
c, mm	36.07±2.58	41.54±2.93	41.57±2.52	44.41±2.06
D_p, mm	45.54±1.39	52.55±2.35	45.02±2.28	50.69±2.61
Mass, g	54.53±3.40	83.58±12.29	53.43±4.94	74.91±11.16
Shape factor	242.33±44.57	246.70±27.65	138.92±16.80	142.08±23.30
Percent sphericity	75±4.00	74±3.00	90±3.00	89±5.00

*, values are presented as mean±standard deviation; *a*, *b* and *c*, dimensions of the principle axes; D_p, geometric mean diameter

Sphericity (S_p) and geometric mean diameter (D_p) were determined by Equation 2 and 3 (Mohsenin 1986).

$$S_p = \frac{(abc)^{1/3}}{a} x100\% \quad (2)$$

$$D_{p=(abc)^{1/3}} \quad (3)$$

2.3. Measurement system

The measuring system was composed of two main parts: 1) Laser measuring unit used to determine the seed spacing uniformity, doubles, and skips, and 2) angular speed measuring unit (Figure 4).

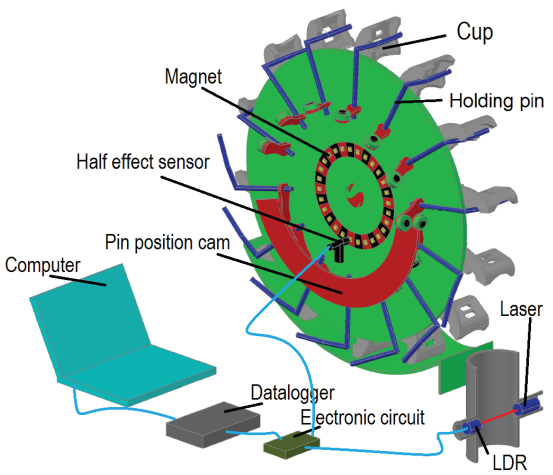

Figure 4- Measurement system

Şekil 4- Ölçüm sistemi

The laser measurement unit consists of a light dependent resistor (LDR), a laser pointer, a pipe of 80 mm diameter, and an electronic circuit. The laser measurement unit was attached under the cups. The unit measures time intervals between seeds falling down from cups (Boydas & Uygan 2012). Seeds passed through the pipe create a signal, and this signal is sent to the electronic circuit, then to the digital port of datalogger. So, a square wave is obtained from the unit. The time interval between two peaks of a square wave is used to determine seed spacing uniformity, percent value of skips, and percent value of doubles (Figure 5).

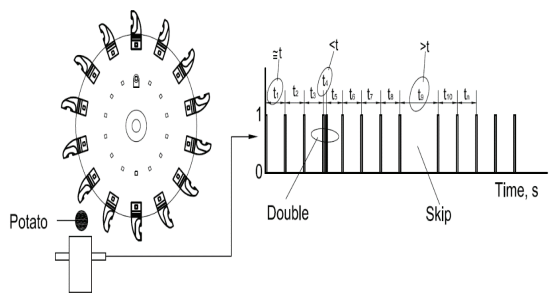

Figure 5- The square wave obtained from falling seeds

Şekil 5- Düşen tohumlardan elde edilen kare dalga

Angular speed measuring unit consists of a half effect sensor, neodymium magnets, and an electronic circuit. The magnets were positioned in the circumference of the vertical disc. The

half effect sensor was placed exactly in front of the magnets (Figure 6). While the vertical disc rotated, a square wave was obtained from the half effect sensor. This signal was sent to the electronic circuit (Figure 7). The rpm of the seed metering mechanism and two threshold values giving doubles and skips were determined with the help of the half effect sensor. The time between two square waves was shown with "t" (Figure 7). The value of t changed depending on the change in angular velocity of the seed metering mechanism. The value of t was calculated with a program written in MATLAB.

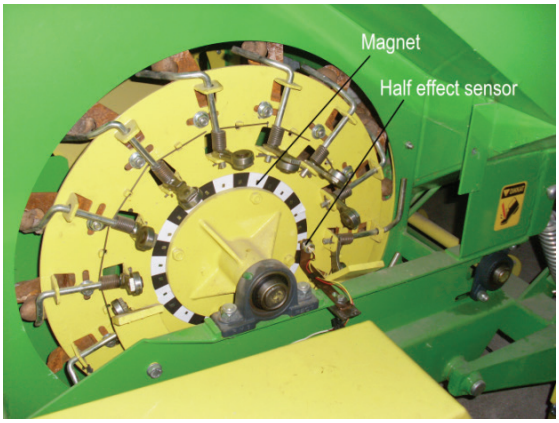

Figure 6- Half effect sensor, and magnets ranked the circumference of the seed metering mechanism

Şekil 6- Half effect sensor ve tohum dağıtma düzeni etrafına dizili mıknatıslar

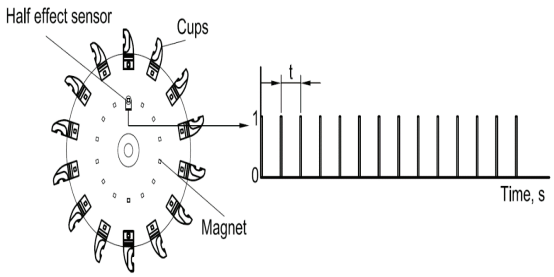

Figure 7- The square wave obtained from half effect sensor

Şekil 7- Hallf effect sensörden elde edilen kare dalga

Time intervals obtained from the laser measurement system and time intervals obtained from the half effect sensor should be equal, theoretically. However, it is not possible in practice, and time intervals obtained from the laser measurement system change due to skips, doubles and irregular drops (Figure 5). To find the percent value of doubles and skips, two threshold values, named as t_d and t_s, were used. The t_d and t_s were determined by using the Equation 4 and 5.

$$t_d \leq t \times 0.7 \quad (4)$$

$$t_s \geq t \times 1.5 \quad (5)$$

If the time interval obtained from the laser measurement system is less than the t_d, there is doubles. If the time interval obtained from the laser measurement system is higher than the t_s, there is skips. Therefore, the values of 0.7 and 1.5 were chosen for safety. For example, the time interval obtained from the half effect sensor is 5 s (t= 5 s), the time intervals obtained from the laser measurement system are 7, 12, 3, 17, 8, and 2 s, respectively. To find skips and doubles, these values were divided by the t value. It gets 7/5= 1.4, 12/5= 2.4, 3/5= 0.6, 17/5= 3.4, 8/5= 1.6, and 2/5= 0.4. The value of 1.4 is between 0.7 and 1.5, then there are no skips and doubles in this time interval. When we consider the value of 2.4, we see the two skips. For the value of 0.6 is smaller than 0.7, there is one doubles (Equation 6).

$$Percent\ value\ of\ doubles = \frac{N_d.100}{N} \quad (6)$$

Where; N_d, total number of doubles and N, total number of time intervals obtained from half effect sensor (Equation 7).

$$Percent\ value\ of\ skips = \frac{N_s.100}{N} \quad (7)$$

Where; N_s, total number of skips.

The t_d, t_s, N_d, and N_s values were determined with the aid of a program written in MATLAB (Mathworks 2011).

To determine coefficient of variation of seed spacing or irregularity in the time interval, coefficient

of variation (CV%) was used, and calculated as shown in Equation 8.

$$CV\% = \frac{SD.100}{X_m} \quad (8)$$

Where; *SD*, standard deviation of time intervals obtained from the laser measurement system; X_m, mean of time intervals obtained from the laser measurement system.

The values obtained from the measuring systems were sent as digital data to the computer via a datalogger. The measuring system had an accuracy of 0.01 seconds.

2.4. Statistical analysis

This study was a factorial design consisting of three levels of cup, three levels of angular speed, two levels of variety, and two levels of seed size with three replications. As stated above, the coefficient of variation of seed spacing, percent value of doubles and skips were calculated. For each replication, the seed metering mechanism was rotated 10 times. The data was analyzed using analyses of variance (ANOVA) and comparison of means was made with Duncan's Multiple Range Test.

3. Results and Discussion

Table 3 shows the effects of the cups, angular speeds, varieties, and sizes on the values of CV%, percent value of doubles and skips. According to results of the ANOVA, the variety, the cup, the size and the angular speed, and two way interactions of cup x angular speed (C x A) had significant effect on the values of CV%. In addition, the cup, variety, size, and angular speed affected the percent value of doubles and skips. There were no significant interactions for the percent value of doubles and skips. On the other hand, as seen from Table 3, the interactions other than C x A were not significant, therefore they were not taken into considerations.

Table 3- Analysis of variance of cup, seed variety, seed size, and angular speed on values of CV%, and the percent value of skips and doubles

Çizelge 3- % CV, ikili atma ve boş bırakma üzerine kepçe, tohum çeşidi, tohum büyüklüğü ve açışal hızın varyans analizi

		CV, %		*Doubles, %*		*Skips, %*	
Variation sources	*DF*	*MS*	*P*	*MS*	*P*	*MS*	*P*
Cup (C)	2	271.967	0.000[a]	127.708	0.000[a]	63.851	0.000[a]
Variety (V)	1	425.667	0.000[a]	6.211	0.001[a]	88.408	0.000[a]
Size (S)	1	141.587	0.000[a]	323.837	0.000[a]	15.177	0.000[a]
Angular speed (A)	2	718.372	0.000[a]	4.980	0.000[a]	9.354	0.000[a]
Replication	2	1.648	0.795	1.050	0.129	0.046	0.953
C x V	2	10.517	0.238	0.141	0.754	0.203	0.810
C x S	2	12.983	0.171	0.131	0.770	1.169	0.301
C x A	4	30.141	0.004[a]	0.366	0.572	0.667	0.597
V x S	1	0.016	0.963	0.002	0.946	0.019	0.889
V x A	2	10.276	0.245	0.298	0.553	0.042	0.957
S x A	2	18.761	0.080	0.117	0.791	0.017	0.983
C x V x S	2	6.899	0.387	0.719	0.243	0.351	0.694
C x V x A	4	2.638	0.831	0.049	0.983	0.012	1.000
C x S x A	4	4.598	0.635	0.355	0.587	0.285	0.878
V x S x A	2	4.062	0.570	0.243	0.616	0.739	0.466
Error	74	7.178		0.499		0.958	
Total	107						

[a], significant at 1% level of probability; DF, degrees of freedom; MS, mean square

3.1. Effect of the cups on the seed spacing uniformity, doubles and skips

The effect of cups on value of CV%, percent value of doubles and skips was statistically significant ($P<0.01$). The highest value of CV% was determined as 29.24% for C1 (Table 4). The lowest value of CV% was determined as 23.76% for C2. The small cup showed more variability of spacing than the big cup. So, it can be said that C2 for potato seeds in the range of 25 to 65 seed size would be appropriate. The doubles and skips were observed as the main source of deterioration of the seed spacing uniformity, the highest percent value of doubles was determined as 6.90% for C3. The lowest percent value of doubles was determined as 3.13% for C1. However, when looking at percent value of skips, the highest percent value of skips was determined as 5.07% for C1. There was no statistically significant difference between C2 and C3 for percent value of skips. As the highest percent value of doubles was 6.90% for C3, the highest percent value of skips was 5.07% for C1. It was shown that the effect of the skips was greater than that of doubles on value of CV%.

Table 4- Effects of cups, seed varieties, seed sizes and angular speeds on values of CV%, percent values of skips and doubles

Table 4- % CV, ikili atma ve boş bırakma üzerine kepçe, tohum çeşidi, tohum büyüklüğü ve açısal hızın etkisi

Treatments		*CV, %*	*Doubles, %*	*Skips, %*
Cups	C1	29.24 a*	3.13 c	5.07 a
	C2	23.76 c	4.95 b	2.94 b
	C3	26.11 b	6.90 a	2.62 b
	LSD	1.26	0.33	0.46
Potato varieties	Agria	24.39 b	5.23 a	2.64 b
	Marfona	28.36 a	4.75 b	4.45 a
Potato sizes, mm	25-45	27.52 a	6.73 a	3.17 b
	45-65	25.23 b	3.26 b	3.92 a
Angular speeds, rad s^{-1}	0.9	22.83 c	5.35 a	3.06 b
	2.04	24.90 b	5.02 a	3.51 b
	3.18	31.39 a	4.61 b	4.08 a
	LSD	1.26	0.33	0.46

*, means in a single column without the same letter are significantly different at the 5% level using the LSD test

3.2. Effect of potato shape on the seed spacing uniformity, doubles and skips

The results of the effect of seed shape on value of CV%, percent value of doubles and skips are given in Table 4. The statistical results show that the seed shape affected the seed spacing uniformity, doubles and skips. The highest value of CV% was determined as 28.36% for Marfona, while the lowest value of CV% was determined as 24.39% for Agria. Oblong shaped Agria had less variability of seed spacing than spherical shape Marfona. Similarly, Buitenverf et al (2006) showed that the standard deviation of round balls was higher than oblong seeds. In contrast, Al-Gaadi & Marey (2011) found that Hermes variety of potato with spherical shape indicated significantly lower value of CV% than oblong shape Sponta variety of potato. The percent values of doubles were 5.23% and 4.75% for Agria and Marfona, respectively. The difference between Agria and Marfona was 0.48% for doubles. The percent values of skips were 2.64% and 4.45% for Agria and Marfona, respectively. The difference between Agria and Marfona was 1.81% for skips. Skips were the main source of disturbance of the seed spacing uniformity. It was observed in experiments that it was more difficult to keep spherical potato seeds on the cup than oblong potato seeds, because, the spherical potato seeds could fall down easier than oblong potato seeds. In addition, this showed that oblong seeds were clutched by holding pins better than spherical seed, and most probably, oblong seeds were grabbed by cups better than spherical seeds.

3.3. Effect of potato size on the seed spacing uniformity, doubles and skips

It was determined that seed size was an important parameter on the seed spacing uniformity. The results of values of CV%, and percent values of doubles and skips affected by seed size are shown in Table 4. As the seed size increased, the seed spacing uniformity increased. The highest value of CV% was determined as 27.52% for 25-45 mm seed size. The lowest value of CV% was determined as 25.23% for 45-65 mm seed size. Misener (1982) found that as the seed size increased, the accuracy of seed spacing increased. The highest percent value of doubles was obtained from 25-45 mm seed size with 6.73%. The lowest percent value of doubles was obtained from 45-65 mm seed size with 3.26%. These results agree with

the results reported by Al-Gaadi & Marey (2011). They found that percent value of doubles were 5.35, 4.18 and 3.31% for 35-45, 45-55 and 55-65 mm seed size, respectively. As potato size increased, percent value of skips increased. The highest percent value of skips obtained from 45-65 mm seed size was 3.92%. The lowest percent value of skips obtained from 25-45 mm seed size was 3.17%. These results were supported by Al-Gaadi & Marey (2011). They determined that percent value of skips had a range from 5.19 to 7.30%. Misener (1982) compared the cup type and pick type potato planters in terms of various seed size. He showed that percent values of skips and doubles ranged from 3.8 to 9.2 and from 6.6 to 23.7, respectively. Misener (1982) and Altuntas et al (2004) determined that as the size of seed increased, the number of skips increased. In addition, they found that small seeds increased the number of doubles.

3.4. Effect of angular speed on the seed spacing uniformity, doubles and skips

The accuracy of the seed spacing uniformity tended to increase as the angular speed reduced. The value of CV% ranged from 22.83 to 31.39% (Table 4). The highest value of CV% was found as 31.39% for the angular speed of 3.18 rad s^{-1}. The lowest value of CV% was found as 22.83% for the angular speed of 0.9 rad s^{-1}. The seed spacing uniformity was the best in lower angular speed as indicated by the seed spacing uniformity values. Research results of Misener (1979), Altuntas (2005) and Al-Gaadi & Marey (2011) agree with these results. However, Buitenwerf et al (2006) and Sieczka et al (1986) stated that as the speed increased, the accuracy of seed spacing became better. Al-Gaadi & Marey (2011) determined that the values of CV% were 28.73, 37.10, and 54.53% for the ground speeds of 1.80, 2.25, and 3.00 km h^{-1}, respectively. Entz & LaCroix (1984), Sieczka et al (1986) and Misener (1982) stated that the coefficient of variation of seed spacing obtained from different potato planters ranged from 20% to 80%. Misener (1979) stated that the values of CV% for the pick type potato planter ranged from 55.3 to 68.7% while the values of CV% for the cup type potato planter ranged from 59.2 to 87.1%. The change of angular speed was significantly affected the percent value of doubles and skips. The highest percent value of doubles for the angular speed of 0.9 rad s^{-1} was determined as 5.35%. The lowest percent value of doubles for the angular speed of 3.18 rad s^{-1} was found as 4.61%. As the angular speed increased, percent value of doubles decreased. The highest percent value of skips for the angular speed of 3.18 rad s^{-1} was determined as 4.08%. The lowest percent value of skips for the angular speed of 0.9 rad s^{-1} was obtained as 3.06%. Increase of the angular speed caused the percent value of skips to increase. Misener (1979) found that the pick type planter gave fewer doubles at the lower ground speeds. He also stated that, except two planters, all the other planters operating in the ground speed range of 5.6 to 7.2 km h^{-1} produced doubles more than skips. Al-Gaadi & Marey (2011) determined that percent value of doubles and skips were 5.93, 4.62 and 2.29%, and 3.91, 5.74 and 9.11% for the ground speed of 1.80, 2.25, and 3.00 km h^{-1}, respectively. These results agree with our results. The effect of C x A interaction on CV% was significant. Plot of this interaction is presented in Figure 8. From this figure, it can be seen that CV% value of C2 was lower than those of the other cups for the angular speed of 0.9 rad s^{-1}.

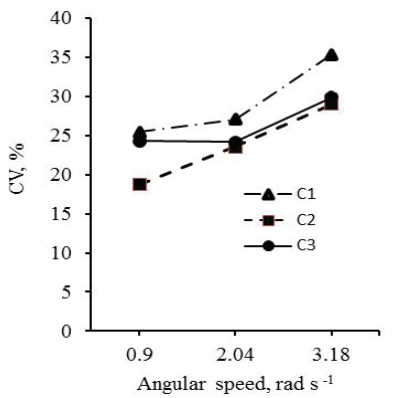

Figure 8- Plot of C x A interaction on CV, % value of angular speed

Şekil 8- Açısal hızın % CV üzerine C x A interaksiyon grafiği

4. Conclusions

A full automatic potato planter with the seed metering mechanism with the vertical disc was tested at different cups, angular speeds, seed sizes

and shapes in laboratory. The laboratory tests showed that the cup, the angular speed, potato sizes and potato shapes have significant effect on the seed metering mechanism. The best seed spacing uniformity was obtained from C2. Both small and large cups disturbed the seed spacing uniformity. As cup size increased, percent value of doubles increased, although percent value of skips decreased. The effects of seed shapes and seed sizes on the seed spacing uniformity, and percent values of doubles and skips were significant. The seed spacing uniformity of oblong potato seeds was better than that of spherical potato seeds. Skips value of oblong potato seeds was lower than that of spherical potato seeds. Nevertheless, the percent value of doubles obtained from oblong potato seeds was slightly higher than that of spherical potato seeds. Small potato seeds led to an increase in the value of CV%. The reason for this was the doubles. The angular speed influenced seed spacing uniformity significantly. Increasing the angular speed decreased the seed spacing uniformity. As the angular speed increased, percent value of doubles decreased and percent value of skips increased.

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Abbreviations and Symbols	
a, b, c	Dimensions of seed, mm
ANOVA	Analysis of variance
CV	Coefficient of variation, %
D_p	Geometric mean diameter, mm
LDR	Light dependent resistor
N	Total number of spacing
N_d	Number of t_d
N_s	Number of t_s
SD	Standard deviation
S_p	Sphericity, %
S_f	Shape factor, %
t, t_d, t_s	Time, s
X_m	Mean of time intervals, s

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Comparison of Microtubule Organization in *Arabidopsis thaliana TUB-GFP* and *MBD-GFP* Mutants Exposed to UV-B Radiation

Dongjing MA[a, b], Huize CHEN[a, b], Rong HAN[a, b]

[a]*Shanxi Normal University, College of Life Science, Linfen, Shanxi, 041000, CHINA*

[b]*Shanxi Normal University, Higher Education Key Laboratory of Plant Molecular and Environmental Stress Response, Linfen, Shanxi, 041000, CHINA*

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Corresponding Author: Rong HAN, E-mail: hhwrsl@163.com, Tel: +86 (0357) 205 86 18
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ABSTRACT

Microtubule organization was compared between the *Arabidopsis thaliana TUB-GFP* and *MBD-GFP* mutants. Plant height and primary root length were measured, and microtubule dynamics were examined by confocal laser scanning microscopy after UV-B radiation to reveal changes in microtubules. Damage caused by UV-B was comparable between transgenic lines and wild-type plants, although transgenic lines were more sensitive to UV-B than the wild-type. Spots and depolymerization of microtubules were detected in both *TUB-GFP* and *MBD-GFP* plants; however, *MBD-GFP* showed better adaptation of changes induced by UV-B treatment. These results indicated that UV-B inhibits the growth and development of transgenic lines, and the inhibitory effects might result from changes in microtubules, as determined by comparison between the *TUB-GFP* and *MBD-GFP* lines.

Keywords: Microtubules; UV-B radiation; *Arabidopsis thaliana TUB-GFP*; *Arabidopsis thaliana MBD-GFP*

UV-B Işığına Maruz Bırakılmış *TUB-GFP* ve *MBD-GFP Arabidopsis thaliana* Mutantlarında Mikrotubulüs Oluşumunun Karşılaştırılması

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Rong HAN, E-posta: hhwrsl@163.com, Tel: +86 (0357) 205 86 18
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ÖZET

Bu çalışmada, *TUB-GFP* ve *MBD-GFP Arabidopsis thaliana* mutantlarında mikrotubulüs oluşumu karşılaştırılmıştır. Mikrotubulüslerdeki değişimleri belirlemek üzere UV-B ışığına maruz bırakıldıktan sonra bitki boyu ve ana kök uzunluğu ölçülmüş ve odaktaş lazer görüntüleyici mikroskopla mikrotbulüs hareketi izlenmiştir. Yabani bitkilere gore, transgenik hatlar UV-B'ye daha duyarlı olmasına karşın, UV-B ışığının neden olduğu zararlanmanın transgenik hatlar ile yabani tip bitkilerde karşılaştırılabilir şekilde oluştuğu belirlenmiştir. *MBD-GFP*, UV-B'nin neden olduğu değişikliklere daha iyi uyum göstermesine karşın hem *TUB-GFP* hem de *MBD-GFP* bitkilerinin mikrotubulüslerinde beneklenme ve

depolimerizasyon olduğu belirlenmiştir. *TUB-GFP* ve *MBD-GFP* hatlarının karşılaştırılmasıyla elde edilen bu sonuçlar, UV-B'nin transgenik hatlarda büyüme ve gelişmeyi engellediğini, bu engellemenin mikrotubulüslerdeki değişimlerden kaynaklanabileceğini göstermiştir.

