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THE POSSIBILITY TO USE THREE PORTABLE CHLOROPHYLL METERS TO ESTIMATE GRAIN YIELD IN RAIN-FED CONDITIONS

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Abstract
Handheld spectroradiometers are used to estimate the canopy's reflective properties, the condition of the plants. In this study, the potential use of three devices (SPAD, Greenseeker and CM 1000 chlorophyll meter) was compared that can estimate indirect the chlorophyll content of the leaves. The present research was established in four replications according to the randomized complete block design in the rain-fed conditions of Diyarbakir in the growing season of 2019. Seven barley cultivars were used as plant material. Chlorophyll measurements from leaves were taken in 2 different plant growth periods (anthesis and milky stage). Greenseeker showed changes between 0.51-0.75 in anthesis and 0.43-0.6 at milk stage. SPAD varied between 30-47.3 in anthesis and 27.6-46.7 in milk stage. CM1000 ranged from 217-548 in anthesis, 121-370 in milk. It was observed that the amount of chlorophyll in the leaf decreased in the milk period compared to the anthesis period. Significant regression relationships were determined with SPAD and greenseeker during anthesis $R^2 = 0.194^*$ and greenseeker and grain yield at anthesis period $R^2 = 0.151^*$. As a result of the study, a significant relationship was found between only grain yield and greenseeker during the anthesis period under rain-based conditions. It has been observed that there is no relationship between other measuring portable devices and grain yield.

Keywords: NDVI, SPAD, CM 1000, Regression analysis, grain yield

YAĞMURA DAYALI KOŞULLARDA TANE VERİMİNİ TAHMİN ETMEK İÇİN ÜÇ FARKLI KLOROFİL METRENİN KULLANILABİLME OLANAĞI

Özet
Elde taşınan spektroradyometreler, bitki örtüsünün yansıtıcı özelliklerini, bitkilerin durumunu tahmin etmek için kullanmaktadır. Bu çalışmada, bitki yapraklarının klorofil içeriğini dolaylı olarak tahmin edebilen üç cihazın (SPAD, Greenseeker ve CM 1000 klorofil ölçer) kullanımı potansiyel karşılaştırılmıştır. Bu araştırma, 2019 yılı yetiştirme sezonunda Diyarbakır da yağışa dayalı koşullarda tesadüf bloklar deneme desenine göre dört tekerrürlü olarak kurulmuştur. Bitki materyali olarak yedi arpa çeşidi kullanılmıştır. Yapraklardan klorofil ölçümleri 2 farklı bitki büyüme periyodunda (çiçeklenme ve süt olum dönemi) alınmıştır. Greenseeker, çiçeklenmede 0.51-0.75 ve süt olum döneminde 0.43-0.60 arasında değişim gösterdi. SPAD, çiçeklenmede 30-47.3, süt olum döneminde 27.6-46.7 arasında değer almıştır. CM1000, çiçeklenmede 217-548, süt olum döneminde 121-370 arasında değişim göstermiştir. Her üç ölçüm aletiyle elde edilen yapraktaki klorofil miktarının değerleri süt

olum döneminde çiçeklenme dönemine göre azaldığı görülmüştür. Çiçeklenme döneminde SPAD ve greenseeker arasında R2 = 0.194* ve çiçeklenme döneminde greenseeker ve tane verimi sırasında R2 = 0.151* önemli regresyon ilişkileri belirlenmiştir. Çalışma sonucunda yağmura dayalı koşullarda çiçeklenme döneminde sadece tane verimi ile greenseeker arasında olumlu ve önemli bir ilişki bulunmuştur. Diğer taşınabilir ölçüm cihazları ile tane verimi arasında önemli bir ilişki olmadığı görülmüştür.

Anahtar Kelimeler: NDVI, SPAD, CM 1000, regresyon analizi, tane verimi

Introduction

Plant analysis is usually used as the standard method to evaluate nutritional status of plants. However, laboratory plant analysis is costly and time-consuming. Tissue testing, such as petiole nitrate concentration, assessed by selective electrodes (Sims et al. 1995) or test strips (Rodrigues et al. 2005) and also measurements of chlorophyll via portable tools (Rodrigues et al. 2006; Kızılgeçi and Yıldırım, 2019) may be valuable alternatives. The reflectance characteristics of the canopy, evaluated by handheld spectroradiometers (Dunn et al., 2016), imagery from satellite sensors (Gitelson et al., 2014) or digital cameras (Lopez-Bellido et al. 2012) have also been used to estimate nutritional status of plants. Portable sensors have opened up a new technique to the acquisition of information on plant growth in a fast and non-invasive manner. They are especially significant in annual crops in which the delay in diagnosing, as is common in standard plant analysis, is not helpful in making in-season fertilization adjustments (Rodrigues et al. 2005). Chlorophyll meters are quicker than tissue testing for nitrogen. Samples can be taken frequently and repeated if the results are questionable. The meters are used to evaluate leaf greenness, which is significantly related to the chlorophyll content of leaf. Study shows a close correlation between chlorophyll content of leaf and nitrogen content of leaf because a lot of the leaf nitrogen is contain in the chlorophyll. There are at least two types of handheld chlorophyll meters available to measure chlorophyll content of plant. One type (SPAD 502) uses thumb pressure to close a chamber and measure light transmittance/absorbance (T/A) to determine chlorophyll content (Chen et al., 2007). The SPAD-502 chlorophyll meter (Minolta Camera Co. Ltd., Japan), which measures the transmittance of light through the leaf, has been widely used. Several researches have shown a significant linear relationship between SPAD measurements and the laboratory determination of the density of leaf chlorophyll. (Ibrahim and Jaafar 2013). The FieldScout CM 1000 meter, more recently manufactured, evaluates by remote sensing the chlorophyll content in the leaves based on the chlorophyll reflectance. Based on a point-and-shoot technology, the FieldScout CM 1000 senses the light at different wavelengths displaying a chlorophyll meter, which is proportional to the leaf chlorophyll content. The FieldScout CM 1000 chlorophyll meter was used to define the actual amount of N needed to optimize playability and aesthetic quality in creeping bentgrass on golf greens by Lopez-Bellido et al. (2012). Mahajan et al. (2014) have also found a strong association between FieldScout CM-1000 chlorophyll meter and nitrogen concentration of leaf in the aromatic rice hybrid PRH-10 in India. The NDVI is successful in predicting photosynthetic activity, because this vegetation index includes both near infrared and red light. Photosynthetic activity of the plant is evaluated by chlorophyll content and activity. The relationship between leaf N and leaf

chlorophyll has been demonstrated for maize (Chapman and Barreto, 1997) and wheat (Evans, 1989).

In this study, the potential use of three devices to estimate the chlorophyll content of the leaves was compared.

Material and Method

Field experiment was conducted during wheat seasons (2018/2019) at Diyarbakir, Turkey (37°55' N, 40°15' E). Seven barley genotypes were used in the study. In this research, three portable devices were used to estimate the leaf chlorophyll content: the SPAD-502 Minolta chlorophyll meter, the FieldScout CM-1000 chlorophyll meter and Greenseeker (normalized differences vegetation index). SPAD-502 measures the transmittance of light throughout the leaf in two different wavelengths, 650 nm (red light, absorbed by chlorophyll pigments) and 940 nm (infrared light, not absorbed by chlorophyll). The FieldScout CM 1000 meter senses light at wavelengths of 700 nm and 840 nm, measuring the ambient and reflected light at each of those wavelengths. The GreenSeeker active optical sensor was used