Anahtar Kelimeler: Mikrotubulüsler; UV-B ışını; *Arabidopsis thaliana TUB-GFP*; *Arabidopsis thaliana MBD-GFP*

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1. Introduction

Microtubules (MTs) are cylindrical polymers composed of α- and β-tubulin heterodimers. They are essential for growth and development, participating in several cellular processes such as cell division, intracellular transport, and signal transduction in plants (Granger & Cyr 2000; Sedbrook 2004). MTs are highly dynamic structures and undergo transitions between states of growth, shrinkage and pause (Kawamura & Wasteneys 2008). However, abiotic stress is one of the environmental stresses. Plants undergo changes in MTs in response to exposure to abiotic stress. For example, when *Lolium rigidum* leaves were treated with high pressure, MTs in epidermal cellular arrays changed from random to organized arrangements in cells in which the length was greater than the width (Cleary & Hardham 1993). When the epidermal cells in the cotyledons of *A. thaliana* are touched by a fine glass or tungsten needles, depolymerization of MTs is induced to form a microtubule-depleted zone surrounding a dense patch of GFP-tubulin beneath the needle tip (Hardham et al 2008). Alterations of turgor disrupt MT organization along with the appearance of crystallization and the distortion of MT arrangement (Shi et al 2011).

Ultraviolet-B radiation (UV-B, 280-320 nm) is an abiotic stress present in the environment. It affects the morphogenesis of plants, modifies plant structure, promotes the production of various secondary metabolites (Rozema et al 1997), and induces changes in the plant cytoskeleton. Previous studies have assessed the effects of UV-B on the cytoskeleton. Han (2002) showed "partition bundle division" in mitotic cells of wheat exposed to UV-B. This research showed that protoplast MTs in wheat seedlings were significantly depolymerized under UV-B, leading to the appearance of spots and dispersive MTs (Guo et al 2010). Chen & Han (2015) showed that actin filaments participate in the process of "partition bundle division" in wheat seedlings injured by enhanced UV-B, supporting that MTs are injured by UV-B treatment (Krasylenko et al 2012). These studies indicate that UV-B has a severe impact on the plant cytoskeleton, especially on the MTs of the cytoskeleton. The damage to MTs affects the growth and development of plants exposed to UV-B radiation.

TUB-GFP was generated by the fusion of green fluorescent protein (GFP) to the N-terminus of *A. thaliana* β-tubulin 6. Its incorporation into MTs as a functional protein analog allows analysis of changes in MT dynamics in response to low concentrations of drugs in *A. thaliana* epidermal cells (Nakamura et al 2004; Wasteneys & Yang 2004). MBD-GFP consists of GFP fused to the microtubule binding domain of microtubule associated protein 4 (MAP4). It allows visualization of MT dynamics not only in mammals, but also in the leaf epidermis of fava bean, *A. thaliana*, and tobacco. It can label MTs in roots and shape dwarf phenotypes in the plants. The expression of *GFP-MBD* does not affect the phenotype of the plants (Marc et al 1998; Granger & Cyr 2000; Granger & Cyr 2001; Wasteneys & Yang 2004). Furthermore, GFP, as a reporter, is important for monitoring MT dynamics in *A. thaliana* seedlings, and it allows direct observation of MT dynamics *in vivo*. The comparison of *TUB-GFP* and *MBD-GFP* is useful for the study of MT dynamics and signaling in response to different kinds of stress. However, the effects of *TUB-GFP* and *MBD-GFP* on MTs under UV-B treatment are unclear. Here, we used *A. thaliana TUB-GFP* seedlings and *A. thaliana MBD-GFP* seedlings to compare MT dynamics in response to UV-B treatment.

2. Material and Methods

2.1. Plant materials and growth conditions

Wild-type (*Arabidopsis thaliana* L. Col-0), *TUB-GFP*, and *MBD-GFP* plants were used. Seeds were surface-sterilized with 1% sodium hypochlorite for 5 min and rinsed several times with sterilized water. Sterilized seeds were germinated on plates containing ½ Murashige and Skoog medium (Hopebio) with 1% (w v^{-1}) sucrose at 4 °C for 3 days, and plants were grown at a temperature of 22 °C and 60-80% humidity under a photoperiod of 16 h light and 8 h dark (100-120 μmol m^{-2} s^{-1}) placed vertically for 4 days.

2.2. Ultraviolet-B radiation treatment

There were two treatments with three replicates as follows: wild-type, *TUB-GFP* and *MBD-GFP* without UV-B treatment; and wild-type, *TUB-GFP* and *MBD-GFP* with UV-B treatment. UV-B lamps (Huaqiang, 40 W) were set vertically above the plates. The intensity was controlled by modifying the distance between the lamp and the plates. The dose was 4.53 kJ m^{-2} d^{-1} (4 h) for 6 days to reach 27.2 kJ m^{-2} (Krasylenko et al 2012; Krasylenko et al 2013).

2.3. Plant height and primary root length quantification

At 6 days after UV-B treatment, 20 seedlings per replicate were randomly selected from each plate, and plant height and primary root length were recorded.

2.4. In vivo microtubule observation

Before the observation, seedlings were placed in the darkroom for at least 12 h under standard growth conditions (Voigt et al 2005). The morphologic variations of MTs were observed using a confocal laser scanning microscope (FV-1000, Olympus, Japan). Images were analyzed using the FV10-ASW 1.7 Viewer supplied with the confocal laser scanning microscope and Photoshop CS5.

2.5. Statistical analysis

Data analysis was performed with SPSS 17.0 and Original 8.0. Statistical significance was estimated at $P<0.05$ according to Duncan's multiple range test. Data are expressed as the mean±SD.

3. Results

3.1. Comparison between the phenotypes of TUB-GFP seedlings and MBD-GFP seedlings exposed to UV-B radiation

Figure 1a shows the appearance of clustered leaves and short petioles in plants without UV-B treatment in *TUB-GFP* compared with wild-type plants. *MBD-GFP* was similar to the wild-type, as reported previously (Granger & Cyr 2001) (Figure 1a). Figure 1b shows dwarf phenotypes and smaller leaves in plants exposed to UV-B in *TUB-GFP*; clustered leaves and shorter petioles were more obvious than those observed in *TUB-GFP* in Figure 1a. Figure 1b shows the inhibitory effect of UV-B on *MBD-GFP* compared with *MBD-GFP* in Figure 1a. However, the inhibitory effects on *TUB-GFP* were more distinct than those on *MBD-GFP*. Figure 1b shows the curled-down leaf phenotype of wild-type seedlings compared with that of seedlings in Figure 1a.

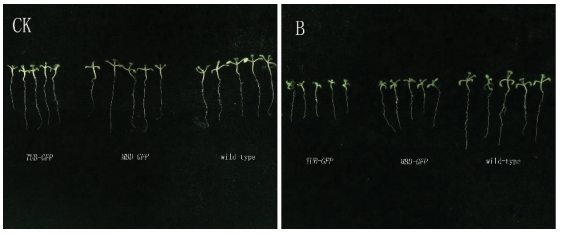

Figure 1- Comparison between *TUB-GFP Arabidopsis* seedlings and *MBD-GFP Arabidopsis* seedlings exposed to UV-B radiation; a, Without UV-B treatment (CK), the *Arabidopsis* seedlings from left to right are *TUB-GFP*, *MBD-GFP*, and wild-type; b, With UV-B treatment (B), the *Arabidopsis* seedlings from left to right are *TUB-GFP*, *MBD-GFP*, and wild-type

Şekil 1- UV-B Işığına maruz bırakılmış TUB-GFP Arabidopsis fideleriyle ve MBD-GFP Arabidopsis fidelerinin karşılaştırılması; a, UV-B ışığı uygulanmamış (CK), soldan saga doğru TUB-GFP, MBD-GFP ve yabani Arabidopsis fideleri; b, UV-B ışığı uygulanmış (B), soldan saga doğru TUB-GFP, MBD-GFP ve yabani Arabidopsis fideleri

3.2. Comparison between plant height and primary root length of TUB-GFP and MBD-GFP exposed to UV-B radiation

Plant height and primary root length in the presence or absence of UV-B were randomly measured in the present study. In Figure 2, quantitative analysis showed that *TUB-GFP* plants were significantly shorter than wild-type and *MBD-GFP* plants, whereas plant height was comparable between *MBD-GFP* and wild-type plants that were not exposed to UV-B radiation. Under UV-B radiation, the plant height of *TUB-GFP* showed the greatest reduction. *MBD-GFP* plants were shorter than wild-type plants. The plant height was significantly changed compared with that of the control (P<0.05).

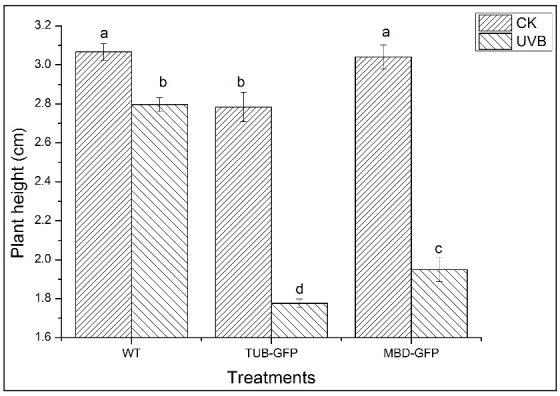

Figure 2- Comparison between the plant height of *TUB-GFP* and *MBD-GFP* exposed to UV-B radiation, data represent the mean±SD (n= 3)

Şekil 2- UV-B ışığına maruz bırakılmış TUB-GFP ve MBD-GFP bitkilerinin bitki boylarının karşılaştırılması, ortalama±SD (n= 3)

The effects of UV-B on primary root length in *TUB-GFP* and *MBD-GFP* were also investigated (Figure 3). Quantitative analysis revealed that the primary root length of *TUB-GFP* was significantly shorter than that of others without UV-B, and the primary root length of *MBD-GFP* was not significantly different than that of the wild-type plants. In plants exposed to UV-B radiation, the primary root length of *TUB-GFP* was decreased. The primary root length of *MBD-GFP* was also decreased, although it was greater than that of *TUB-GFP*. The primary root length was significantly changed compared with that of the control (P<0.05).

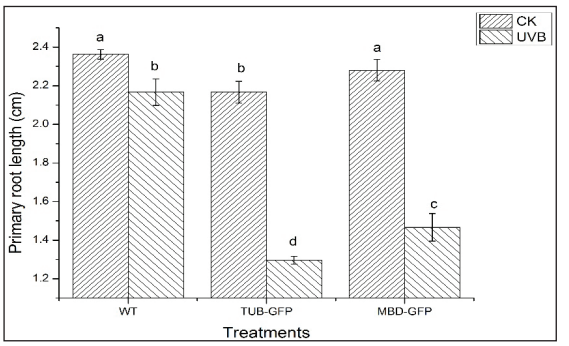

Figure 3- Comparison between the primary root length of *TUB-GFP* and *MBD-GFP* exposed to UV-B radiation, data represent the mean±SD (n= 3)

Şekil 3- UV-B ışığına maruz bırakılmış TUB-GFP ve MBD-GFP bitkilerinin ana kök uzunluklarının karşılaştırılması, ortalama±SD (n= 3)

3.3. In vivo visualization of microtubules in TUB-GFP and MBD-GFP under UV-B treatment.

Based on the results described above, we compared the microtubule dynamics of *TUB-GFP* and *MBD-GFP* in response to UV-B treatment by confocal microscopy. In this experiment, we observed the microtubule dynamics of stomata. Total fluorescence was intense in *TUB-GFP*, and guard cells were symmetrical in the absence of UV-B (Figure 4a). However, UV-B treatment caused severe depolymerization of MTs and a reduction in total fluorescence in *TUB-GFP*. Guard cells were asymmetric, twisted and patched MTs were observed in stomata (Figure 4a′). By contrast, MTs in guard cells of *MBD-GFP* appeared radial and fluorescence intensity was high without UV-B (Figure 4b). Exposure to UV-B caused the appearance of spots, the depolymerization of MTs, and a reduction in fluorescence in guard cells of *MBD-GFP* (Figure 4b′).

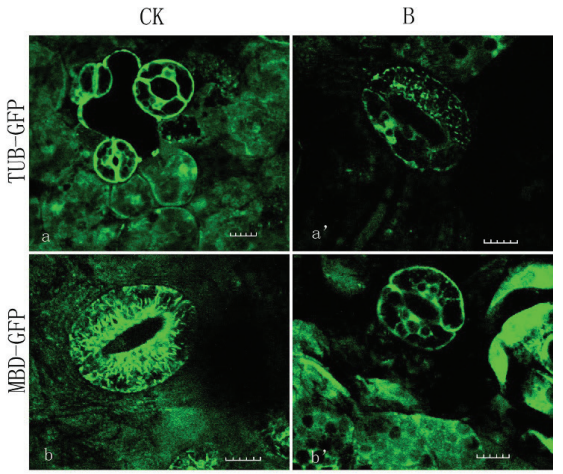

Figure 4- Microtubule dynamics of stomata in *TUB-GFP* and *MBD-GFP* exposed to UV-B radiation (Scale bar= 10 μm); a, a′ show the microtubule dynamics of stomata in *TUB-GFP* without UV-B treatment (CK) and with UV-B treatment (B), respectively; b, b′ show the microtubule dynamics of stomata in *MBD-GFP* without UV-B treatment (CK) and with UV-B treatment (B), respectively

Şekil 4- UV-B ışığına maruz bırakılmış TUB-GFP and MBD-GFP stomalarında mikrotubulüs hareketi (Ölçek boyutu= 10 μm); a ve a′ sırasıyla UV-B ışığı uygulanmamış (CK) ve UV-B uygulanmış (B) TUB-GFP stomalarındaki mikrotubulüs hareketi; b ve b′ sırasıyla UV-B ışığı uygulanmamış (CK) ve UV-B uygulanmış (B) MBD-GFP stomalarındaki mikrotubulüs hareketi

4. Discussion

The effects of UV-B radiation have attracted significant attention. UV-B radiation inhibits the growth and development of plants, and causes changes in architecture, such as curled leaves and other leaf changes, shorter petioles, and decreased stem elongation among others (Robson & Aphalo 2012; Robson et al 2015). Hectors et al (2010) reported that UV-B resulted in transient changes in the length: width ratio of *A. thaliana* leaves. In the present study, the same characteristics were observed in the transgenic *A. thaliana TUB-GFP* and *MBD-GFP*; however, the extent of the changes was different (Figure 1). Previous studies suggested that UV-B decreases stem elongation and inhibits root growth (Jansen 2002; Robson et al 2015), which is consistent with the present results shown in Figure 2 and 3. These phenotypes reflect the resistance to stress in plants and their protective effects in response to UV-B stress. The phenotypes of *TUB-GFP* and *MBD-GFP* exposed to UV-B indicate damage to MTs caused by UV-B, and this damage was more severe in *TUB-GFP* than in *MBD-GFP*. These results support that MTs play a critical role in the growth of plants and their adaptation to the environment, and could be used as an indicator of UV-B associated damage.

Leaves are the principal direct recipient site in plants exposed to UV-B, and the responses of leaves to UV-B, and the effects of UV-B on stomata were significant. Therefore, we observed the MT dynamics of stomata in our study. In Figure 4a′, guard cells appeared asymmetric and showed a deformed kidney shape, with patches and depolymerization of MTs under UV-B, compared with Figure 4a. In Figure 4a, MTs were not arranged radially, which may be caused by stomatal movement (Yu et al 2001; Lucas et al 2006). Figure 4b′ shows depolymerization of MTs and their disappearance compared with Figure 4b. MTs are necessary for maintaining the kidney shape of guard cells (Yu et al 2001). Under UV-B stress, MTs aggregated in *MBD-GFP*, whereas they appeared patched and depolymerized, leading to slower growth in *TUB-GFP*. These results indicated that depolymerization of MTs is one of the main factors leading to the effects described above, and *MBD-GFP* could be better adapted to the changes induced by UV-B.

Studies have shown that UV-B induces MT depolymerization and leads to a series of effects (Guo et al 2010; Krasylenko et al 2012; Krasylenko et al 2013). However, the mechanisms of depolymerization of MTs under UV-B remain unclear. Abiotic stress is one of the factors causing MT reorientation, such as drought, turgor pressure, and osmotic stress (Bisgrove 2008; Hong et al 2010; Liu et al 2014).Turgor pressure maintains cell tension, regulates stomatal opening and closing, and is closely related to the growth of plant cells. At the

same time, turgor pressure regulates MTs (Iwata et al 2001; Yu et al 2001; Liu et al 2014). When stomata close, fewer MT structures are detected in guard cells and MTs are disassembled (Eisinger et al 2012). UV-B could change the membrane permeability of guard cells, and induce stomatal closure (Zhang & Zhou 2009). Therefore, MTs are closely related to turgor pressure, and MTs can be altered under UV-B, leading to changes in plants. This implies that UV-B may indirectly affect turgor pressure and lead to changes of MT dynamics, causing changes in the plants.

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Determination of Genotypic Variation among Sorghum Cultivars for Seed Vigor, Salt and Drought Stresses

Süleyman AVCI[a], Onur İLERİ[a], Mehmet Demir KAYA[a]

[a]*Eskisehir Osmangazi University, Faculty of Agriculture, Department of Field Crops, Eskişehir, TURKEY*

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Corresponding Author: Mehmet Demir KAYA, E-mail: demirkaya76@hotmail.com, Tel: +90 (222) 324 29 90
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ABSTRACT

This study was conducted to determine genotypic variation among sorghum cultivars grown under similar ecological conditions for seed vigor, salt (NaCl) and drought stresses. A seedling survival test was also performed in a pod experiment to investigate genotypic differences in terms of sorghum drought tolerance. In seven sorghum cultivars, seed vigor was determined using electrical conductivity and accelerated ageing tests. Also, germination rate and seedling growth of these cultivars were evaluated under salt and drought stress induced by PEG 6000 at water potentials of 0.0 (distilled water), -1.8, -3.6, -7.2 and -10.8 bar. The results showed that there was a significant difference in seed vigor of sorghum cultivars grown at same ecological conditions. Akdarı produced more vigorous seeds than the other cultivars. The significant relationship between accelerated ageing and laboratory emergence (r= 0.967**), and between electrical conductivity and germination percentage (r= -0.873**) were determined. The suitable tests for germination and emergence potential in sorghum were electrical conductivity and accelerated ageing, respectively. Increasing NaCl and PEG levels inhibited germination and seedling growth. Germination, root length and shoot length were higher, whereas mean germination time was lower, in NaCl solution compared to in PEG solution at the same water potential. In salt, drought and seedling survival tests, Aldarı showed the better performance than the others. It could be concluded that seed vigor is not a reliable indicator of germination performance under salt and drought stress conditions and that genetic differences may play an important role in stress tolerance.

Keywords: *Sorghum bicolor* L.; Accelerated ageing; Salinity; Drought; Germination; Cultivar

Sorgum Çeşitleri Arasında Tohum Gücü, Tuz ve Kuraklık Stresi Bakımından Genotipik Varyasyonun Belirlenmesi

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Mehmet Demir KAYA, E-posta: demirkaya76@hotmail.com, Tel: +90 (222) 324 29 90
Geliş Tarihi: 26 Ocak 2015, Düzeltmelerin Gelişi: 31 Aralık 2015, Kabul: 22 Ocak 2016

ÖZET

Bu çalışma aynı ekolojik koşullarda yetiştirilen sorgum çeşitleri arasında tohum gücü, tuz (NaCl) ve kuraklık stresi bakımından genetik farklılıkların belirlenmesi amacıyla yürütülmüştür. Ayrıca sorgum çeşitleri arasında kuraklık stresine

toleransın belirlenmesi amacıyla saksı denemesi olarak fide canlılık testi yapılmıştır. İncelenen 7 sorgum çeşidinde tohum gücü, elektriksel iletkenlik ve hızlı yaşlandırma testleriyle belirlenmiştir. PEG 6000 ve NaCl kullanarak su tutma gücü 0.0 (saf su), -1.8, -3.6, -7.2 ve -10.8 bar olarak ayarlanan solüsyonlarda çeşitlerin çimlenme ve fide gelişimi incelenmiştir. Araştırma sonuçlarına göre, aynı ekolojik koşullarda yetiştirilen sorgum çeşitlerinin tohum güçleri arasında önemli farklılıkların olduğu belirlenmiştir. Akdarı çeşidi diğer çeşitlere göre daha güçlü tohum üretmiştir. Tohum güç testlerinden hızlı yaşlandırma ile laboratuvar çıkışı arasında (r= 0.967**) ve elektriksel iletkenlik ile çimlenme arasında (r= -0.873**) önemli ilişkilerin olduğu belirlenmiştir. Sorgum çeşitlerinin çimlenme potansiyelini belirlemede elektriksel iletkenlik testi, çıkış performansının belirlenmesinde ise hızlı yaşlandırma testi uygun bulunmuştur. Artan NaCl ve PEG konsantrasyonları çimlenme ve fide gelişimini engellemiştir. NaCl ile karşılaştırıldığında, PEG solüsyonlarında çimlenme, kök ve sürgün uzunluğu daha yüksek, ortalama çimlenme süresi daha kısa bulunmuştur. Tuz, kuraklık ve fide canlılık testlerinde, Aldarı çeşidinin diğer çeşitlerden daha yüksek performans göstermiştir. Sonuç olarak, tohum güç testlerinin tuz ve kuraklık stresinde çimlenme performansı için güvenilebilir olmadığı ve genetik farklılıkların stres toleransında önemli rol oynadığı söylenebilir.

Anahtar Kelimeler: *Sorghum bicolor* L.; Hızlı yaşlandırma; Tuzluluk; Kuraklık; Çimlenme; Çeşit

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1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench), a crop native to Sub-Saharan Africa, is widely used for multiple purposes, such as feed, food, fiber and fuel (Tari et al 2013). Sorghum is adapted to semi-arid tropical regions and produces a reasonable yield under high temperatures, high radiation, high evaporative demand, unreliable and irregular rainfall and soil properties of low fertility and low water holding capacity, all of which cause detrimental effects on seed germination and seedling growth as well as plant survival (Doggett 1988; Mutavaa et al 2011).

Osmotic stress created by salinity and drought represents one of the major yield constraints in many parts of the world (Araus et al 2002; Munns 2002; Kandil et al 2012). This type of stress adversely affects crop plants at all life cycle stages, with germination and seedling establishment being more sensitive than subsequent growth stages (Khan & Gulzar 2003; El Naim et al 2012). Drought and salt stress tolerance in sorghum has been investigated in previous studies by Smith et al (1989), Igartua et al (1994), Maiti et al (1994), Kaur Gill et al (2002) and Ambika et al (2011); however, limited information about the relationship between germination performance under these stresses and seed vigor of sorghum.

A germination test determines the viability of seeds but it fails to estimate field performance, as the seedbed conditions at planting are less than optimum. The seedbed conditions can impose moderate to severe stress on the seed, thereby delaying or preventing germination (TeKrony & Egli 1991). These stress conditions can lead to decreased emergence rates, namely, lower values reported by the germination test. Seed vigor tests, including emergence, osmotic stress generated by NaCl and PEG, temperature, conductivity and accelerated ageing provide more sensitive measures of physiological seed quality, which more accurately reflect a seed lot's potential performance (McDonald 1993; Milosevic et al 2010).

This study aimed to investigate differences in seed vigor of sorghum cultivars grown under the same ecological conditions and to determine whether seed vigor influences germination under drought and salt stress conditions.

2. Material and Methods

This study was conducted at the seed science laboratory of the Field Crops Department, Agricultural Faculty, Eskisehir Osmangazi University, Turkey. Seeds of sorghum cultivars Aldarı, Akdarı, Beydarı, Gözde-80, Greengo, Leoti and Rox were harvested from the experimental

fields at Eskisehir Osmangazi University in 2011. All of the seeds were stored at 4 °C prior to the start of the experiment.

Germination test: Four replicates of 50 seeds from each cultivar were germinated on three rolled filter papers with 10 mL of distilled water. Each rolled paper was placed in a sealed plastic bag to prevent moisture loss. Seeds were allowed to germinate at 25±1 °C in the dark for 10 days. Seeds were considered to have germinated when the emerging radicle was at least 2 mm long. Germination percentage (GP) was recorded every 24 h for 10 days. Mean germination time (MGT) was calculated to assess the speed of germination (ISTA 2003).

Salt and drought stres: Germination and early seedling growth of the cultivars were studied under osmotic potentials of -1.8, -3.6, -7.2 and -10.8 bar, produced by either NaCl or polyethylene glycol (PEG 6000) (Michel & Kaufmann 1973). NaCl concentrations had the electrical conductivity (EC) values of 5, 10, 20 and 30 dS m^{-1}. The germination test results were used as a control.

For the seed vigor tests accelerated ageing (AA) test, electrical conductivity (EC) test, emergence test and seedling survival test were conducted as detailed below.

Accelerated ageing (AA) test: Two hundred seeds were sampled from each cultivar. Using an ageing temperature and time combination of 45 °C for 144 h, the AA test was performed in plastic boxes (11×11×4 cm) to which 40 mL of distilled water was added (Hampton & TeKrony 1995). Seeds were uniformly distributed on wire mesh trays (10×10×3 cm), which were placed inside the boxes. After ageing, 50 seeds per replicate were allowed to germinate on filter paper at 25±1 °C in a dark growth chamber for 10 days.

Electrical conductivity (EC) test: The electrolyte leakage was measured for four replicates of 50 weighed seeds from each ageing combination. Seeds were immersed in 50 mL deionized water at 25±1 °C for 24 h (ISTA 2003). The electrical conductivity of soaked water was measured using a conductivity meter (Model WTW Cond 314i, Germany). Results were expressed in μS cm^{-1} g^{-1} to take into account any variability in seed weight among the seed lots.

Emergence test: Four replicates of 50 seeds from each cultivar were sown at a 2 cm depth in sand-filled seedling trays (30×20×7 cm) to determine laboratory emergence percentage (LEP) under salinity stress. Seedlings were grown in an incubator set at 25±1 °C for 10 days. The emerged seedlings (identified by the appearance of hypocotyls at the surface) were counted at ten days after sowing.

Seedling survival test: Seven sorghum cultivars were tested for water stress tolerance at the seedling growth stages described by Hameed et al (2010). Ten seeds were sown at a depth of 1.5 cm in a plastic pot (24×19 cm) filled with an equal quantity of field soil. All of the pots were irrigated to the soil water holding capacity every other day during the experiment. Once each plant reached the stage where it had 5 leaves, irrigation was no longer provided. Data were recorded for percent wilting due to drought for 15 days.

The experiment was arranged in a completely randomized design (CRD) with four replicates and 50 seeds per replicate. Germination percentage data were subjected to arcsine transformation before analysis of variance was performed using the MSTAT-C program (Michigan State University). The differences among the means were compared using the LSD values ($P<0.05$).

3. Results and Discussion

The standard germination test showed significant differences among the sorghum cultivars. The lowest germination rate was obtained in Gözde 80 (89.5%), while higher values were obtained from Akdarı and Leoti with 100% than the others (Figure 1). When the germination decreased EC values increased considerably. The highest EC value was recorded in Gözde 80. Accelerated ageing resulted in decreased germination in all cultivars. Significant decreases in germination percentage of Gözde 80 and Greengo were detected. The highest germination percentage in the accelerated ageing

test was detected in Akdarı (96.5%). The laboratory emergence test demonstrated that the Gözde 80 had the lowest emergence percentage (79.0%), while Akdarı was superior to all of the other sorghum cultivars. Correlation coefficient between laboratory emergence and accelerated ageing was positive and significant (r= 0.967**). The cultivars with lower germination percentages had lower emergence percentages but higher electrical conductivity values. Significant and negative correlation coefficient (r= -0.873**) were determined between germination percentage and electrical conductivity. In other words, germination and emergence of sorghum cultivars were negatively correlated with electrical conductivity. The conductivity test has been suggested as a method to evaluate seed vigor of pea and soybean (Hampton & TeKrony 1995). Furthermore, this test has been routinely used for other crops in seed laboratories due to its simplicity and potential for rapid implementation. Our findings indicate that electrical conductivity might be a satisfying indicator of seed vigor of sorghum cultivars, as similar results were obtained from the accelerated ageing test. Soares et al (2010) reported that the electrical conductivity test should only be used if the seed lots with low vigor have been identified. The detrimental effect of accelerated ageing was more prominent in Gözde 80 and Greengo. These results agree with those reported by Santipracha et al (1997) in corn and Cisse & Ejeta (2003) in sorghum. Furthermore, they confirm that genetic differences may play an important role in determining seed vigor. Based on the results of the accelerated ageing test along with laboratory emergence, the sorghum cultivars were arranged as Akdarı>Leoti>Beydarı>Rox>Aldarı>Greengo>Gözde 80 in terms of decreasing seed vigor. The electrical conductivity test results suggested a different sequence as Akdarı>Aldarı>Leoti>Greengo>Rox>Beydarı>Gözde 80 (Figure 1).

A significant ($P<0.05$) two-way interaction (genotype and NaCl) was found for all investigated characters under salt stress. The germination percentage was significantly reduced at NaCl levels of 20 dS m^{-1}. The minimum germination were detected

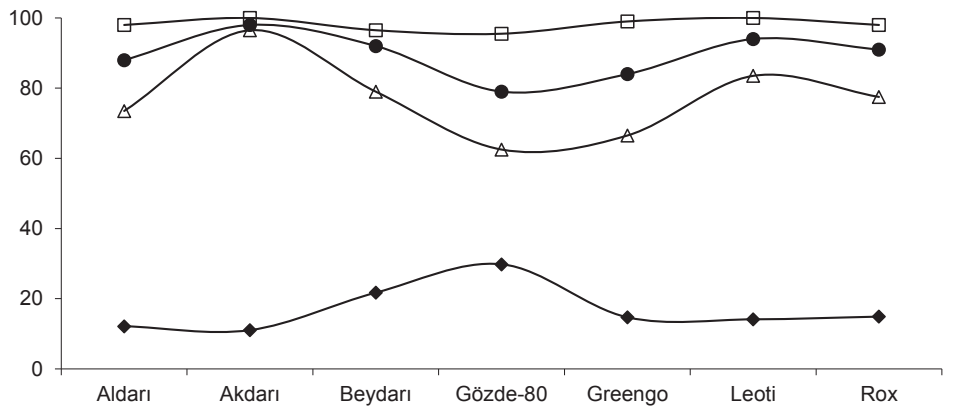

Figure 1- Germination percentage (□), laboratory emergence (●), germination after accelerated ageing (Δ) at 45 °C for 144 h and electrical conductivity (♦) for 24 h results for the seven sorghum cultivars used in this study, significant correlation coefficients between germination and electrical conductivity (r= -0.873), laboratory emergence and accelerated ageing (r= 0.967**) were determined**

*Şekil 1- Araştırmada kullanılan sorgum çeşitlerinin çimlenme yüzdesi (□), laboratuvar çıkış (●), 45 °C'de 144 saat hızlı yaşlandırma sonrası çimlenme (Δ) ve 24 saat sonra elektriksel iletkenlik (♦), çimlenme ve elektriksel iletkenlik arasında (r= -0.873**), laboratuvar çıkışı ve hızlı yaşlandırma arasında (r= 0.967**) önemli korelasyon katsayıları belirlenmiştir*

in Gözde 80 (7.5%), while the highest germination percentage (74.0%) was detected in Aldarı at the NaCl concentration of 30 dS m^{-1} (Table 1). The MGT was delayed by increasing the degree of salinity stress, on NaCl level of 20 dS m^{-1} retarded MGT considerably compared to lower levels of NaCl. Due to insufficient germination, the MGT was not calculated at 30 dS m^{-1}, except in Aldarı. The most rapid germination at 20 dS m^{-1} occurred in Aldarı after 2.67 d. NaCl adversely affected the germination percentage and mean time to germination in sorghum cultivars, and inhibitory effects of NaCl on germination could be detected at 30 dS m^{-1}. Among the sorghum cultivars, Akdarı had the highest emergence percentage (98.0%) in the control treatment, while Beydarı had the highest emergence proportion (85.0%) at the NaCl level of 10 dS m^{-1}. At the highest salt concentration, the maximum emergence percentage was recorded in Leoti (13.0%) (Table 1). The final germination percentage was markedly reduced at the NaCl level of 20 dS m^{-1} however mean germination time increased as NaCl levels increased. However, Tabatabaei & Anagholi (2012) found that NaCl levels between 0 and 15 dS m^{-1} did not adversely affect the germination percentage. Similar results were reported by Francois et al (1984), Maiti et al (1994), Faheed et al (2005) and Kandil et al (2012) whom determined that germination and seedling growth were reduced in saline soils with responses varying depending on the cultivar while NaCl diminished the germination of seeds by creating an external osmotic potential, thereby preventing water uptake. Increased drought stress resulted in decreased germination and seedling growth, especially at salinity levels higher than -7.2 bar, which is in line with earlier observations made by Kaur Gill et al (2002). Saint-Clair (1976) determined a close relationship between germination under drought stress induced by PEG and field drought tolerance in 11 sorghum cultivars.

Generally, increasing salinity levels decreased root length except Rox, and Greengo and Leoti exhibited the longer roots than the others. Root growth was not detected in Aldarı, Akdarı and Rox at 20 dS m^{-1} NaCl. The shoot lengths of nearly all of the sorghum cultivars did not change significantly at salinity levels up to 20 dS m^{-1}. None of the genotypes observed in this study were able to grow shoots at salinity levels of 30 dS m^{-1}. At 20 dS m^{-1}, Leoti was superior to the other cultivars, exhibiting a shoot length of 6.87 cm. Greater reductions in seedling fresh weight due to NaCl were significantly prominent at 20 dS m^{-1}, and no shoot growth was observed at 30 dS m^{-1}. NaCl enhanced shoot growth at salinity concentrations up to 10 dS m^{-1} but inhibited shoot growth dramatically at 20 dS m^{-1}. Seedling dry weight showed a trend similar to that of fresh weight, and Leoti, Greengo and Gözde 80 produced seedling dry weights at 20 dS m^{-1}.

Drought stress induced by PEG adversely affected germination and seedling growth of sorghum cultivars. Higher germination rates were obtained in Aldarı (28.5%) and in Beydarı (13.0%) at a PEG level of -10.8 bar (Table 2). Increased drought stress delayed the mean germination time. The shortest MGT (2.49 d) at -7.2 bar was observed in Aldarı. Seedling growth of the sorghum cultivars was severely influenced by increasing drought stress. No shoot and root development and subsequently no seedling fresh and dry weights were observed at a drought stress level of -7.2 bar in all cultivars. Leoti and Gözde 80 developed shoots and roots at drought stress levels of -1.8 and -3.6 bar. As no shoot growth was recorded under higher levels of drought stress, seedling fresh and dry weights were not evaluated. Each increase in PEG level caused a remarkable decrease in seedling fresh weight for all cultivars. However, the changes in seedling dry weight of Beydarı, Gözde 80, Greengo and Leoti due to drought stress were not significant. Apparent genetic differences were found among the sorghum cultivars subjected to salt and drought stresses with respect to seedling growth. Root and shoot length, in addition to seedling fresh and dry weight, decreased under increasing salt and drought concentrations. In terms of germination and seedling growth, cultivars were arranged in the following order, based on performance under NaCl stress as Aldarı>Greengo >Rox>Beydarı>Leoti>Akdarı>Gözde 80. The order of cultivars under drought stress was Aldarı>Greeng o>Beydarı>Rox>Leoti>Akdarı>Gözde 80.

Table 1- Germination and seedling growth of sorghum cultivars under different NaCl levels*

*Çizelge 1- Farklı NaCl seviyelerinde sorgum çeşitlerinin çimlenme ve fide gelişimi**

Sorghum cultivars	*NaCl (dS m^{-1})*	*Germination (%)*	*MGT (d)*	*Emergence (%)*	*Root length (cm)*	*Shoot length (cm)*	*Seedling fresh weight (mg plant^{-1})*	*Seedling dry weight (mg plant^{-1})*
	0	100.0±0.00	1.96±0.02	88.0±5.65	10.52±0.72	11.17±0.38	85.87±5.13	10.40±0.33
	5	96.5±3.41	2.03±0.05	73.0±5.03	11.52±1.16	9.42±0.68	63.20±6.25	9.00±0.55
Aldarı	10	92.5±2.51	2.11±0.07	49.0±6.83	10.67±0.57	7.46±0.80	50.20±6.17	8.35±0.36
	20	89.5±2.51	2.67±0.23	2.0±2.30	-	-	-	-
	30	74.0±4.32	4.16±0.26	0.0±0.0	-	-	-	-
	0	98.0±2.82	2.59±0.08	98.0±2.30	8.57±1.17	8.41±0.42	84.77±8.73	8.60±0.64
	5	96.0±3.65	2.89±0.11	95.0±2.00	8.15±0.98	8.45±0.34	66.42±5.26	7.27±0.49
Akdarı	10	90.0±5.41	3.19±0.06	84.5±3.41	7.75±0.51	7.36±0.26	52.42±3.00	6.62±0.26
	20	64.0±8.79	4.71±0.15	49.0±6.00	-	-	-	-
	30	21.5±6.40	-	7.0±6.00	-	-	-	-
	0	96.5±3.00	2.18±0.06	92.0±0.0	10.83±1.59	7.22±0.31	24.02±0.55	7.97±0.25
	5	91.5±3.41	2.26±0.05	88.0±10.83	11.31±0.96	6.63±0.54	31.02±2.03	8.05±0.36
Beydarı	10	86.0±4.00	2.65±0.07	85.0±3.82	9.76±0.99	7.33±0.52	27.55±2.43	7.30±0.54
	20	67.0±6.63	3.37±0.20	59.0±6.00	4.22±2.82	2.86±1.91	9.82±6.57	2.95±1.97
	30	31.5±9.00	-	12.0±3.26	-	-	-	-
	0	78.5±5.25	2.94±0.11	79.0±6.83	13.26±1.09	8.57±0.49	73.90±7.71	7.72±0.43
	5	73.5±9.00	2.75±0.12	64.0±5.65	12.56±0.19	9.42±0.74	71.65±2.31	6.97±0.12
Gözde 80	10	63.5±7.72	3.15±0.32	58.0±6.92	12.36±0.67	9.32±0.53	61.15±4.21	6.27±0.17
	20	32.0±0.0	-	23.0±6.00	3.37±3.93	2.67±3.11	31.60±4.77	3.60±0.54
	30	7.5±4.72	-	4.0±3.26	-	-	-	-
	0	99.0±1.15	2.14±0.15	84.0±6.53	12.61±1.56	9.33±0.87	58.75±18.13	6.52±2.52
	5	90.5±5.74	2.70±0.25	63.0±9.45	12.15±1.31	8.35±0.34	41.67±4.40	4.35±0.55
Greengo	10	82.5±4.43	2.41±0.12	21.0±8.24	11.62±0.83	7.07±0.68	75.20±4.66	8.60±0.70
	20	72.0±4.89	3.97±0.31	0.0±0.0	7.50±0.55	3.78±0.73	32.22±2.88	4.65±0.36
	30	44.5±10.87	-	0.0±0.0	-	-	-	-
	0	100.0±0.00	1.99±0.03	94.0±2.30	11.18±1.55	10.25±0.86	77.52±4.13	9.37±0.09
	5	100.0±0.00	2.13±0.03	94.0±2.30	9.27±0.32	12.71±0.28	68.90±4.75	8.30±0.45
Leoti	10	97.0±1.15	2.26±0.12	78.0±5.16	9.65±0.49	12.16±0.54	50.77±5.41	7.75±0.44
	20	89.0±2.00	3.27±0.07	65.0±3.82	7.28±0.31	6.87±0.35	26.02±1.54	5.07±0.35
	30	31.0±8.08	-	13.0±6.83	-	-	-	-
	0	97.0±3.46	1.96±0.13	91.0±8.24	9.66±0.67	7.92±0.45	88.47±7.36	9.35±0.46
	5	96.0±3.26	1.95±0.09	78.0±8.32	10.13±0.61	7.97±0.65	79.32±8.35	8.37±0.82
Rox	10	90.5±1.91	2.33±0.09	43.5±10.63	10.18±0.58	7.35±0.75	69.32±9.07	7.42±0.79
	20	69.0±8.08	3.78±0.09	0.0±0.0	-	-	-	-
	30	43.0±10.00	-	0.0±0.0	-	-	-	-
LSD_{int} (P<0.05)		7.58	0.19	7.87	1.56	1.09	7.61	0.93

*, data represent mean±standard deviation (SD) of four replicates

Table 2- Germination and seedling growth of sorghum cultivars under different drought stress*

*Çizelge 2- Farklı kuraklık streslerinde sorgum çeşitlerinin çimlenme ve fide gelişimi**

Sorghum cultivars	*PEG (bar)*	*Germination (%)*	*MGT (d)*	*Root length (cm)*	*Shoot length (cm)*	*Seedling fresh weight (mg plant^{-1})*	*Seedling dry weight (mg plant^{-1})*
	0	100.0±0.00	1.96±0.02	10.52±0.72	11.17±0.38	85.87±5.13	10.40±0.33
	-1.8	96.0±1.63	1.70±0.13	11.57±1.04	6.62±0.27	29.00±1.41	9.42±0.20
Aldarı	-3.6	99.0±1.15	1.99±0.07	8.83±1.35	4.50±0.21	22.00±0.81	7.42±0.28
	-7.2	91.5±7.18	2.49±0.21	-	-	-	-
	-10.8	28.5±4.12	-	-	-	-	-
	0	98.0±2.82	2.59±0.08	8.57±1.17	8.41±0.42	84.77±8.73	8.60±0.64
	-1.8	94.5±4.12	3.02±0.12	7.10±1.00	5.56±0.45	16.75±1.50	6.17±0.45
Akdarı	-3.6	89.5±2.51	3.56±0.46	6.45±0.87	2.60±0.17	11.75±1.25	4.07±0.18
	-7.2	33.5±7.54	-	-	-	-	-
	-10.8	0.00±0.00	-	-	-	-	-
	0	96.5±3.00	2.18±0.06	10.83±1.59	7.22±0.31	24.02±0.55	7.97±0.25
	-1.8	98.5±1.00	2.03±0.07	11.95±0.44	6.75±0.20	26.75±2.36	9.02±0.45
Beydarı	-3.6	97.0±3.46	2.19±0.20	8.83±1.25	5.46±0.64	23.00±3.74	7.45±0.55
	-7.2	76.0±6.53	2.84±0.31	-	-	-	-
	-10.8	13.0±5.77	-	-	-	-	-
	0	78.5±5.25	2.94±0.11	13.26±1.09	8.57±0.49	73.90±7.71	7.72±0.43
	-1.8	84.0±8.79	2.57±0.16	11.08±0.28	9.28±0.90	29.00±2.16	7.00±0.00
Gözde 80	-3.6	70.0±9.09	2.94±0.06	10.41±0.24	7.38±0.45	28.25±1.70	6.25±0.50
	-7.2	27.0±3.82	-	-	-	-	-
	-10.8	0.00±0.00	-	-	-	-	-
	0	99.0±1.15	2.14±0.15	12.61±1.56	9.33±0.87	58.75±18.13	6.52±2.52
	-1.8	96.5±1.00	1.39±0.15	9.77±1.36	8.82±0.46	25.50±3.78	8.00±0.57
Greengo	-3.6	92.0±4.89	1.92±0.08	9.51±1.48	5.87±0.96	28.00±4.76	7.25±0.50
	-7.2	74.5±7.72	2.60±0.06	-	-	-	-
	-10.8	14.5±8.38	-	-	-	-	-
	0	100.0±0.0	1.99±0.03	11.18±1.55	10.25±0.86	77.52±4.13	9.37±0.09
	-1.8	99.5±1.00	1.91±0.02	13.33±1.74	9.90±0.24	37.00±3.16	8.50±0.57
Leoti	-3.6	99.0±2.00	2.00±0.05	11.16±0.58	8.60±0.54	33.75±3.94	7.50±0.57
	-7.2	92.0±3.65	2.50±0.17	-	-	-	-
	-10.8	3.0±3.82	-	-	-	-	-
	0	97.0±3.46	1.96±0.13	9.66±0.67	7.92±0.45	88.47±7.36	9.35±0.46
	-1.8	97.5±2.51	2.02±0.05	9.01±0.51	7.42±0.24	30.00±2.70	8.00±0.00
Rox	-3.6	96.0±1.63	2.25±0.19	9.60±1.36	6.12±0.35	30.25±2.50	8.25±0.50
	-7.2	36.0±7.11	-	-	-	-	-
	-10.8	4.5±1.91	-	-	-	-	-
LSD_{int} (P<0.05)		6.38	0.20	1.23	0.57	6.14	0.74

*, data represent mean±standard deviation (SD) of four replicates

In the seedling survival test, the sorghum seedlings started wilting 11 days after the drought incubation. Significant differences among the cultivars were determined (P<0.05). Aldarı and Rox were the last cultivars to wilt while Akdarı and Gözde 80 died earlier (Table 3). Genotypic variation among the sorghum cultivars was determined. Seedlings began wilting after 13 days following drought incubation. The wilting sequence, from late to early, among cultivars was recorded as Alda rı>Rox>Beydarı>Leoti>Greengo>Gözde 80>Akdarı, indicating that Akdarı was the first cultivar to wilt.

Table 3- Mean seedling wilting day of sorghum cultivars subjected to drought stress in the pod experiment

Çizelge 3- Saksı denemelerinde kuraklık stresi uygulanan sorgum çeşitlerinin ortalama fide kuruma süresi

Sorghum cultivars	*Mean seedling wilting day (d)*
Aldarı	15.36[a*]
Akdarı	13.68[c]
Beydarı	14.26[bc]
Gözde 80	13.92[c]
Greengo	14.22[bc]
Leoti	14.25[bc]
Rox	15.14[ab]

*, different letters in each column indicate significance at P<0.05

4. Conclusions

Differences in seed vigor were observed among the sorghum cultivars grown under identical conditions. By contrast, seed vigor was not related to the germination tests under salt and drought stress conditions, thereby suggesting that the cultivars with vigorous seeds did not perform better under the investigated stresses. This result suggests that there is no relationship between seed vigor and germination under abiotic stress conditions. Thus, it was concluded that seed vigor test results are not a reliable indicator of seed performance under salt and drought stress conditions.

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Pre-harvest Application of ReTain (Aminoethoxyvinylglycine, AVG) Influences Pre-harvest Drop and Fruit Quality of 'Williams' Pears

Sinan BUTAR[a], Melike ÇETİNBAŞ[a]

[a]*Fruit Research Institute, 32500, Eğirdir, Isparta, TURKEY*

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Corresponding Author: Sinan BUTAR, E-mail: sinanbutar@gmail.com, Tel: +90 (246) 313 24 20
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ABSTRACT

'Williams' is the highly quality pear cultivar mostly produced in the Eğirdir region of Turkey. ReTain (15% aminoethoxyvinilglycine, AVG) is a plant growth regulator used to control pre-harvest drop and increase fruit weight and firmness. The objective of this study was to determine the responses of AVG treatments on the pre-harvest drop and fruit quality of 'Williams' pear. Pear trees of the cultivar 'Williams' were sprayed 30, 21 and 7 days before commercial harvest (DBH) with AVG, at doses of 100, 125 and 150 mg L^{-1}, and assessed for pre-harvest drop, yield, maturity, delay in harvest, fruit quality, ethylene production and respiration rate at the harvest time. Fruit samples were analyzed for fruit quality parameters which are: fruit width, fruit weight, soluble solids content (SSC), titratable acidity (TA), fruit firmness, fruit colour, fruit macro and micro elements content. Maturation of the 30 and 21 DBH AVG-treated fruits were delayed 3-4 days compared to the 7 DBH AVG-treated and control groups. The pre-harvest drop decreased with all AVG applications by approximately 38-100% in comparison with the control group fruits. AVG treatments increased fruit size (7-10%), fruit weight (26-41%) and fruit firmness (2-16%) of 'Williams' pear. AVG application reduce ethylene production and respiration rate and it was found that the applications enhance the ethylene production and respiration rate by approximately (100%) compared to the control fruits on the harvest date. Results of this study indicated that 30 DBH and 21 DBH AVG-treatments at 100 mg L^{-1} can be recommended for 'Williams' pear cultivar on both pre-harvest fruit drop, as well as in harvest date and fruit quality.

Keywords: Pear; Harvest time; Fruit quality; 'Williams'; Pre-harvest drop; AVG

Hasat Öncesi ReTain (Aminoethoxyvinylglycine, AVG) Uygulamalarının 'Williams' Armut Çeşidinde Hasat Önü Dökümü ve Meyve Kalitesi Üzerine Etkileri

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Sinan BUTAR, E-posta: sinanbutar@gmail.com, Tel: +90 (246) 313 24 20
Geliş Tarihi: 18 Temmuz 2014, Düzeltmelerin Gelişi: 23 Mart 2015, Kabul: 19 Şubat 2016

ÖZET

'Williams' armudu Türkiye'nin Eğirdir bölgesinde üretimi fazla olan kaliteli bir çeşittir. ReTain (% 15 aminoetoksivinilglisin, AVG), hasat önü meyve dökümünün kontrolünde, meyve ağırlığı ve meyve eti sertliğinin artırılmasında kullanılmakta olan bir bitki büyüme düzenleyicisidir. Bu çalışma, 'Williams' armudunda hasat önü meyve dökümü ve meyve kalitesi üzerine AVG uygulamalarının etkilerini incelemek amacıyla yürütülmüştür. Bu amaçla, tahmini hasat zamanından (THZ) 30, 21 ve 7 gün önce 0, 100, 125, 150 mg L^{-1} dozlarında AVG armut ağaçlarına püskürtme şeklinde uygulanmıştır. Hasat önü meyve dökümü, verim, olgunluk, hasat tarihinin gecikmesi, meyve kalitesi, meyvelerin etilen üretimi ve solunum hızları hasat zamanında incelenmiştir. Hasat edilen meyvelerin kalite parametreleri olarak meyve çapı, meyve ağırlığı, meyve eti sertliği, meyve rengi, suda çözünebilir kuru madde, titre edilebilir asitlik ve meyvelerde makro-mikro elementler analiz edilmiştir. THZ 30 ve 21 önce uygulanan AVG uygulamaları ile meyve olgunluğu kontrol grubuna ve THZ 7 önce uygulanan AVG uygulamalarına göre 3-4 gün gecikmiştir. AVG uygulamaları ile hasat önü meyve dökümü % 38-100 arasında oldukça azalmış olup meyve boyutu (% 7-10), ağırlığı (% 26-41) ve meyve sertliği de (% 2-16) artmıştır. AVG uygulamaları meyvelerdeki etilen üretimi ve solunum hızını da kontrol grubuna göre neredeyse % 100 yavaşlatmıştır. Sonuç olarak, 'Williams' armut çeşidinde, gerek hasat önü meyve dökümü, gerekse hasat zamanı ve meyve kalitesi bakımından THZ 30 ve 21 gün önceki 100 mg L^{-1}'lik uygulamaların en uygun uygulamalar olduğu tavsiye edilmektedir.

Anahtar Kelimeler: Armut; Hasat zamanı; Meyve kalitesi; 'Williams'; Hasat önü döküm; AVG

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1. Introduction

Pre-harvest drop of pears happens because the fruit developed an immaturity, and in most cases, economic damage usually causes a serious economic loss. A good quality 'Williams' (Bartlett) pear should have a fruit medium large-large conical neck; the middle part is wide. Light green peel, a thin, hollow stem with rust coloured surroundings, eating death are yellow. The flesh is white, fine-textured, like butter type, very juicy, sweet and aromatic and the quality is excellent. Suppressing ethylene production in 'Williams' pears may increase yields by reducing premature fruit abscission, and indirectly increase fruit size by delaying harvest of slower-maturing fruit. 'Williams' growers often use the synthetic auxin, naphthaleneacetic acid (NAA), which can compress pre-harvest abscission, however can also result in fruit softening. Reducing fruit ethylene production may reduce the incidence of premature ripening on the tree, enhance the storage life, and reduce the rate of ripening of 'Williams' pears (Clayton et al 2000). AVG (aminoethoxyvinylglycine) inhibit ethylene biosynthesis pathway (Kim et al 2004), and can thus compress ethylene production in many climacteric fruits (Yang et al 1982). Pre and post-harvest applications of AVG have been evaluated as a tool to enhance production and quality attributes of climacteric fruits (Çetinbaş et al 2012). AVG delaying the harvest of fruits result in them being larger and thus increases the yield. Delay in harvesting may convenience flexibility in labor, packaging and fruit processing, storage and marketing (Amarante et al 2005).

Pre and post-harvest treatments with AVG inhibited ethylene production and delayed harvesting of pears (Romani et al 1983) and peaches (Çetinbaş & Koyuncu 2011). With the 'Barlett' pear, pre-harvest AVG treatments either 14 or 7 days before harvest did not affect ethylene production at harvest, but delayed changes in skin colour, softening and starch content (Clayton et al 2000). Andreotti et al (2004) found that pre-harvest treatment with AVG at 125 mg L^{-1} delayed maturation of 'Abbe Fetel' pears by 5 to 15 days.

Therefore, this study was conducted to determine the effects of AVG applications different doses, sprayed 30, 21 and 7 days before commercial harvest, on pre-harvest drop, fruit maturity and fruit quality of 'Williams' pears.

2. Material and Methods

2.1. Plant material

The trials were conducted at the Fruit Research Station of Eğirdir, Turkey in 2011-2012. Uniform 10-years-old pear trees of the cv. 'Williams', grafted on Quince C rootstock and spaced at 1.5x4 m were used. The experiment was designed in completely randomized blocks of 4 replications, using a single tree for each treatment.

2.2. AVG treatments

ReTain was (Valent BioScience Corporation) sprayed at 0 (water+surfactant), 100, 125, 150 mg L^{-1} plus 1% (v v^{-1}) Tween 20 as a surfactant onto fruits and leaves around the fruits until runoff. The spraying was performed with a hand pump sprayer at 7, 21 and 30 days before (DBH) in 2011 and 2012. Application time and dose of AVG were determined according to Çetinbaş & Koyuncu (2011).

2.3. Fruit maturity and harvest determination

When the pear fruits firmness were 80 to 89 N, fruits were harvested at a commercial stage of maturity. AVG-treated fruits and untreated fruits were harvested separately and picked into specially designated bins. After each harvest pick, fruit was transported to the Pomology Laboratory of Fruit Research Station. Fruits were harvested 2 times from 21 to 24 September 2011 (I. year) and from 19 to 23 September 2012 (II. year).

2.4. Yield and pre-harvest drop determination

The yield was determined at harvest as per tree kg in the first and second year. In order to determine the pre-harvest drop rate, existing fruits on each tree were identified one month before commercial harvest (DBH) and then, twice every week. Fallen fruits were counted under the trees in the first and second year. The results were expressed as percent (%).

2.5. Fruit quality determination

Fruit width, fruit weight and fruit firmness: The measurement of twenty fruits were determined using digital calipers for fruit width (mm). Fruit weight (g) was measured by a digital scales sensitive to 0.01 g. Fruit firmness (Newton) was measured by using a texture analyser (Lloyd Instruments LF Plus) incorporating an 8 mm diameter probe.

Soluble solid content (SSC) and titratable acidity (TA): The rates of SSC were measured by a digital refractometer (Palette PR-32 Atago). TA by manual titration with 0.1 N NaOH and expressed as g malic acid 100 g^{-1}.

Fruit colour: The colour of the fruit was measured with a colorimeter (Minolta CR-300). Peel colours were evaluated as CIE L*, a*, b*, C*, h°.

2.6. Respiration rate and ethylene production determination

Ethylene production (µL kg^{-1} h^{-1}) and respiration rate (µL kg^{-1} h^{-1}) were defined pear of close to the jar after 1 day. Measurement of respiratory rate was done with gas analizator. Ethylene production was determined by using gas chromatography with a flame ionization detector (Gunes et al 2001).

Fruit mineral composition determination: The mineral contents of the fruit samples were analyzed. Samples were washed thoroughly with fountain water, dilute acid (0.2 N HCl) and distilled water to remove surface residues, and dried at 70±5 °C. Dried samples were ground with a stainless-steel mill for analytic procedures. The P, K, Ca, Mg, Fe, Cu, Mn, Zn and B concentrations were determined by Inductively Coupled Plasma Atomic Emission spectrometry (Perkin Elmer Optima, Germany) method. Nitrogen was determined by the Kjeldahl (Gerhardt, Germany) procedure. The resulting data was expressed as a percentage of dry tissue (%) for N, P, K, Ca, Mg, whereas Fe, Cu, Mn, Zn and B were recorded as milligrams per kilogram of dry fruit.

2.7. Statistical analysis of results

The experiment was based as a completely randomized blocking pattern as four replications and was assigned as one tree for each replication. The data was statistically analyzed (Duncan's multiple

range test at P≤ 0.05) using SPSS (V.18; Statistical software, SPSS. Inc., USA) software program. Fruit colours and fruit mineral compositons were done during two years and the data presented here are the mean results of these years.

3. Results and Discussion

3.1. Fruit maturity and harvest

Considering fruit firmness and colour, 'Williams' pear harvests of all treatments were performed at harvest maturation in our study. The 30 DBH and 21 DBH AVG treatments were harvested later than control and 7 DBH AVG-treated fruits (In the first and second year). Control and 7 DBH AVG-treated fruits were harvested on the 21st September while 30 and 21 DBH AVG applied fruits were harvested on the 24th September (in 2011). In 2012, fruits were harvested on the 19th September (control and 7 DBH AVG-treated fruits) and 23 September (30 and 21 DBH AVG-treated fruits). Consequently, it was observed AVG treatments delayed harvest time by 3 days. It was reported in many studies done with pears and apples that AVG applications delay harvest time showing similarities with our findings (Clayton et al 2000; Schupp & Greene 2004; Greene 2006; Petri et al 2006; Rath et al 2006; WookJae et al 2006; Kang et al 2007; Whale et al 2008). Phan-Thien et al (2004) showed the effect of 125 mg L^{-1} of AVG sprayed onto 'Gala' and 'Pink Lady' apples in the first 5 to 12 days delayed ripening by 5 to 7 days. In a study conducted in a commercial orchard of 'Arctic Snow' nectarines, application of 125 mg L^{-1} AVG 7 days before anticipated first harvest gave a 2.75 day harvest delay based on standard commercial maturity criteria (Rath & Prentice 2004).

3.2. Yield and pre-harvest drop

In both years, AVG treatments increased fruit yield. AVG concentrations x application times interaction on the yield was found to be statistically significant (P≤0.05) in 2011. In the second year (2012), AVG had not significant effects on yield (Table 1). The highest yield was found in the plot submitted to 30 DBH-100 mg L^{-1} AVG treatment (in the first year). In both years, as illustrated in Table 1, pre-harvest fruit drop was influenced significantly by AVG concentrations and application times (P≤0.05). The highest pre-harvest fruit drop was observed in 7 DBH-control fruits (in 2011). In 2012, fruits of the 21 DBH-control were higher than the others. In both years, the pre-harvest drop was not observed after treatment with 150 mg L^{-1} AVG concentration at 21 DBH (Table 1). Karaçalı (2009) reported that pre harvest drop depends on the plant species and its variety. Hot or cold weather conditions, late time fertilization with high nitrogen content, drought and high soil water level, low boron and magnesium levels in the soil increase pre harvest drop ratio. Cultural practices are not enough to prevent pre harvest drop. Plant growth regulators must be used to prevent pre harvest drop. In our study, AVG treatments were used in an orchard which has regular cultural practice and AVG treatments were used to control pre harvest drop. The effects of AVG applications on pre-harvest fruit drop and yield are highly significant in our research. It was determined that pre-harvest fruit drop was reduced by AVG treatments. Pre-harvest fruit drop has never been detected after 30 DBH-150 mg L^{-1} and all doses of 21 DBH applications. Accordingly, it was found that the aforementioned applications enhance the fruit yield as compared to the other applications. The percentage of pre-harvest fruit drop decreased in parallel with the increase in treatment doses. In one of his studies regarding AVG's effectiveness on pre-harvest apple drop control, Greene (2006) stated that increase in AVG is directly correlated with its concentration, meaning increase in dose. Greene (2006) also reported that the most appropriate and effective time to apply the treatment is 2-3 weeks before the estimated harvest. It was revealed in our study, in line with the results of many researchers, that AVG prevents or reduces the pre-harvest fruit drop (Greene 2006; Petri et al 2006; Rath et al 2006; WookJae et al 2006; Kang et al 2007; Whale et al 2008). These results are considered to be important for the prevention or reduction of pre-harvested losses approximately 10% of pre-harvest drop. We also believe the results affect pear growers favourably on economic aspects.

Table 1- The effect of AVG treatments on yield and pre-harvest fruit drop in the 'Williams' pear, 2011 and 2012

Çizelge 1- AVG uygulamalarının 'Williams' armudunda verim ve hasat önü meyve dökümüne etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*Yield (kg tree^{-1})*		*Pre-harvest drop (%)*	
		2011	*2012*	*2011*	*2012*
30 d	0	8.30 a-c	9.65	24.92 a	8.52 b
	100	12.4 6a	16.81	0.00 b	2.51 c
	125	9.07 a-c	16.06	0.00 b	0.79 c
	150	7.74 bc	13.05	2.54 b	0.00 c
21 d	0	7.53 bc	11.71	25.60 a	16.43 a
	100	11.18 ab	14.04	0.00 b	0.00 c
	125	6.69 bc	11.84	4.25 b	0.00 c
	150	7.02 bc	15.71	0.00 b	0.00 c
7 d	0	4.42 c	12.62	26.90 a	13.12 a
	100	5.35 c	13.24	6.06 b	1.96 c
	125	6.63 bc	13.68	3.49 b	7.90 b
	150	7.73 bc	14.32	4.75 b	0.84 c
Time					
30		9.39	12.82	6.87	2.96
21		8.10	12.62	7.46	13.12
7		6.03	12.77	10.30	5.96
	AVG concentrations				
	0	6.75	12.17	25.81	12.04
	100	9.66	13.77	2.02	1.49
	125	7.46	13.86	2.58	2.90
	150	7.50	12.92	2.43	0.28
P values					
Time (T)		0.016	0.951	0.747	0.477
Concentrations (C)		0.184	0.381	0.000	0.000
T × C		0.027	0.867	0.000	0.000

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

3.3. Fruit quality

Fruit width, fruit weight and fruit flesh firmness: In both years, AVG applications significantly (P≤0.05) increased fruit width and weight in 'Williams' pear cultivar. The heaviest fruits were obtained from 21 DBH-100 mg L^{-1} (380.46 g in first year and 335.00 g in second year) AVG dose (Table 2). AVG applications increase 'Williams' pear fruit width and weight and it was found that the applications enhance the fruit width by approximately 7-10% and fruit weight by 26-41% in comparison with the control group fruits. Petri et al (2006) states AVG enhances fruit weights of 'Gala' and 'Fuji' apples as compared to the control group. Greene (2006) also expresses that AVG-applied fruits are generally bigger since it helps fruit remain on the tree for a longer time. In our study, the biggest pears were obtained from the application of 21 DBH-100 mg L^{-1} and 21 DBH-150 mg L^{-1}. Venburg et al (2008) stated that continuing research has extended and refined the use of AVG in apples and stone fruit. AVG's ripening and harvest delay effect have been investigated, examining the effect of harvest delay on fruit size and yield. When the untreated fruit and ReTain-treated fruit were

harvested at the same stage of ripening, the fruit size in the ReTain treatment was larger due to the 7 days delay. In the ReTain treatments, the mass of small size fruit per tree (<65 mm) was reduced and the mass of larger size fruit per tree (>65 mm) was increased. In addition, the overall yield was 11% greater treatment. In both years, AVG treatments had a significant influenced on fruit flesh firmness. In 2011, Fruit flesh firmness was affected significantly by AVG concentrations and application times (P≤0.05). In 2012, Fruit flesh firmness was influenced significantly by AVG concentrations (P≤0.05) (Table 2). In first year, the harder fruits were found after 21 DBH-100 mg L^{-1} (88.72 N) and 7 DBH-100 mg L^{-1} (88.30 N) AVG treatments. However, the fruit firmness-increasing effect of AVG concentrations was more distinctive in the second year experiments. The 125 mg L^{-1} AVG treatment determined the highest fruit firmness values (88.39 N) at the harvest. This was followed by 100 and 150 mg L^{-1} AVG doses (Table 2). Similarly to our findings, the dose of 125 mg L^{-1} AVG enhanced the fruit firmness before the harvest time of 'Tsugaru' apples (WookJae et al 2006). Besides, it was stated that AVG application has favourable impact on fruit firmness of different apple types such as 'McIntosh', 'Spartan', 'Spencer' (Bramlage et al 1980), 'Gala' and 'Jonagold' (Wang & Dilley 2001). In a study done with 'Bartlett' pear, Clayton et al (2000) states that AVG boosted fruit firmness. Keeping the pears

Table 2- The effect of AVG treatments fruit width, weight and flesh firmness in 'Williams' pear, 2011 and 2012

Çizelge 2- AVG uygulamalarının 'Williams' armudunda meyve çapına, ağırlığına ve sertliğine etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations*	*Fruit width (mm)*		*Fruit weight (g)*		*Fruit flesh firmness (N)*	
	(mg L^{-1})	*2011*	*2012*	*2011*	*2012*	*2011*	*2012*
30 d	0	70.73 f	74.20 cd	189.13 f	226.33 e	78.04 c	84.71
	100	78.07 c	82.94 ab	266.54 c	315.17 a-c	82.12 a-c	88.44
	125	77.03 cd	82.54 ab	252.28 cd	314.00 a-c	86.32 ab	89.25
	150	74.04 e	77.17 b-d	217.23 e	257.67 c-e	86.52 ab	90.12
21 d	0	70.60 f	72.50 cd	193.12 f	241.00 de	76.77 cd	84.31
	100	86.17 a	84.75 a	380.46 a	335.00 a	88.72 a	89.54
	125	80.83 b	84.29 ab	303.19 b	326.67 ab	85.92 a-c	88.15
	150	81.17 b	83.07 ab	302.54 b	330.00 a	87.49 ab	85.57
7 d	0	69.88 f	70.73 d	185.03 f	203.67 e	81.62 a-c	84.34
	100	74.83 de	78.51 a-c	233.94 de	263.33 c-e	88.30 a	85.23
	125	76.48 cd	79.30 a-c	239.06 d	302.33 a-d	85.30 a-c	87.76
	150	81.80 b	77.40 b-d	293.95 b	265.67 b-e	84.45 a-c	86.54
Time							
30		74.97	79.21	231.30	278.29	85.25	88.13
21		79.69	81.15	294.83	308.17	84.73	86.89
7		75.74	76.48	237.99	258.75	84.92	85.97
	AVG concentrations						
	0	70.40	72.48	189.09	223.67	78.81	84.45 b
	100	79.69	82.06	293.65	304.50	86.38	87.74 a
	125	78.11	82.04	264.84	314.33	85.85	88.39 a
	150	79.00	79.21	271.24	284.44	86.15	87.41 a
P values							
Time (T)		0.045	0.117	0.008	0.054	0.832	0.225
Concentrations (C)		0.000	0.000	0.000	0.000	0.006	0.030
T × C		0.000	0.001	0.000	0.000	0.000	0.108

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

under shelf life conditions and cold storing them protect their hardness more effectively than the control group fruits. As a kind of flavoured pear, 'Williams' directly takes place both in domestic and foreign market. Hence a portion of shelf life is consumed during transport. In accordance with the data obtained from this study, it is probable that increase in fruit firmness may have favourable impact on shelf life of fruits, thus reducing effects of loss of quality during transportation.

Soluble solid content (SSC) and titratable acidity (TA): In both years, AVG concentrations × application time interaction on the SSC and TA in was found to be statistically significant (P≤0.05) (Table 3). In the first year, compared to only 21 DBH-AVG treated fruits showed lower values of SSC, while in the second year all AVG applications determined the same effect. In both years, AVG treatments had unstable effects on TA (Table 3). The effect was reported as variable depending on concentration of AVG application, time of application, variety and environmental conditions (Bramlage et al 1980). AVG applications reduced the SSC amount, however, no effect has been detected at quinic and malic acid amount (Drake et al 2005). Furthermore, Clayton et al (2000) reported that AVG applications

Table 3- The effect of AVG treatments total soluble solids (SSC) and titratable acidity (TA) in 'Williams' pear, 2011 and 2012

Çizelge 3- AVG uygulamalarının 'Williams' armudunda suda çözünebilir kuru madde (SÇKM) ve titre edilebilir asitliğe (TA) etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*SSC (%)*		*TA (%)*	
		2011	*2012*	*2011*	*2012*
30 d	0	14.40 c	16.90 a	0.45 c-e	0.62 a
	100	15.57 a	13.30 cd	0.49 a-d	0.42 cd
	125	15.03 a-c	12.83 d	0.42 de	0.48 b-d
	150	15.93 a	15.43 ab	0.40 e	0.63 a
21 d	0	15.30 a-c	14.93 bc	0.48 a-d	0.59 ab
	100	14.50 bc	14.37 b-d	0.44 c-e	0.49 b-d
	125	14.93 a-c	13.00 c	0.55 a	0.41 d
	150	15.30 a-c	14.07 b-d	0.55 ab	0.54 a-c
7 d	0	14.37 c	15.23 ab	0.44 c-e	0.59 ab
	100	15.43 ab	13.97 b-d	0.47 b-d	0.51 a-d
	125	15.27 a-c	13.03 cd	0.38 e	0.51 a-d
	150	15.27 a-c	14.60 b-d	0.51 a-c	0.60 ab
Time					
30		15.23	14.62	0.44	0.54
21		15.01	14.09	0.50	0.51
7		15.08	14.21	0.45	0.55
	AVG concentrations				
	0	14.69	15.69	0.46	0.60
	100	15.17	13.88	0.47	0.47
	125	15.08	12.96	0.45	0.47
	150	15.50	14.70	0.49	0.59
P values					
Time (T)		0.695	0.654	0.016	0.467
Concentrations (C)		0.056	0.000	0.697	0.000
T × C		0.029	0.000	0.000	0.003

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range tests

increase SSC amount and reduce the amount of TA, which has also been observed in our results.

Fruit colours: AVG concentrations × application times interaction on the fruit colour component L*, b* and C* values was found to be statistically significant (P≤0.05). AVG concentrations on the h° values in was found to be statistically significant (P≤0.05). AVG treatments had no significant influenced on a* values (Table 4). L* values decreased with AVG treatments. The highest L* value was observed in control fruit groups. The AVG applications increased b* value (yellowness). AVG effected on late ripening and also on late colouration of fruits, for this reason in our study b* value increased. The highest C* value (49.33) was determined in 30 DBH-100 mg L^{-1} AVG fruits. The only AVG concentrations reduced h° values (Table 4). However, all AVG concentrations were included same group in statistics. The effect of AVG applications on fruit coloration resulted differently in several studies. The colouration was delayed for 'Redfree', 'Gala' and 'Golden Delicious' varieties with AVG applications, while red colour was not affected in 'Rome' variety. Greene (2006) stated that decrease in red color is correlated with delay in maturation rather than the prevention of red color development.

Table 4- The effect of AVG treatments fruit colour (L*, a*, b*, C* and h°) in 'Williams' pear (2011 and 2012 means)

Çizelge 4- AVG uygulamalarının 'Williams' armudunda meyve rengine (L, a*, b*, C* and h°) etkisi (2011 ve 2012 ortalamaları)*

Application time[1]	*AVG concentrations (mg L^{-1})*	*Fruit colour*				
		*L**	*a**	*b**	*C**	*h°*
30 d	0	68.45 a	-10.23	45.04 a-d	46.99 b-d	101.90
	100	65.50 bc	-11.13	47.14 a	49.33 a	102.21
	125	64.05 c	-10.40	46.02 a-c	48.34 a-c	101.22
	150	64.17 c	-8.12	46.18 a-c	48.08 a-c	98.54
21 d	0	68.43 a	-9.93	45.34 a-d	47.05 b-d	100.93
	100	63.59 c	-10.62	46.60 ab	49.13 ab	101.20
	125	62.88 c	-8.87	45.74 a-c	48.57 a-c	98.65
	150	64.72 c	-9.02	46.35 a-c	48.96 ab	99.09
7 d	0	67.86 ab	-9.41	45.02 a-d	46.52 cd	100.93
	100	63.27 c	-7.56	46.63 b-d	47.01 b-d	97.34
	125	63.03 c	-9.60	44.12 cd	46.83 b-d	100.11
	150	62.49 c	-5.43	43.25 d	45.31 d	95.29
Time						
30		65.54	-9.96	46.10	46.42	100.97
21		64.91	-9.61	46.01	48.43	100.14
7		64.16	-8.00	44.26	48.18	98.42
	AVG concentrations					
	0	68.25	9.85	45.13	46.85	101.48 a
	100	64.12	9.77	46.12	48.49	100.25 ab
	125	63.32	9.62	45.29	47.91	99.9a b
	150	63.79	7.52	45.26	47.45	97.64 b
P values						
Time (T)		0.275	0.076	0.000	0.000	0.094
Concentrations (C)		0.000	0.085	0.386	0.079	0.041
T × C		0.000	0.133	0.011	0.002	0.094

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

3.4. Ethylene production and respiration rates

As showed in Table 5, ethylene production rate was influenced significantly (P≤0.05) by AVG applications in 2011 and 2012. In the first year, the ethylene production of all application time in control group fruits illustrated the highest value (5.46 µL kg^{-1} h^{-1}, 4.05 µL kg^{-1} h^{-1} and 3.63 µL kg^{-1} h^{-1}, respectively) while 30 DBH-100 mg L^{-1} AVG fruits had the lowest value (0.22 µL kg^{-1} h^{-1}). In the second experiment year, all of the control groups determined ethylene production. In 2011, AVG concentrations × application time interaction on the fruit respiration rates were found to be statistically significant (P≤0.05). In 2012, respiration rates of fruits were influenced significantly by AVG concentrations (P≤0.05). All the AVG-treated fruits showed the lowest respirations rates in 2011 and 2012. Besides all AVG applications were included in the same group in statistics (Table 5). Similar to our findings, Clayton et al (2000) and Bregoli et al (2002) stated that AVG decreases the amount of ethylene and the respiration rate of 'Bartlett' pear, 'Jersey Mac' apple, 'Red Haven' peach, respectively. They also specified that the application doses showed similar impact.

Table 5- The effect of AVG treatments on ethylene production rate and respiration rate in 'Williams' pear, 2011 and 2012

Çizelge 5- AVG uygulamalarının 'Williams' armudunda etilen üretimi ve solunum hızına etkisi, 2011 ve 2012

Application time[1]	*AVG concentrations (mg L^{-1})*	*Ethylene production (µL kg^{-1} h^{-1})*		*Respiration rate (µL kg^{-1} h^{-1})*	
		2011	*2012*	*2011*	*2012*
30 d	0	3.63 a	4.00 ab	42.99 b	42.02
	100	0.22 b	0.00 c	6.20 c	1.99
	125	0.35 b	0.00 c	4.39 c	1.45
	150	0.29 b	0.00 c	6.81 c	1.76
21 d	0	4.05 a	4.30 a	59.11 ab	51.68
	100	0.27 b	0.00 c	6.89 c	1.72
	125	0.36 b	0.00 c	8.14 c	1.59
	150	0.53 b	0.00 c	4.15 c	1.42
7 d	0	5.46 a	2.70 b	78.88 a	62.10
	100	0.27 b	0.00 c	5.49 c	1.74
	125	0.30 b	0.00 c	6.33 c	1.686
	150	0.31 b	0.00 c	5.20 c	1.51
Time					
30		1.12	1.00	15.10	11.81
21		1.30	1.08	19.57	14.10
7		1.58	0.68	23.97	16.76
	AVG concentrations				
	0	4.38	3.66	60.33	51.93 a
	100	0.25	0.00	6.19	1.82 ab
	125	0.34	0.00	6.28	1.56 b
	150	0.38	0.00	5.39	1.57 b
P values					
Time (T)		0.860	0.840	0.755	0.220
Concentrations (C)		0.000	0.000	0.000	0.017
T × C		0.000	0.000	0.000	0.097

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

3.5. Fruit mineral composition

Effects of AVG applications on 'Williams' pear mineral composition were given in Table 6 and 7 (in 2011 and 2012 means). Interactive effects of AVG concentrations and application times on the calcium were (P≤0.05). Nitrogen and phosphorus were influenced significantly (P≤0.05) by AVG concentrations. The average nitrogen contents were 0.31-0.50% and phosphorus contents were determined between 0.088-0.110%. Potassium and magnesium were not found statistically significant (P≤0.05) (Table 6). AVG treatments showed different effects on calcium contents. 30 DBH-125 mg L^{-1} AVG-treated fruits and 30 DBH-control fruits had the highest calcium (0.083 and 0.085%) contents (Table 6). Effects of AVG concentrations and application times on other mineral contents (iron, copper, manganese, zinc, boron) were not statistically significant (Table 7). Even though not many studies are done regarding the effect of AVG applications on micro and macro elements of fruits, Butar (2013) observed that AVG treatments

Table 6- The effect of AVG treatments on fruit mineral composition (nitrogen, phosphorus, potassium, calcium, magnesium) in 'Williams' pear (2011 and 2012 means)

Çizelge 6- AVG uygulamalarının 'Williams' armudunda meyvenin mineral içeriklerine (azot, fosfor, potasyum, kalsiyum, magnezyum) etkisi (2011 ve 2102 ortalamaları)

Application time[1]	*AVG concentrations (mg L^{-1})*	*Nitrogen*	*Phosphorus*	*Potassium*	*Calcium*	*Magnesium*
				(%)		
30 d	0	0.31	0.091	0.81	0.085 a	0.057
	100	0.41	0.110	0.86	0.064 b	0.049
	125	0.40	0.110	0.84	0.083 a	0.056
	150	0.35	0.100	0.81	0.064 b	0.049
21 d	0	0.34	0.092	0.78	0.061 b	0.052
	100	0.39	0.100	0.78	0.062 b	0.053
	125	0.37	0.100	0.84	0.063 b	0.053
	150	0.32	0.100	0.81	0.068 ab	0.050
7 d	0	0.31	0.088	0.75	0.067 ab	0.052
	100	0.31	0.100	0.78	0.070 ab	0.052
	125	0.50	0.100	0.88	0.059 b	0.056
	150	0.37	0.090	0.75	0.076 ab	0.052
Time						
30		0.36	0.099	0.79	0.074	0.052
21		0.35	0.098	0.82	0.063	0.052
7		0.38	0.095	0.80	0.068	0.053
	AVG concentrations					
	0	0.32b	0.090 b	0.80	0.070	0.054
	100	0.39ab	0.100 a	0.82	0.060	0.051
	125	0.42a	0.100 a	0.83	0.070	0.055
	150	0.35ab	0.096 ab	0.77	0.070	0.050
P values						
Time (T)		0.201	0.555	0.377	0.051	0.862
Concentrations (C)		0.031	0.030	0.198	0.771	0.124
T × C		0.201	0.354	0.485	0.026	0.462

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

affect nitrogen, manganese and iron contents and this effect was noticeably seen in 150 mg L^{-1} AVG treatment of 'Jersey Mac' apple. At the end of 3 days shelf life, and 500 mg L^{-1} and 1000 mg L^{-1} doses of after-harvest AVG-applied 'Fuji' and 'Granny Smith' apples, nitrogen amount was found to reduce in 'Granny Smith' variety, while increase at 500 mg L^{-1} AVG application and decrease at 1000 mg L^{-1} AVG application on 'Fuji' apple. On the other side, it was determined that Ca amount increases with AVG treatments of 'Fuji', Mg amount increases only after 500 mg L^{-1} treatment and both Ca and Mg amounts increase only after 1000 mg L^{-1} AVG application on 'Granny Smith' variety (Fadhil 2007). Karaçalı (2009) stated that pre harvest drop may occur if the phosphorus level decreases and a fruit with high quality can contain phosphorus 11 mg 100 g^{-1}. In our study AVG treatments increased phosphorus levels and fruits contained 10-11 mg 100 g^{-1} phosphorus. It was identified that AVG applications have an effect on the macro elements of fruit. AVG concentrations increased nitrogen contents from 32% to 38% on average and phosphorus contents from 0.090% to 0.099% on average. Referring to the micro elements of fruits, AVG applications were not found to be effective on micro elements.

Table 7- The effect of AVG treatments on fruit mineral composition (Iron, copper, manganese, zinc, boron) in 'Williams' pear (2011 and 2012 means)

Çizelge 7- AVG uygulamalarının 'Williams' armudunda meyvenin mineral içeriklerine (demir, bakır, mangan, çinko, bor) etkisi (2011 ve 2012 ortalamaları)

Application time[1]	*AVG concentrations (mg L^{-1})*	*Iron*	*Copper*	*Manganese*	*Zinc*	*Boron*
				(mg kg^{-1})		
30 d	0	12.74	8.48	3.51	8.56	14.43
	100	12.76	8.75	2.71	8.57	12.36
	125	11.87	8.58	3.00	8.80	13.49
	150	12.13	8.64	2.48	7.86	11.74
21 d	0	11.50	9.28	2.70	8.38	14.54
	100	16.38	8.43	2.89	8.47	14.14
	125	13.53	9.04	2.97	8.69	13.89
	150	12.22	9.62	3.18	9.34	15.15
7 d	0	12.02	8.64	3.08	8.30	13.93
	100	13.31	9.34	3.34	9.64	14.87
	125	11.89	9.91	3.36	9.43	14.11
	150	12.57	9.23	3.07	8.07	14.67
Time						
30		12.06	8.61	2.92	8.45	13.00
21		13.88	9.09	2.94	8.72	14.45
7		12.45	9.28	3.21	9.11	14.35
	AVG concentrations					
	0	12.71	8.80	3.10	8.41	14.30
	100	13.85	8.84	2.98	8.87	13.79
	125	12.52	9.17	3.11	8.97	13.86
	150	12.12	9.16	2.91	8.76	13.85
P values						
Time (T)		0.149	0.147	0.539	0.581	0.083
Concentrations (C)		0.467	0.689	0.923	0.882	0.931
T × C		0.582	0.516	0.900	0.983	0.533

[1], days before harvest (DBH); in each column, values followed by the same letter are not significantly different at P≤0.05 level according to Duncan's multiple range test

4. Conclusions

Considering all results together, in respect to pre-harvest fruit drop and fruit quality, AVG applications were found to be significant for 'Williams' pear and, the most significant application time and doses were considered to be 100 mg L^{-1} treatment 30 and 21 days before the estimated harvest. High AVG treatment concentrations were used in the study. They were effective also for fruit quality but low AVG concentrations can be advised for human health and environmental conditions.

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Seasonal Carbohydrate Changes in the Leaves of Some Satsuma Cultivars on Different Rootstocks

Ercan YILDIZ[a], Mustafa KAPLANKIRAN[b], Turan Hakan DEMİRKESER[b], Celil TOPLU[b]

[a]*Uşak University, Faculty of Agriculture and Natural Sciences, Department of Horticulture, Uşak, TURKEY*

[b]*Mustafa Kemal University, Faculty of Agriculture, Department of Horticulture, Antakya, Hatay, TURKEY*

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Corresponding Author: Ercan YILDIZ, E-mail: ercanyildiz54@gmail.com, Tel: +90 (276) 221 22 00
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ABSTRACT

The seasonal changes of carbohydrate content were monitored in the leaves of 'Okitsu', 'Clausellina', and 'Silverhill' satsuma cultivars budded on the sour orange (*Citrus aurantium* L. var. Yerli), Carrizo and Troyer citranges (*Poncirus trifoliata* Raf. x *Citrus sinensis* Osb. var. Troyer and Carrizo) during the 2010 and 2011 seasons. The seasonal changing trends of leaf soluble sugar contents of 3 satsuma cultivars budded on different rootstocks were similar. The sucrose was the most abundant soluble sugar. Carbohydrate contents had a maximum level at dormant period, and remained at low level during summer. In this period, the sharp decrease in leaf total carbohydrate concentration of 'Okitsu', 'Clausellina' and 'Silverhill' occurred in April with a rate of 27.9%, 22.6% and 21.0%, respectively. Accumulation of carbohydrate in leaves generally started after mid summer and continued until the end of year. The rootstocks were found to be not significant for total soluble sugar, starch and total carbohydrate concentration in most of the months. The cultivars had a significant effect on carbohydrate fractions of leaves compared to rootstocks. The scion-rootstock combination was significant on total carbohydrate concentration of leaves in all months investigated.

Keywords: Satsuma; Cultivar; Rootstock; Non-structural carbohydrates; Leaf tissue

Farklı Anaçlar Üzerine Aşılı Bazı Satsuma Çeşitlerinin Yapraklarında Karbonhidrat Fraksiyonlarının Değişimi

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Ercan YILDIZ, E-posta: ercanyildiz54@gmail.com, Tel: +90 (276) 221 22 00
Geliş Tarihi: 16 Aralık 2014, Düzeltmelerin Gelişi: 19 Şubat 2016, Kabul: 19 Şubat 2016

ÖZET

2010 ve 2011 yıllarında 'Okitsu', 'Clausellina' ve 'Silverhill' satsuma çeşitlerinin yapraklarındaki karbonhidrat içeriklerinin mevsimsel değişimi üzerine Troyer ve Carrizo sitranjları (*Poncirus trifoliata* Raf. x *Citrus sinensis* Osb. var. Troyer ve Carrizo) ile Yerli turunç (*Citrus aurantium* L. var. "common") anacının etkisi ortaya konmuştur. Farklı anaçlar üzerine aşılı 3 satsuma çeşidinin karbonhidrat içeriklerinin mevsimsel değişimi birbirlerine benzer olmuştur.

Sakaroz yapraklarda en baskın indirgen şeker olarak belirlenmiştir. Yaprakların karbonhidrat içerikleri dinlenme döneminde maksimum seviyelerde iken, Yaz periyodunda düşük seviyelerde yer almıştır. 'Okitsu', 'Clausellina' ve 'Silverhill' çeşitlerinde yaprakların toplam karbonhidrat içerikleri nisan ayında çeşitlere göre sırasıyla % 27.9, % 22.6 ve % 21.0 oranlarında keskin bir azalma göstermiştir. Yapraklarda karbonhidrat birikimi genellikle yaz ortasından sonra başlamış ve bu durum yılsonuna kadar devam etmiştir. Anaçlar arasında toplam şeker, nişasta ve toplam karbonhidrat içeriğindeki farklılıklar çoğu aylarda istatistiksel olarak önemsiz bulunmuştur. Yapraklardaki karbonhidrat fraksiyonları üzerine çeşitlerin etkisi anaçlardan daha önemli olmuştur. Örnekleme yapılan tüm aylarda yapraklardaki toplam karbonhidrat içeriği üzerine anaç-kalem kombinasyonunun etkisi önemli bulunmuştur.

Anahtar Kelimeler: Satsuma; Çeşit; Anaç; Karbonhidratlar; Yaprak dokusu

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1. Introduction

Rootstocks have had a substantial role in the development of the citrus industry in the world. Rootstock utilization is necessary for solving both limiting and restricting factors of citrus production (soil, climate, disease, and pests, etc.) and meeting producers and consumers demands such as productivity, earliness, shorter juvenility, fruit quality (Davies & Albrigo 1998). The researchers have demonstrated that citrus rootstocks have differently influenced the growth and development, including yield, fruit quality, and tolerance to stress caused by biotic and abiotic factors of budded cultivars in relation to ecological conditions (Stenzel et al 2003; Filho et al 2007).

In deciduous trees, the root system is the major storage organ for carbohydrates. In evergreen citrus, the root system may be the major storage organ for carbohydrates, but high concentrations of carbohydrates can also be found in the leaves (Goldschmidt 1999). The crop load inversely effects the accumulation of reserves and under heavy crop load causing depletion of it may cause to tree collapse and the triggering of an alternate bearing habit (Monerri et al 2011). There are correlations between accumulation of carbohydrates and flower formation in some experiments, but carbohydrate levels are not the sole factor regulating citrus flowering (Garcia-Luis & Guardiola 2000). Although the evidence is still mostly indirect, it may be concluded that the level of carbohydrates is often a major factor limiting fruit set (Monerri et al 2011). The decrease in carbohydrate levels during the flowering and fruit set period, which is accelerated by heavy flowering, shows that reserve carbohydrates are indeed utilized to sustain the early stages of reproductive development. The energy demand during the flowering and fruit set period may be more than the supply of carbohydrates from current photosynthesis and tree reserves. This occurs especially in abundant flowering and heavy initial fruit set. The costs of reproduction require the use of stored reserves in addition to current photosynthate (Goldschmidt 1999).

High levels of starch stored during the fall and carbohydrate status of trees are indicative of their vitality and photosynthetic capacity. It was reported that changes in such patterns could reflect variations in physiological performance and could be useful in understanding the physiology of trees affected by environmental stress (Wong et al 2003). It is important to know carbohydrate reserve status for experiments involving manipulation of the carbon balance of fruit trees (McQueen et al 2004). Annual patterns of carbohydrate storage and mobilization vary among species and genotypes based on growing conditions, growth characteristics, crop load and other factor (Spann et al 2008).

Sour orange (*Citrus aurantium* L. var. Yerli) has been widely used for citrus production in Turkey. On the other hand, Carrizo and Troyer citranges [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.] are currently the most important citrus rootstocks all over the world, mainly due to their tolerance to tristeza virus (Forner-Giner et al 2003). The effect of these three rootstocks on seasonal carbohydrate

variability in citrus species is not yet completely clarified. This study was conducted to determine the role of cultivar, rootstock and cultivar-rootstock interaction on seasonal carbohydrate changes in leaf tissues in Eastern Mediterranean Region of Turkey.

2. Material and Methods

The experiment was conducted at the experimental farm of Mustafa Kemal University in Dörtyol, Hatay, Turkey (36º 09′ E, 36º 51′ N; 9 m above the sea level) in the 2010 and 2011 growing seasons. 'Okitsu', 'Clausellina', and 'Silverhill' satsuma cultivars were budded on the sour orange (So), Carrizo (Cc) and Troyer (Tc) citranges. The experimental orchard was established with one year old budded young trees in five replicates with 7x7 m plots in November 1998 and February 1999.

On a monthly basis leaf samples were collected from the fruitless shoots of each mandarin cultivar trees on each rootstock during the entire year. Leaves were sampled from the summer flush of the previous year, which were about 5-6 months old at January (form January to June), and from the spring flush of the current season, which were about 3-4 months old at July (from July to December). Sampled leaves were decontaminated by washing with a detergent solution, tap water and rinsed with distilled water. Then, samples were dried to a constant mass at 65-70 ºC and homogenized by particle size reduction to <0.5 mm, then stored at 4 °C until extraction.

The soluble carbohydrates (fructose, glucose, and sucrose) were analyzed by high-performance liquid chromatography (HPLC) similar to the procedures of Kafkas et al (2007). The sugars were detected using a refractive index detector and quantified by the external standard method. Total sugar and starch contents were determined using the anthrone method with spectrophotometric assay, according to the procedure described by Kaplankiran (1984). Concentrations of total sugar and starch were summed to give an estimate of total non-structural carbohydrate. All carbohydrate results were expressed as glucose equivalents according to dry mass basis (%).

The carbohydrate data collected in 2010 and 2011 from the leaves of three mandarin cultivars budded on different rootstocks and were subjected to the analysis of variance using GLM procedure of SAS software (SAS Institute Inc., North Carolina, USA). Mean separations were carried out by a Tukey test and assessed at the 5% significance level.

3. Results and Discussion

The results showed that the seasonal changing trends of leaf soluble sugar contents of 3 satsuma cultivars budded on different rootstocks were similar (Figure 1, 2, 3). The sucrose was the predominant soluble sugar in different satsuma cultivars. The sucrose concentrations decreased steadily from maximum concentrations (January) until June for 'Clausellina', and until July for 'Okitsu' and 'Silverhill'. In this period, the sharp decrease in leaf sucrose concentrations of 'Okitsu', 'Clausellina' and 'Silverhill' happened after flowering in April (39.6%, 39.8% and 43.1%, respectively). Accumulation of sucrose in leaves generally started after mid summer and continued until the end of year. During the whole year, the mean leaf sucrose concentrations changed in 'Okitsu' between 1.74% (Cc) and 1.85% (Tc), in 'Clausellina' between 1.78% (Tc) and 2.00% (So), and in 'Silverhill' between 1.94% (So) and 2.13% (Cc). Seasonal pattern of fructose and glucose concentrations were almost similar for all mandarin cultivars. Considering all rootstocks, in dormant period maximum fructose and glucose levels approximated 1.49% and 1.69% in 'Okitsu', 1.49% and 1.70% in 'Clausellina', and 1.98% and 1.97% in 'Silverhill', respectively. Also, the minimum concentrations were 0.23% for fructose and 0.09% for glucose in 'Okitsu', and were similar with 0.31% for both fructose and glucose in 'Clausellina' and 'Silverhill', during July and August. Throughout the entire season, the mean contents of fructose and glucose in leaves were the highest level with 0.81% (Cc) and 0.69% (Cc and So) in 'Okitsu', 0.86% and 0.80% (So) in 'Clausellina' and 0.86% (Tc) and 0.88% (Tc and So) in 'Silverhill'.

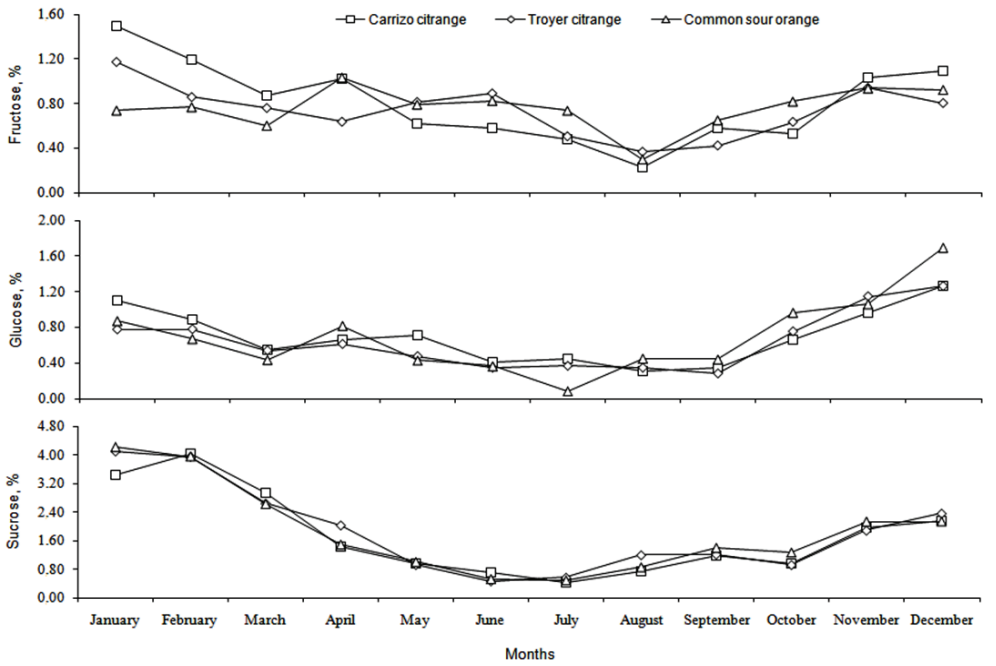

Figure 1- Seasonal variation in soluble sugar content in leaves of 'Okitsu' cultivar budded on different rootstocks

Şekil 1- Farklı anaçlar üzerine aşılı 'Okitsu' çeşidinin yapraklarındaki çözünebilir şeker içeriklerinin aylık değişimi

In this study, the level of sucrose in the leaf tissues of all satsuma cultivars budded on different rootstocks was higher than those of fructose and glucose throughout the entire year. It is well known that sucrose is the major translocated sugar in the most of plants. During the active growing period (from June to August), the photosynthate produced by leaves is not stored but is mobilized and transported as sucrose to various sinks for growth and metabolism (Quick & Neuhaus 1997).

The total soluble sugar content was high level at dormant period, and remained low level during summer. The sharp decrease in total soluble sugar concentration of leaves occurred in April and May. The cultivars had a significant effect on total soluble sugar concentration of leaves compared to rootstocks. The rootstocks were found to be not significant for total soluble sugar concentration in most of the months. The cultivar x rootstock interactions was significant on leaf total soluble sugar content within year, but August (Table 1).

In general, the starch level was lower than total soluble sugar level in leaves. The highest leaf starch contents were observed in winter (5.51%) with the lowest values obtained in late summer (2.00%) and early autumn (1.98%). The effect of cultivars on leaf starch content was higher than those of both rootstocks and scion-rootstock relation. There was no consistent significant difference in starch content of leaves among rootstocks, except for November (Table 2).

Total carbohydrate concentration of leaves showed a decrease from dormant period to mid or late summer, and then accumulation started until the end of year. In fruit development, a sharp fall in total carbohydrate concentration occurred in April

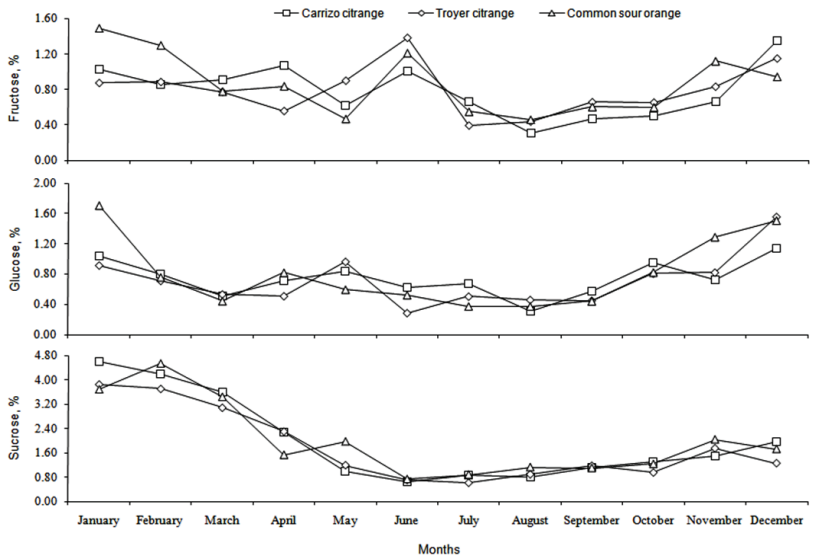

Figure 2- Seasonal variation in soluble sugar content in leaves of 'Clausellina' cultivar budded on different rootstocks

Şekil 2- Farklı anaçlar üzerine aşılı 'Clausellina' çeşidinin yapraklarındaki çözünebilir şeker içeriklerinin aylık değişimi

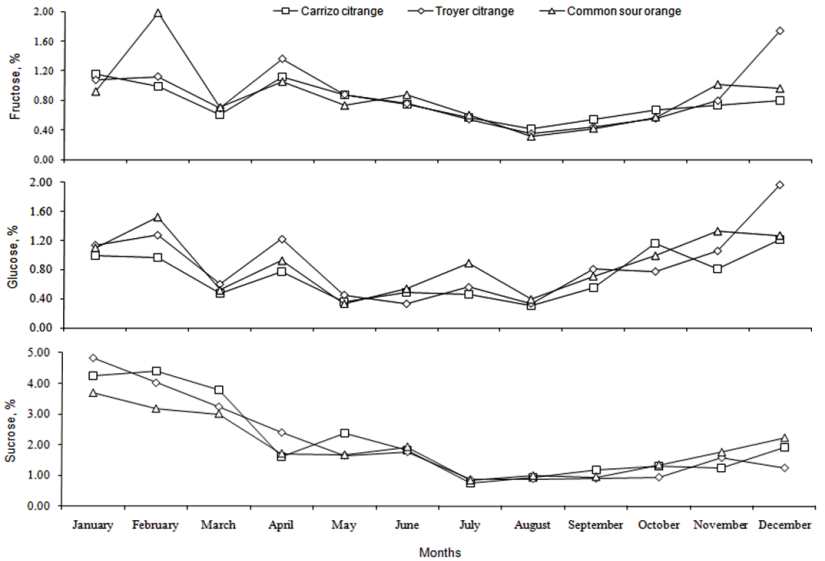

Figure 3- Seasonal variation in soluble sugar content in leaves of 'Silverhill' cultivar budded on different rootstocks

Şekil 3- Farklı anaçlar üzerine aşılı 'Silverhill' çeşidinin yapraklarındaki çözünebilir şeker içeriklerinin aylık değişimi

Table 1- The effect of cultivar, rootstock and scion-rootstock combination on total soluble sugar content of leaves in different cultivars (%)

Çizelge 1- Farklı çeşitlerin yapraklarındaki toplam şeker içeriği üzerine çeşit, anaç ve çeşit-anaç kombinasyonunun etkisi (%)

Source	*Months*												*Mean*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	
Cultivars													
Okitsu	8.10	7.24	6.03	4.81	3.10	2.76	2.24	2.82	3.76	4.38	6.95	7.77	5.00
Clausellina	8.60	7.77	6.84	5.74	4.55	3.72	3.07	2.88	4.00	4.22	6.19	7.63	5.43
Silverhill	8.48	8.10	7.34	6.21	5.41	4.25	3.20	2.79	3.68	4.47	5.90	7.85	5.64
HSD (5%)	ns	0.52	0.89	0.55	0.41	0.36	0.53	ns	ns	ns	0.65	ns	-
Rootstocks													
Carrizo citr.	8.86	7.83	7.10	5.47	4.23	3.57	3.06	2.51	3.91	4.73	6.21	7.89	5.45
Troyer citr.	8.02	7.45	7.01	5.90	4.57	3.47	2.59	3.11	3.82	3.80	6.17	7.44	5.28
Sour orange	8.31	7.83	6.10	5.39	4.25	3.69	2.87	2.87	3.71	4.55	6.65	7.91	5.34
HSD (5%)	0.67	ns	0.87	ns	ns	ns	ns	0.43	ns	0.77	ns	ns	-
Scion-rootstock combination													
Okitsu													
Carrizo cit.	8.68	7.51	5.95	4.36	3.06	2.86	2.41	2.33	3.62	3.75	6.92	7.52	4.91
Troyer citr.	8.16	7.10	6.82	5.07	3.11	2.63	2.16	3.35	3.30	4.13	6.86	7.60	5.02
Sour orang.	7.47	7.13	5.31	5.00	3.12	2.78	2.17	2.78	4.37	5.26	7.06	8.18	5.05
Clausellina													
Carrizo cit.	9.26	7.85	7.06	5.97	4.17	3.72	3.77	2.52	3.96	4.98	6.59	8.58	5.70
Troyer citr.	7.68	7.14	6.76	5.97	4.98	3.59	2.61	3.13	4.36	3.56	5.75	6.35	5.16
Sour orang.	8.87	8.33	6.71	5.28	4.50	3.84	2.84	2.98	3.69	4.11	6.24	7.96	5.44
Silverhill													
Carrizo cit.	8.64	8.13	8.30	6.09	5.46	4.11	2.99	2.68	4.15	5.45	5.12	7.56	5.72
Troyer citr.	8.21	8.12	7.45	6.67	5.63	4.18	3.00	2.85	3.82	3.70	5.92	8.39	5.66
Sour orang.	8.60	8.05	6.27	5.89	5.13	4.46	3.60	2.84	3.06	4.27	6.66	7.59	5.53
HSD (5%)	1.23	1.01	1.34	1.04	0.83	0.91	0.91	ns	0.82	1.12	1.09	0.84	-

ns, non-significant

Table 2- The effect of cultivar, rootstock and scion-rootstock combination on starch content of leaves in different cultivars (%)

Çizelge 2- Farklı çeşitlerin yapraklarındaki nişasta içeriği üzerine çeşit, anaç ve çeşit-anaç kombinasyonunun etkisi (%)

Source	*Months*												*Mean*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	
Cultivars													
Okitsu	4.46	5.13	5.02	3.15	2.18	2.13	2.06	1.76	1.91	2.47	3.07	4.60	3.16
Clausellina	4.55	5.42	5.80	4.04	2.88	2.32	2.41	2.01	1.90	2.54	3.82	5.02	3.56
Silverhill	4.73	5.39	5.71	4.10	3.29	2.91	2.62	2.24	2.14	2.67	3.72	5.00	3.71
HSD (5%)	ns	ns	0.53	0.50	0.47	0.63	0.40	0.42	ns	ns	0.46	ns	-
Rootstocks													
Carrizo citr.	4.76	5.45	5.32	3.80	2.65	2.46	2.28	1.99	1.91	2.54	3.84	5.03	3.50
Troyer citr.	4.42	5.07	5.61	3.69	2.86	2.50	2.36	1.92	2.02	2.50	3.27	4.67	3.41
Sour orange	4.57	5.42	5.60	3.80	2.84	2.39	2.45	2.09	2.00	2.63	3.49	4.93	3.52
HSD (5%)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.54	ns	-
Scion-rootstock combination													
Okitsu													
Carrizo cit.	4.61	5.19	4.72	3.12	2.02	2.03	1.78	1.75	1.68	2.32	3.28	4.80	3.11
Troyer citr.	4.46	4.78	5.28	2.96	1.96	2.40	2.12	1.56	1.95	2.52	3.00	4.22	3.10
Sour orang.	4.31	5.41	5.05	3.35	2.54	1.95	2.29	1.97	2.09	2.56	2.95	4.79	3.27
Clausellina													
Carrizo cit.	4.88	5.40	5.52	3.77	2.84	2.56	2.50	1.87	2.08	2.64	4.08	5.12	3.60
Troyer citr.	4.17	5.28	5.58	3.95	3.17	2.16	2.15	2.11	2.04	2.43	3.36	4.81	3.43
Sour orang.	4.62	5.59	6.30	4.40	2.64	2.25	2.60	2.05	1.57	2.54	4.02	5.12	3.64
Silverhill													
Carrizo cit.	4.80	5.75	5.71	4.50	3.09	2.81	2.56	2.36	1.98	2.65	4.18	5.15	3.80
Troyer citr.	4.62	5.14	5.98	4.15	3.44	2.94	2.81	2.10	2.08	2.56	3.46	4.98	3.69
Sour orang.	4.77	5.28	5.44	3.64	3.34	2.97	2.47	2.25	2.34	2.80	3.52	4.86	3.64
HSD (5%)	ns	ns	1.14	1.02	1.09	ns	0.92	ns	ns	ns	0.83	ns	-

ns, non-significant

and May with 27.9-33.8% for 'Okitsu', 22.6-24.0% for 'Clausellina' and, 21.0-15.6% for 'Silverhill'. The amounts of total carbohydrate reduced in 25.4-25.8%, 24.1-22.5% and 21.5-22.9% rates for Cc, Tc and So, respectively, in April and May as compared to the previous month. The effect of cultivars on total carbohydrate concentration in leaves was almost similar with rootstocks. Rootstocks had no significant effect on leaf total carbohydrate content, but January, August, October and November. The scion-rootstock combination was significant in total carbohydrate concentration of leaves in investigated all months (Table 3).

The reported seasonal patterns of carbohydrate in citrus trees (Goldschmidt 1999; Monerri et al 2011) were similar to those seen in satsuma trees grown in Eastern Mediterranean conditions. In this study, the carbohydrate content of the leaves in investigated all satsuma cultivars budded on different rootstocks continuously decreased from January to mid or late-summer, then gradually began to rise during autumn and winter. The carbohydrate concentration of leaves returned to similar levels over winter. The concentration of carbohydrate in leaves declined sharply in April and May. This may suggest that these

Table 3- The effect of cultivar, rootstock and scion-rootstock combination on total carbohydrate content of leaves in different cultivars (%)

Çizelge 3- Farklı çeşitlerin yapraklarındaki toplam karbonhidrat içeriği üzerine çeşit, anaç ve çeşit-anaç kombinasyonunun etkisi (%)

Source	*Months*												*Mean*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	
Cultivars													
Okitsu	12.57	12.37	11.04	7.96	5.27	4.88	4.31	4.58	5.67	6.85	10.02	12.37	8.16
Clausellina	13.16	13.20	12.64	9.78	7.43	6.04	5.49	4.88	5.90	6.75	10.01	12.65	8.99
Silverhill	13.22	13.49	13.05	10.31	8.70	7.16	5.81	5.03	5.81	7.14	9.62	12.84	9.35
HSD (5%)	ns	0.67	1.07	0.69	0.62	0.57	0.57	ns	ns	ns	ns	ns	-
Rootstocks													
Carrizo citr.	13.62	13.28	12.42	9.27	6.88	6.03	5.34	4.50	5.82	7.26	10.05	12.91	8.95
Troyer citr.	12.44	12.52	12.63	9.59	7.43	5.97	4.95	5.03	5.85	6.30	9.45	12.11	8.69
Sour orange	12.88	13.26	11.70	9.19	7.09	6.08	5.32	4.96	5.71	7.18	10.14	12.84	8.86
HSD (5%)	0.80	ns	ns	ns	ns	ns	ns	0.44	ns	0.84	0.58	ns	-
Scion-rootstock combination													
Okitsu													
Carrizo cit.	13.29	12.70	10.66	7.48	5.08	4.89	4.19	4.08	5.29	6.08	10.19	12.32	8.02
Troyer citr.	12.62	11.88	12.10	8.04	5.08	5.03	4.28	4.91	5.25	6.65	9.86	11.81	8.13
Sour orang.	11.78	12.53	10.36	8.35	5.66	4.73	4.46	4.75	6.46	7.81	10.01	12.98	8.32
Clausellina													
Carrizo cit.	14.13	13.26	12.57	9.74	7.01	6.28	6.27	4.39	6.04	7.62	10.66	13.71	9.31
Troyer citr.	11.85	12.42	12.34	9.92	8.15	5.75	4.76	5.23	6.40	5.99	9.10	11.16	8.59
Sour orang.	13.49	13.91	13.01	9.68	7.14	6.09	5.44	5.03	5.27	6.65	10.25	13.08	9.09
Silverhill													
Carrizo cit.	13.44	13.88	14.01	10.59	8.55	6.92	5.55	5.04	6.14	8.10	9.30	12.71	9.52
Troyer citr.	12.84	13.27	13.43	10.82	9.07	7.12	5.81	4.95	5.89	6.26	9.38	13.36	9.35
Sour orang.	13.37	13.32	11.72	9.53	8.47	7.43	6.07	5.09	5.40	7.07	10.17	12.45	9.18
HSD (5%)	1.11	1.08	1.57	1.37	1.17	1.46	0.86	0.81	1.16	1.12	0.93	1.05	-

ns, non-significant

carbohydrates were transported from the leaves to support active growth such as bud break, primary root growth, shoot expansion, leaf emergence and enlargement, flowering, and fruit and seed set (Goodman et al 1990). Carbohydrates mobilized during the spring flush of growth. The seasonal carbohydrate profile of the leaves of satsuma cultivars showed seasonal patterns that closely relate to seasonal changes in phenological and physiological activities.

Under Eastern Mediterranean conditions, in citrus bud break occurred at early spring as from the second half of March and then vegetative development such as shoot expansion, young leaf and root growth began. Citrus flowering happened primarily during the spring following the inductive winter season. In citrus, anthesis occurred as from mid April after the flower bud induction and differentiation of floral organs processes, which begins at the first stages of bud swelling and sprouting. Thus, carbohydrate reserves are used primarily for vegetative growth. Spann et al (2008) reported that the extent to which reserves are used to support vegetative versus reproductive growth early in the season depends on their temporal relationship with growth. Nzima et al (1997) showed that developing fruits serve as competitive sinks for available metabolites. During the period of fruit abscission (May and June), in which competition for carbohydrates is considered to be a limiting factor for fruit retention, fruit nutrition is supported by current photosynthesis and stored reserves (Goldschmidt 1999).

In other reports it has been noticed that different rootstocks affect citrus tree physiology especially net photosynthetic rates (Gonzalez-Mas et al 2009; Sheng et al 2009). However, there is not sufficient study about the effect of rootstocks on accumulation of carbohydrate changes in citrus plant tissues. In this study, there was no consistent significant difference in starch content of leaves among rootstocks, except for November, and the rootstocks were found to be not significant for total soluble sugar and carbohydrate concentration in most of the months. It has been reported that the soluble sugar, starch and total carbohydrate content of 'Washington Navel' leaves (Yildirim 2003) and 'Navelina' roots (Lliso et al 2004) was affected by the rootstocks, but that the effect of rootstocks on soluble sugar and starch content of 'Marsh Seedless' leaves (Acikalin et al 2009) was not found in most of the samples time. The scion-rootstock combination had a higher effect on carbohydrate content of leaves in investigated all months, except for starch, than those of both cultivar and rootstock. This finding is supported that rootstock and scion have affected each other in terms of activities for physiological events. Likewise, the effect of rootstocks on tree canopy volume changed according to cultivars in this study (not show data). For example, So rootstock in 'Okitsu', Tc rootstock in 'Clausellina', and both So and Tc rootstocks in 'Silverhill' obtained lower canopy volume than those of used in study other rootstocks. However, the mean carbohydrate concentration of leaves in 'Okitsu' budded on So rootstock, which is low yield and short shoot, was higher than those of Cc and Tc rootstocks. Also, in June and July carbohydrate loss of leaves in 'Clausellina' budded on Tc rootstock, which is high fruit set after June drop, was higher than those on Cc and So rootstocks as compared to the previous month. But, the differences in carbohydrate content of leaves in 'Silverhill' among rootstocks were not related to crop load.

4. Conclusions

This investigation indicated that there was carbohydrate loss largely in the vegetative and generative development phases in satsuma cultivars budded on different rootstocks. The carbohydrate production and accumulation in satsuma trees should be increased at the previous year for using next spring. The rootstock used should be considered at fertilization program because of the citrus rootstocks have different abilities to utilize plant nutrient elements. In addition, satsuma trees should not have problems of nutrients especially in the first months of the growth.

Acknowledgements

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Selection of Suitable Sites for Small Ruminant Production Using Remote Sensing and the Geographic Information System

Esin DERİ[a], Halil Baki ÜNAL[a]

[a]*Ege University, Faculty of Agriculture, Department of Farm Structures and Irrigation, İzmir, TURKEY*

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Corresponding Author: Esin DERİ, E-mail: esinderi@hotmail.com, Tel: +90 (535) 109 04 08
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ABSTRACT

The aim of this study was to determine the most suitable areas for small ruminant production in the Karaburun area in Izmir province, Turkey. To this purpose, an inquiry model was first developed using remote sensing and a geographic information system. In developing the model, legal and technical factors were taken into consideration, and eight evaluation criteria (distance from settled areas, distance from lakes or similar water sources, distance from protected water catchment basins, distance from wind energy generators, distance from irrigation and drainage canals, slope, aspect-direction of slope-and land use class) and three evaluation classes in relation to these criteria (suitable, conditionally suitable and unsuitable) were planned. Later, the model was used to test the suitability of the study area in general and five sample farms in that area for suitability. According to all of the criteria of evaluation, 3.54% of the 42,707.15 ha study area was found to be suitable for small ruminant production, 2.78% was conditionally suitable, and 93.60% was unsuitable. As for the five sample farms in the study area, none of them was found to be suitable according to all of the evaluation criteria. In addition, suggestions were made for the functionality and effectiveness in use of the geography information inquiry models used in the choice of places for small ruminant production.

Keywords: Remote sensing; Geographic information system; Small ruminant production; Farm location; Karaburun

Uzaktan Algılama ve Coğrafi Bilgi Sistemi Kullanılarak Küçükbaş Hayvancılık İşletmeleri İçin Uygun Yerlerin Seçimi

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Esin DERİ, E-posta: esinderi@hotmail.com, Tel: +90 (535) 109 04 08
Geliş Tarihi: 04 Ocak 2016, Düzeltmelerin Gelişi: 19 Şubat 2016, Kabul: 20 Şubat 2016

ÖZET

Bu araştırmada, İzmir ili Karaburun yöresinde küçükbaş hayvancılık işletmeleri için en uygun alanların belirlenmesi amaçlanmıştır. Bu amaçla, ilk olarak uzaktan algılama ve coğrafi bilgi sistemi kullanılarak bir sorgu modeli geliştirilmiştir. Modelin geliştirilmesinde, küçükbaş hayvancılık işletmeleri için uygun yer seçimine ilişkin yasal ve teknik esaslar dikkate alınarak, sekiz değerlendirme ölçütü (yerleşim yerlerine uzaklık, göl ve benzeri su kaynaklarına

uzaklık, su havzaları koruma alanlarına uzaklık, rüzgar enerji santrallerine uzaklık, sulama ve drenaj kanallarına uzaklık, eğim, bakı ve arazi kullanım sınıfı) ve bu ölçütlere ilişkin üç değerlendirme sınıfı (uygun, koşullu uygun ve uygun değil) öngörülmüştür. Sonra, geliştirilen sorgu modeli ile araştırma alanı genelinin ve bu alan içerisindeki mevcut beş örnek işletmenin uygunluğu sorgulanmıştır. Tüm değerlendirme ölçütlerine göre, 42,707.15 ha'lık araştırma alanının % 3.54'ünün küçükbaş hayvancılığın yapılmasına "uygun", % 2.78'inin "koşullu uygun" ve % 93.60'ının ise "uygun olmayan" alanlar olduğu belirlenmiştir. Araştırma alanındaki mevcut beş örnek işletmenin yerlerinin ise tüm değerlendirme ölçütlerine göre hiçbirinin uygun olmadığı belirlenmiştir. Ayrıca araştırmada, hayvancılık işletmesi yerlerinin seçiminde kullanılacak coğrafi bilgi sistemi sorgu modellerinin işlevselliğinin ve kullanım etkinliğinin arttırılmasına yönelik öneriler sunulmuştur.

Anahtar Kelimeler: Uzaktan algılama; Coğrafi bilgi sistemi; Küçükbaş hayvancılık; İşletme yeri; Karaburun

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1. Introduction

As the world's population increases rapidly and industrialisation causes a decrease in the quality of water, air and soil, it becomes increasingly difficult to meet the needs of large societies for food. Thus, in order to provide this increasing population with sufficient and balanced nutrition, developing the animal husbandry sector has become of strategic importance for all countries of the world (Ünal et al 2013). In the rapidly developing animal husbandry sector, there has been an increase in the number of animals on farms and a corresponding increase in waste from those farms, creating large problems for the environment. If necessary measures are not taken, it is unavoidable that the waste originating from animal production activities will pollute the environment, the groundwater, and surface water (Ongley 1996; Mutlu 1999; Karaman 2006; Çayır et al 2012).

Although Turkey has more small ruminants than most countries in the world, the amount of yield is low compared with more developed countries. One of the main reasons for this is that the choice of location and the design of shelters on livestock farms are not appropriate. Thus recent scientific studies of livestock farming enterprises have pointed to mistaken practices with regard to the location of animal shelters and shelter construction (Kaymakçı et al 2005; Alkan et al 2013). Also, there is no accepted decision mechanism in Turkey for the choice of location of livestock farming enterprises, and therefore this choice is left to the farmers' own knowledge and physical resources. In animal production, the choice of location for production with optimum profit and minimum environmental damage is of the utmost importance (Karaman 2006; Boyacı et al 2011). However, scientific studies in this country of choice of location for animal production activities are extremely limited (Çiçek & Şenkul 2006).

Many studies have been conducted on the analysis by the Geography Information System (GIS) of spatial data such as crop cover, slope and aspect obtained by the remote sensing (RS) technique (Aranoff 1989; Yomralıoğlu 2000; Kurucu et al 2004; Alsancak 2005; Daşdemir 2006; Demirkesen 2007; Susam & Karaman 2007; Töreyen et al 2011; Cengiz et al 2013). At the same time, inquiry models to determine suitable locations for animal production have been developed, and are starting to be used along with RS and GIS techniques (Zeng & Hong 2008; Beyazıt et al 2011; Terfa & Suryabhagavan 2015).

The objective of this study was to determine the most suitable locations in the Karaburun, Izmir area for small ruminant production from a legal and technical standpoint with the help of RS and GIS techniques.

2. Material and Methods

2.1. Determination of the research area

Choice of location in small ruminant production is of great importance according to the type of animal being kept, especially for hair goats. In selecting the study area, account was taken of the numbers

of different goat breeds being kept in the various districts of Izmir province, in the Aegean Region of Turkey. According to statistics for the year 2014, the number of hair goats, 35,600, constituted 15.1% of the total number of goats (235,834 hair and angora goats), giving it greater potential than other districts in the province (TÜİK 2014). In addition, a variety of spatial factors affect animal production in this area. For this reason, Karaburun district in the province of Izmir was seen to be suitable for this research. The location of the research area is shown in Figure 1.

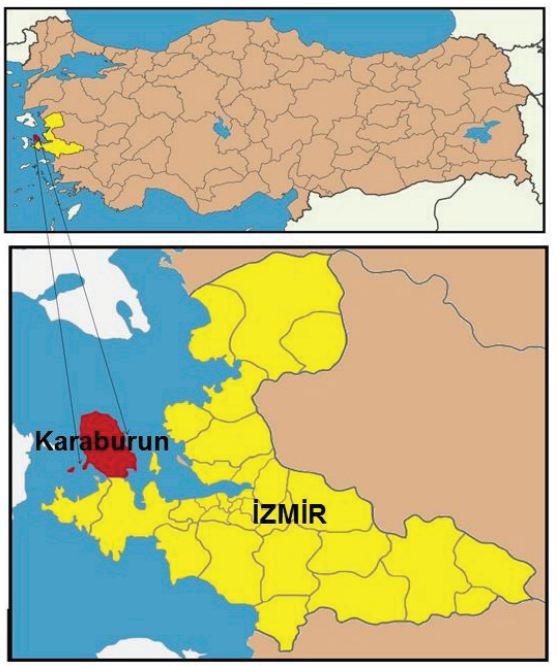

Figure 1- Location of the study area

Şekil 1- Araştırma alanının konumu

Subsequently, five farms, which were the subject of a study by Ünal et al (2015) in the Karaburun area, were considered for analysis of the suitability of location of current small ruminant production using the GIS inquiry model which was developed. These farms were registered with the Izmir Sheep and Goat Breeders' Association, and had 100 or more animals. The coordinates of these sample farms are given in Table 1.

Table 1- Coordinates of the locations of sample farms in the study area (Ünal et al 2015)

Çizelge 1- Araştırma alanındaki örnek işletmelerin konumlarına ilişkin koordinat değerleri (Ünal et al 2015)

Sample farm no	*Longitude*	*Latitude*
1	26° 22' 09.04" E	38° 39' 18.12" N
2	26° 21' 38.98" E	38° 38' 31.55" N
3	26° 23' 30.26" E	38° 33' 29.15" N
4	26° 23' 33.65" E	38° 31' 31.13" N
5	26° 26' 39.61" E	38° 28' 40.89" N

Karaburun district, which formed the study area, is located in the northern part of the Urla peninsula, which extends into the Aegean Sea. It is surrounded on the west, north and east by the sea, with the district of Urla to the south (Karaburun Kaymakamlığı 2015). Karaburun district area covers an area of 42,707.15 ha (İzmir İl Özel İdaresi 2011).

Table 2 shows the map data used in the development of the model, which consisted of the type and format of data, the coordinate system and the source of the data. Also, safety strips were created for 14 wind turbine generators planned in the study area, and the coordinates of these generators were used as material (ARİ-ES 2015).

Table 2- Map data used in the study

Çizelge 2- Araştırmada kullanılan harita verilerinin tanımlanması

Data	*Data source*	*Data type and format*	*Coordinate system*
Slope map Land use map Map of land classification according to law No. 5403 on soil protection and land use	İzmir İl Özel İdaresi (2011)	Numerical/Shape file	UTM, ED50, 6 degrees
DEM map, (ASTER GDM Version 1, 30 metre resolution)	Japan Space System (2015)	Raster/GeoTIFF	WGS84

2.2. Numerical data for the research area

Numerical data for the research area were taken as ED 1950 UTM 35 N conversions for the map projection system, and therefore there was no need for a separate correction of coordinates. In order to obtain data on the aspect of land in the study area, raster data of ASTER GDEM Version 1, was used (Japan Space System 2015). This raster data is provided in Geo TIFF format and with WGS84 projection, and so the coordinate system was converted to ED 1950 UTM 35 N and cell size was corrected to 30x30. After that, aspect data were obtained using the DEM map on the program ArcGIS10.2.2 created according to these data and taking the borders of Karaburun district as a base. Slope data were obtained from a 1/100,000 scale shape file map previously created for the study area (İzmir İl Özel İdaresi 2011).

2.3. Predicted evaluation criteria in the inquiry into suitable choice of location

In this study, eight different evaluation criteria and three different evaluation classes were planned, taking account of legislation on the choice of suitable locations for small ruminant production and information in the literature. These are defined in Table 3.

Table 3- Evaluation criteria and categories planned in the inquiry for choice of suitable location for small Ruminant farms

Çizelge 3- Küçükbaş hayvancılık işletmeleri için uygun yer seçimi sorgulamasında öngörülen değerlendirme ölçütleri ve sınıfları

Evaluation criteria	*Values for criteria*	*Evaluation classes*			*References*
		Unsuitable	*Conditionally suitable**	*Suitable*	
1) Distance from inhabited areas	>500 m	<500 m	500-1000 m	>1000 m	SB (2000); Çevre Bakanlığı (1986); Tarım ve Köyişleri Bakanlığı (2006)
2) Distance from water sources	>300 m	<300 m	300-600 m	>600 m	Olgun (2011)
3) Distance from irrigation and drainage canals	>100 m	<100 m	-	≥100 m	Olgun (2011)
4) Distance from wind turbine safety strips	Distance of specified safety strip	<300 m	-	≥300 m	ETKB (2015)
5) Distance from water catchment basin protected areas	Specified distances of defined protection areas	Inside definite, short-distance or medium-distance protected areas	Inside long-distance protected areas	Outside long-distance protected areas	İZSU (2002)
6) Slope	2-6%	>60%	30-60%	<30%	MWPS (1982); Olgun (2011)
7) Aspect	South or southeast	North, ortheast, east, west, orthwest	-	South, southeast, southwest	Olgun (2011)
8) Land use class	Land not suitable for agriculture	Land suitable for agriculture	-	Marginal agricultural land	Şengonca et al (2009); İzmir İl Özel İdaresi (2011)

***,** on condition of extra measures being taken

2.4. Development of the inquiry model

An inquiry model was developed using GIS on data derived from images provided by RS with the aim of determining suitable locations where small ruminant rearing could be practiced in the study area. The program ArcGIS10.2.2 was used for all operations at this stage. In the inquiry according to the first five planned evaluation criteria (distance from inhabited areas, distance from lakes or similar water sources, distance from protected water catchment basins, distance from wind energy generators and distance from irrigation and drainage canals), a buffer zone analysis was made according to the evaluation classes of these criteria. The inquiry according to the other three evaluation criteria (slope, aspect and land use class) was made according to the evaluation classes in the layers with the help of the "Select" tool. In this way the eight new data layers obtained were joined and converted to a single layer. Later, an inquiry of the farm location was made according to the evaluation classes using "Query builder" according to single layer analysis logic, and the results were interpreted by mapping (Töreyen et al 2011).

3. Results and Discussion

3.1. The inquiry model

Figure 2 shows layer and attribute information of the inquiry model which was developed concerning the eight evaluation criteria (model layers) and the three evaluation classes relating to these criteria (attributes of the model layers) taking account of the legislation and technical basis for the choice of a suitable location for small ruminant rearing in the study area. In this model, layers were created according to environmental factors. However, it is possible to carry out this enquiry according to more layers including socio-economic factors (Terfa & Suryabhagavan 2015).

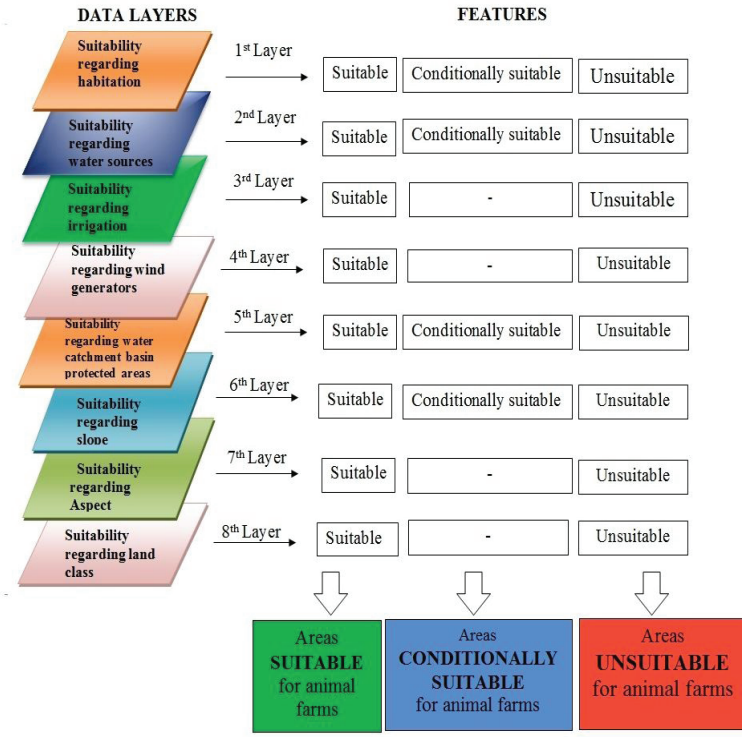

Figure 2- The inquiry model

Şekil 2- Geliştirilen sorgu modeli

3.2. Suitability according to evaluation criteria in the research area

Table 4 gives the spatial and proportional distribution of the suitability of each evaluation criterion according to the suitability maps produced. It was seen that according to the land use class criterion 78.4% of the study area was unsuitable for small ruminant rearing, and 65% was unsuitable because of the criterion of aspect. Also, according to the criterion of inhabited areas, 12.1% of the study area was unsuitable for small ruminant production (Table 4). Sustainable animal farming which does not damage the environment does not seem possible in areas which were unsuitable according to the laws which were taken as a basis in this study, or on a scientific basis (MWPS 1982; Ongley 1996; SB 2000; Olgun 2011).

3.3. Suitability of the study area according to all evaluation criteria

The model which was developed was questioned as to the suitability of the study area for small ruminant production according to the eight evaluation criteria as a whole, and the results are given in Figure 3. The suitability of the study area for small ruminant production according to this suitability map is shown in Figure 4 along with spatial and proportional distribution. It was found that 3.54% of the 42,707.15 ha study area was classed as suitable according to the total of the evaluation criteria, 2.78% as conditionally suitable, and 93.68% as unsuitable (Figure 3-4).

Setting up small ruminant farms in unsuitable areas will have a negative effect on inhabited areas, water sources, water storage basins and irrigated areas. This will threaten environmental cleanliness and hygiene, as well as human health. In addition, the land use classification of these areas and the land slope and aspect are not suitable for these farm structures (shelters and service structures). This will cause damage to crop production areas, the structures will increase the cost of construction, and the shelter will make the inspection of internal and external conditions difficult (MWPS 1982; Ongley 1996; Zeng & Hong 2008; Olgun 2011).

Table 4- Suitability of the study area for small ruminant production according to the planned evaluation criteria

Çizelge 4- Araştırma alanının öngörülen değerlendirme ölçütlerine göre küçükbaş hayvancılık işletmeleri için uygunluk durumu

Evaluation criteria	*Evaluation classes*					
	Unsuitable		*Conditionally suitable*		*Suitable*	
	(ha)	*%*	*(ha)*	*%*	*(ha)*	*%*
1) Distance from inhabited areas	5,151.34	12.1	2,821.56	6.6	34,734.24	81.3
2) Distance from water sources	407.63	1	924.71	2.2	41,374.80	96.9
3) Distance from irrigation and drainage canals	558.55	1.3	Not applicable	-	42,148.59	98.7
4) Distance from wind turbine safety strips	359.64	0.8	Not applicable	-	42,347.50	99.2
5) Distance from water catchment basin protected areas	4,731.28	11.1	8,159.84	19.1	29,815.87	69.8
6) Slope	1,341.84	3.1	4,854.59	11.4	36,501.22	85.5
7) Aspect	27,752.18	65	Not applicable	-	14,954.97	35.0
8) Land use class	33,492.21	78.4	Not applicable	-	9,214.94	21.6

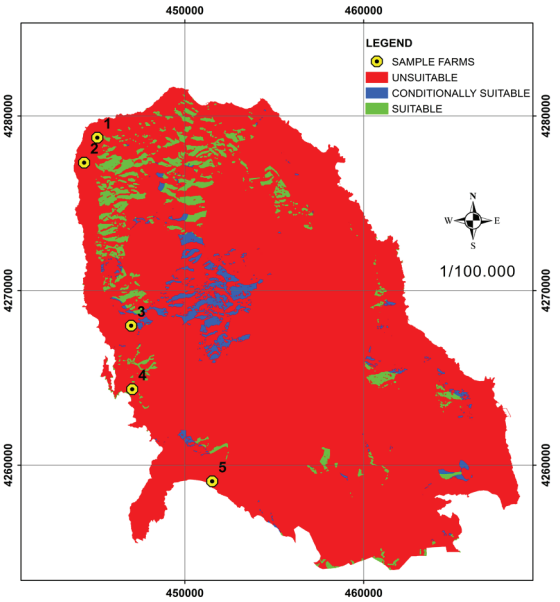

Figure 3- Map of the suitability of the study area for small ruminant rearing and location of existing sample farms

Şekil 3- Araştırma alanının küçükbaş hayvancılık işletmeleri için uygunluk haritası ve mevcut örnek işletmelerin konumu

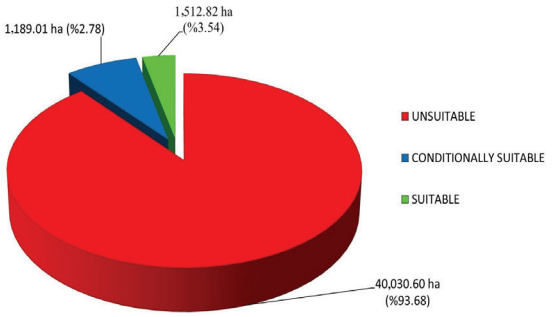

Figure 4- Spatial and proportional distribution of suitability for small ruminant rearing in the study area

Şekil 4- Araştırma alanının küçükbaş hayvancılık işletmeleri için uygunluk durumunun alansal ve oransal dağılımı

3.4. Suitability of the location of the sample farms in the research area

The locations in the study area of the five sample small ruminant farms are shown in Figure 3. The locations of these farms were analyzed with the help of the inquiry model according to each evaluation criterion, and the results are given in Table 5.

When the locations of the sample farms were examined according to the totality of the eight evaluation criteria, it was found that none of the locations of the farms was suitable for small ruminant rearing (Figure 3). When they were examined according to the evaluation criteria individually, it was seen that there was no risk in any of the farms according to criteria 2-5, but that

Table 5- Suitability of locations of sample farms in the study area according to each criterion individually

Çizelge 5- Araştırma alanındaki mevcut örnek işletmelerin konumlarının her bir değerlendirme ölçütüne göre uygunluk durumu

Farm no	*Evaluation criteria*																			
	1) Distance from inhabited areas			*2) Distance from water sources*			*3) Distance from irrigation and drainage canals*		*4) Distance from wind turbine safety strips*		*5) Distance from water catchment basin protected areas*			*6) Slope*			*7) Aspect*		*8) Land use class*	
	NS	*CS*	*S*	*NS*	*CS*	*S*	*NS*	*S*	*NS*	*S*	*NS*	*CS*	*S*	*NS*	*CS*	*S*	*NS*	*S*	*NS*	*S*
1			x			x		x		x			x			x		x	x	
2			x			x		x		x			x			x	x		x	
3	x					x		x		x			x			x	x			x
4			x			x		x		x			x			x	x		x	
5	x					x		x		x			x			x	x		x	

NS, not suitable; CS, conditionally suitable; S, suitable

according to criterion No. 1, the locations of farms No. 3 and 5 were not suitable. It was also seen that in general, the locations of the farms were not suitable according to criterion No. 7 (except for farm No. 1) and according to criterion No. 8 (except for farm No. 3) (Table 5). It has been reported that farms closer than 500 m to an inhabited area constitute a social and environmental health risk (SB 2000; Karaman 2006; Ünal et al 2013). It has been shown that farms on land with a northerly, north-westerly, westerly or easterly aspect will encounter difficulties in benefitting from winter sun and protection from summer sun and winter winds (Olgun 2011).

4. Conclusions

The present study was conducted to determine the most suitable areas for small ruminant production in the Karaburun district of Izmir province according to legal and technical evaluation criteria, and a GIS inquiry model was developed for locational data provided by the RS technique. Using this inquiry model, locations which were potentially suitable for small ruminant production were determined and the suitability of the locations of existing sample farms was analyzed. In farms established in the locations determined as suitable, it will be possible to conduct faming activities in a way which is better for animal welfare, prevents environmental damage and is more economic and sustainable.

The following recommendations are presented for the more successful choice of a suitable location for animal farming. In order to determine suitable locations where all kinds of animal farming can be practiced over wider areas, there is a need for scientific research to be conducted on the development of more inclusive evaluation criteria in the GIS model. Taking into account such factors as geological factors (mechanical and hydraulic characteristics of the ground, groundwater sources, etc), ownership, the characteristics of the breeds of animal reared or their environmental needs, sources of water and feed, market conditions, or economic factors such as building costs, there will be a wider range of inquiry possibilities with inquiry models which will be developed. In this way, it will provide very effective evaluation in the choice of suitable locations for farms. If the GIS models developed are used in setting up livestock farms, the new farms which are given permission to operate in suitable locations will be able to carry on their activities under more suitable conditions. In this way a contribution will be made to more productive, profitable and sustainable animal production. In order to increase the functionality and effectiveness in use of this type of inquiry model, it is of great importance that universities and public and private institutions should work together with farming organizations such as associations and cooperatives.

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TARIM BİLİMLERİ DERGİSİ-JOURNAL OF AGRICULTURAL SCIENCES

YAZIM KURALLARI

Genel

Tarım Bilimleri Dergisi, tarım bilimleri alanında ve yazım dili İngilizce olan özgün araştırma makaleleri yayınlar. Sonuçları önceden bilinen ve yenilik getirmeyen araştırma makaleleri, taksonomi ile sadece durum tespitine dayanan ve yöresel çalışmalar ile veri ve anket analizine dayanan çalışmalar derginin kapsamı dışındadır. Basılacak makalelerin daha önce hiçbir yerde yayınlanmamış olması ve yayın haklarının verilmemiş olması gerekir. Dergide yayımlanacak makalelerin her türlü sorumluluğu yazarına/yazarlarına aittir.

Yayımlanması için gönderilen eser, yayın ilkeleri doğrultusunda Başeditör tarafından ön incelemeye alınır. Başeditör, dergide yayınlanabilecek nitelikte bulmadığı makaleleri editörlere/hakemlere göndermeden yazara/yazarlara iade kararı verme hakkına sahiptir. Ayrıca yazım kurallarına uymayan veya anlatım dili yetersiz olan makaleler, düzeltilmek üzere yazara/yazarlara iade edilir. Değerlendirmeye alınan makaleler, incelenmek üzere en az 2 hakeme gönderilir. Hakem değerlendirmesinden geçen makalelere ait düzeltmeler, düzeltmeler listesiyle birlikte en fazla 30 gün içerisinde sisteme yüklenerek gönderilmelidir. Bu süreden sonraki gönderimler kabul edilmez. Yazarlara makaleleri hakkındaki editör ve hakem görüşleri ve önerileri 8 hafta içerisinde bildirilir. Başeditör, hakem raporlarını ve/veya istenilen düzeltmelerin yeterli olup olmamasını dikkate alarak makalenin yayımlanıp yayımlanmamasına yönelik nihai karar vericidir.

Makalede isimleri yer alan tüm yazarlar, yayım haklarını Tarım Bilimleri Dergisine verdiklerine dair **Makale Gönderme ve Telif Hakkı Devir Sözleşmesini** imzalamalıdır. Makalenin yayımlanması kabul edildikten sonra makale metninde, yazarlarında ve yazarların sıralamasında değişiklik yapılamaz. Makale sunum ya da işlem ücreti alınmamakla birlikte, yayıma kabul edilen makaleler için, sorumlu yazar Ankara Üniversitesi adına açılmış banka hesabına 400 TL yatırmalıdır. Makaleden sorumlu yazara banka hesap numarası, makalenin basıma kabul edilmesinden sonra bildirilir.

Makale Yükleme

Hazırlanan makaleler; sadece makaleden sorumlu yazar (makalenin yayım başlangıcından basım sonrasındaki her türlü yazışmalarda sorumluluğu bulunan) tarafından Tarım Bilimleri Dergisi web sayfasındaki çevrimiçi **Makale Gönderme ve Değerlendirme Sistemi** kullanılarak elektronik ortama yüklenmelidir. Makale yükleme bölümünün **"Başvuruyu Yükle"** bölümünde pdf formatındaki makale dosyasına ilave olarak "**Ek Dosyalar**" bölümüne aşağıdaki dosyaların da yüklenmesi gerekir.

- ✓ Makalenin pdf ve Word (2003 veya daha üst versiyonları) formatındaki dosyası. Sisteme yüklenen makalenin hem pdf formatında ve hem de Word formatında iletişim, ad-soyad, kurum gibi yazarları tanıtıcı bilgiler bulunmamalıdır.
- ✓ Tüm yazarlar tarafından imzalanmış ve pdf formatında taranmış olan "Makale Gönderme ve Telif Hakkı Devir Sözleşmesi". Yayıma kabul edilmesi durumunda bu formların aslı da posta ile editöre gönderilmelidir.
- ✓ Yazar Makale Kontrol Listesi (pdf formatında),
- ✓ Yazarların ad-soyad, kurum ve iletişim bilgilerini içeren Word dosyası,
- ✓ Gerekiyorsa Etik Kurul Raporu eklenmelidir.

Derginin Kapsamı

Tarım Bilimleri Dergisi, tarım bilimleri alanında yapılan özgün araştırmaları ve yeni bulguları içeren makaleleri yayımlar. Sonuçları önceden bilinen ve yenilik getirmeyen araştırma makaleleri, taksonomi ile sadece durum tespitine dayanan ve yöresel çalışmalar ile veri ve anket analizine dayana çalışmalar derginin kapsamı dışındadır. Derleme makaleler, yayın komisyonunun çağrısı üzerine hazırlanmışsa normal inceleme ve değerlendirme sürecinden geçirilerek yayınlanır.

Makale Hazırlama

Makaleler, A4 boyutundaki kâğıdın tek yüzüne 12 punto Times New Roman yazı tipinde ve çift satır aralıklı yazılmalıdır. Sayfanın sağında, solunda, altında ve üstünde 3'er cm boşluk bırakılmalıdır. Makalenin her sayfası ve satırları numaralandırılmalıdır. Yazar ad(lar)ı açık olarak yazılmalı ve herhangi bir akademik unvan belirtilmemelidir. Editörler kurulu, anlatım dili yeterli olmayan makaleleri değerlendirme dışı tutabilir. Yazar(lar)ın makale göndermeden önce eseri dil yönünden bir dil bilimciye incelettirmesi tavsiye olunur. Sıralama olarak, İngilizce özet ve peşinden Türkçe özet verilir. Bu durum şekil ve çizelge başlıkları için de geçerlidir.

Makale; Türkçe Başlık, Türkçe Özet, Anahtar Kelimeler, İngilizce Başlık, İngilizce Özet, Keywords, 1.Giriş, 2.Materyal ve Yöntem, 3.Bulgular ve Tartışma, 4.Sonuçlar, Teşekkür (varsa), Kısaltmalar ve/veya Semboller (varsa), Kaynaklar bölümleri ile Şekil ve Çizelgelerden oluşmalıdır. Bölüm adları koyu yazılmalıdır.

Makale, "Kaynaklar" bölümü dâhil 16 sayfayı geçmemelidir. Yazar(lar), bu kısımların oluşturulmasında derginin web sayfasındaki **Makale Hazırlama Şablonunu** kullanmalıdır.

Başlık: Kısa ve açıklayıcı olmalı, 14 punto ve koyu, kelimelerin ilk harfi büyük olmalı, ortalanarak yazılmalı ve 15 kelimeyi geçmemelidir. İngilizce başlık Türkçe başlığı tam olarak karşılamalı, 13 punto ve koyu yazılmalıdır.

Özet ve Anahtar Kelimeler: Türkçe ve İngilizce özetlerin her biri 300 kelimeyi geçmemelidir. Türkçe ve İngilizce özetlerde sırasıyla "Özet" ve "Abstract" kelimeleri kullanılmalıdır. Özet, çalışmanın amacını, nasıl yapıldığını, sonuçları ve sonuçlar üzerine yazar(lar)ın yaptığı değerlendirmeleri içermelidir. Özetlerin 1 satır altına, her anahtar kelimenin ilk harfi büyük diğerleri küçük harflerle, mümkünse başlıkta kullanılmayan, çalışmayı en iyi biçimde tanımlayacak ve aralarında noktalı virgül (;) olacak şekilde en fazla 6 anahtar kelime yazılmalıdır.

1. Giriş: Bu bölümde; çalışma konusu, gerekçesi, konu ile doğrudan ilgili önceki çalışmalar ve çalışmanın amacı verilir.

2. Materyal ve Yöntem: Kullanılan materyal ve yöntem aynı başlıkta verilmelidir. Alt başlık verilecekse bölüm numarası ile birlikte numaralandırılmalı (2.1. gibi) ve italik yazılmalıdır. Yeni veya değiştirilmiş yöntemler, aynı konuda çalışanlara araştırmayı tekrarlama olanağı verecek nitelikte açıklanmalıdır.

3. Bulgular ve Tartışma: Elde edilen bulgular verilmeli, gerekirse çizelge, şekil ve grafiklerle desteklenerek bulgular açıklanmalıdır. Elde edilen bulgular tekrardan kaçınılması amacıyla ya çizelge ya da grafik olarak verilmelidir. İstatistikî olarak önemli bulunan faktörler, uygulanan istatistik analiz tekniğine uygun karşılaştırma yöntemi ile yorumlanarak ilgili istatistikler üzerinde harflendirme yapılmalıdır. İstatistiki analiz yönteminin doğru seçilmediği ve/ya analizin gereği gibi yapılmadığı durumlarda Başeditör makaleyi değerlendirme dışında tutabilir. Bulgular tartışılmalı ancak gereksiz tekrarlardan kaçınılmalıdır. Bulguların başka araştırmalarla benzerlik ve farklılıkları verilmeli, nedenleri açıklanmalıdır.

4. Sonuçlar: Elde edilen sonuçlar, bilime ve uygulamaya katkısıyla birlikte kısa ve öz olarak verilmelidir. Giriş ile Bulgular ve Tartışma bölümünde verilen ifadeler bu kısımda aynı şekilde tekrar edilmemelidir.

Teşekkür: Gerekli ise mümkün olduğunca kısa olmalı ve yapılan katkı ifade edilerek verilmelidir.

Kısaltmalar ve/veya Semboller: Makalede kısaltmalardan mümkün olduğunca kaçınılmalıdır. Semboller Makale Hazırlama Şablonunda belirtildiği gibi verilmelidir. Kısaltma ve semboller metin içinde ilk kez kullanıldığı yerde açıklanmalıdır. Uluslararası geçerliliği olan ve yerleşik kısaltmalar tercih edilmelidir. Kısaltmalar makalenin başlığında kullanılmamalıdır. Semboller SI sistemine göre verilmelidir.

Kaynaklar: Eserde yararlanılan kaynaklara ilişkin atıf metin içinde "(Yazarın soyadı yıl)" yöntemine göre yapılmalıdır. Örnek: (Doymaz 2003), (Basunia & Abe 2001). Yazara atıf yapılırsa sadece yayının yılı parantez içine alınmalıdır. Örnek: Doymaz (2003)'e göre ya da Basunia & Abe (2001). Üç ya da daha fazla yazar için makale içindeki atıfta "et al" kullanılmalıdır. Örnek: (Lawrence et al 2001) veya Lawrence et al (2001)'e göre. Aynı yazarın aynı yıl içinde 1'den fazla yayını varsa, yıldan sonra küçük harfler verilmelidir. Örnek: (Akpınar et al 2003a). Aynı yazarın birden fazla yayınına atıf yapılacaksa yıldan sonra noktalı virgül (;) işareti ile ayırt edilmelidir. Örnek: (Akpınar 2007; 2009; 2013). Birden fazla atıf yapılırsa atıflar arasında noktalı virgül (;) kullanılmalı ve eskiden yeniye doğru yıl sırasına göre verilmelidir. Örnek: (Perl et al 1987; Bailly et al 1996; Copeland & McDonald 2001; Goel & Sheoran 2003). Eğer bilginin, kaynağın belirli bir sayfasından ya da sayfalarından alındığı belirtilmek istenirse (Hardeman & Jochemsen 2012, s 657-674; Naess 1991, s 34) biçiminde gösterilmelidir. Kaynaklarda Anonim ya da Anonymous şeklinde gösterim yapılmamalıdır.

Kaynaklar bölümünde metin içinde atıfı yapılan tüm kaynaklar alfabetik olarak (yazarların soyadlarına göre) ve orijinal dilinde verilir. Aynı yazara birden çok atıf yapılıyorsa önce tek isim, sonra iki isim ve sonra da üç ve daha fazla yazarlı kaynak sırasına göre hepsi kendi içinde eskiden yeniye yıl sırasına göre verilmelidir. İki veya daha fazla yazarlı eserlerin bildiriminde son yazardan önce "&" kullanılmalıdır. Örnek: Lawrence K C, Funk D B & Windham W R (2001). Dergi isimleri kısaltma yapılmadan tam adı ile ve italik yazılmalıdır. Kongre kitaplarında Türkçe ya da yabancı dilde özeti yayınlanmış çalışmalara atıf yapılamaz. Makaledeki yanlış atıf ve kaynak gösterimlerine ait sorumluluk yazar(lar)a aittir. Kaynaklar bölümündeki her bir kaynağın sonuna nokta (.) konmamalıdır.

Dergi:

Doymaz I (2003). Drying kinetics of white mulberry. *Journal of Food Engineering* **61**(3): 341-346

Basunia M A & Abe T (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47**(4): 295-301

Lawrence K C, Funk D B & Windham W R (2001). Dielectric moisture sensor for cereal grains and soybeans. *Transactions of the ASAE* **44**(6): 1691-1696

Akpinar E, Midilli A & Bicer Y (2003a). Single layer drying behaviour of potato slices in a convective cyclone dryer and mathematical modelling. *Energy Conversion and Management* **44**(10): 1689-1705

Kitap:

Yıldırım O (1996). Bahçe Bitkileri Sulama Tekniği. Ankara Üniversitesi Ziraat Fakültesi Yayınları: 1438, Ders Kitabı: 420, Ankara

Mohsenin N N (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

Kitapta Bölüm:

Fıratlı Ç (1993). Arı yetiştirme. (Ed: M Ertuğrul), *Hayvan Yetiştirme*, Baran Ofset, Ankara, s. 30-34

Rizvi S S H (1986). Thermodynamic properties of foods in dehydration. In: M A Rao & S S H Rizvi (Eds), *Engineering Properties of Foods*, Marcel Dekker, New York, pp. 190-193

Yazarı Belirtilmeyen Kurum Yayınları:

TUİK (2012). Tarım İstatistikleri Özeti. Türkiye İstatistik Kurumu, Yayın No: 3877, Ankara

ASAE (2002). Standards S352.2, 2002, Moisture measurement-unground grain and seeds. ASAE, St. Joseph, MI

İnternetten Alınan Bilgi:

FAO (2013). Classifications and standards. http://www.fao.org/economic/ess/ess-standards/en/ (Erişim tarihi:10.02.2013)

Tez:

Koyuncu T (1992). Tarım arabalarında kullanılan çarpma etkili frenlerin araştırılması. Yüksek lisans tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü (Basılmamış), Ankara

Berbert P A (1995). On-line density-independent moisture content measurement of hard winter wheat using the capacitance method. PhD Thesis, Crandfield University (Unpublished), UK

Tam Metin Kongre/Sempozyum Kitabı:

Yağcıoğlu A, Değirmencioğlu A & Cağatay F (1999). Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, 26–27 May, Adana, Turkey, pp. 565–569

Kara Z & Beyoğlu N (1995). Konya ili Beyşehir yöresinde yetiştirilen üzüm çeşitlerinin göz verimliliklerinin belirlenmesi üzerine bir araştırma. *Türkiye II. Ulusal Bahçe Bitkileri Kongresi. Bildiriler (II)*: 3-6 Ekim, Adana, s. 524-528

Şekiller ve Çizelgeler: Şekil, grafik, fotoğraf ve benzerleri "Şekil", sayısal değerler ise "Çizelge" olarak belirtilmelidir. Tüm şekil ve çizelgeler makalenin sonuna yerleştirilmelidir. Şekil ve çizelgelerin boyu tek sayfa düzeninde en fazla 16x20 cm ve çift sütun düzeninde ise genişliği en fazla 8 cm olmalıdır. Şekil ve çizelgelerin boyutu baskıda çıkabilecek çözünürlükte olmalıdır. Araştırma sonuçlarını destekleyici nitelikteki resimler 600 dpi çözünürlüğünde "jpg" formatında olmalıdır. Renkli resimler yerine gri ya da siyah tonlu resimler tercih edilmelidir. Çizelgelerde düşey çizgi kullanılmamalı ve makale hazırlama şablonunda belirtildiği gibi hazırlanmalıdır. Her çizelge ve şekle metin içerisinde atıf yapılmalıdır. Tüm çizelge ve şekiller makale boyunca sırayla sadece **Table 1** ve **Figure 1** kısmı koyu olacak şekilde numaralandırılmalıdır. Çizelge ve şekil başlıkları ve açıklamaları kısa ve öz olmalıdır. Çizelge ve şekillerin İngilizce başlıkları, Türkçe başlığın hemen altına italik olarak yazılmalı, ilk yazılan Türkçe başlık yazısı koyu olmalıdır. Şekil ve çizelge başlık yazıları 9.5 punto, şekil ve çizelgelerin içindeki yazılar 9 punto, çizelge altı yazılar 8 punto Times New Roman yazı karakterinde olmalıdır. Şekillerde yatay ve düşey kılavuz çizgiler ve rakamlar bulunmamalıdır. Ancak istatistiksel karşılaştırmalar yapılıyorsa küçük harfler bulunabilir. Çizelge ve şekillerde kısaltmalar kullanılmış ise hemen altına bu kısaltmalar açıklanmalıdır. Şekil ve çizelge başlıkları ile çizelge altı yazılarının sonuna nokta (.) konmamalıdır.

Birimler: Tüm makalelerde SI (Systeme International d'Units) ölçüm birimleri kullanılmalıdır. Ondalık kesir olarak nokta kullanılmalıdır (1,25 yerine 1.25 gibi). Birimlerde "/" kullanılmamalı ve birimler arasında bir boşluk verilmelidir (m/s yerine m s^{-1}, J/s yerine J s^{-1}, kg m/s^2 yerine kg m s^{-2} gibi). Sayı ile sembol arasında bir boşluk bırakılmalıdır (4 kg N ha^{-1}, 3 kg m $^{-1}$ s^{-2}, 20 N m, 1000 s^{-1}, 100 kPa, 22 °C ve % 29 gibi). Bu kuralın istisnaları düzlemsel açılar için kullanılan derece, dakika ve saniye sembolleridir (°, ′ ve ″). Bunlar sayıdan hemen sonra konmalıdır (10°, 45', 60" gibi). Litrenin kısaltması "l" değil "L" olarak belirtilmelidir. Cümle sonunda değillerse sembollerin sonuna nokta konulmamalıdır (kg. değil kg).

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JOURNAL OF AGRICULTURAL SCIENCES

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Acknowledgements

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References

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Journal Articles

Doymaz I (2003). Drying kinetics of white mulberry. *Journal of Food Engineering* **61**(3): 341-346

Basunia M A & Abe T (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47**(4): 295-301

Lawrence K C, Funk D B & Windham W R (2001). Dielectric moisture sensor for cereal grains and soybeans. *Transactions of the ASAE* **44**(6): 1691-1696

Akpinar E, Midilli A & Biçer Y (2003a). Single layer drying behavior of potato slices in a convective cyclone dryer and mathematical modeling. *Energy Conversion and Management* **44**(10): 1689-1705

Books

Mohsenin N N (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

Book Chapter

Rizvi S S H (1986). Thermodynamic properties of foods in dehydration. In: M A Rao & S S H Rizvi (Eds.), *Engineering Properties of Foods*, Marcel Dekker, New York, pp. 190-193

Publications of Institutions / Standard Books

ASAE (2002). Standards S352.2, 2002, Moisture measurement - unground grain and seeds. ASAE, St. Joseph, MI

Internet Sources

FAO (2013). Classifications and standards. Retrieved in April, 12, 2011 from http://www.fao.org/economic/ess/ess-standards/en/

Thesis and Dissertations

Berbert P A (1995). On-line density-independent moisture content measurement of hard winter wheat using the capacitance method. PhD Thesis, Crandfield University (Unpublished), UK

Conference Proceedings (Full papers)

Yağcıoğlu A, Değirmencioğlu A & Cağatay F (1999). Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, 26–27 May, Adana, pp. 565–569

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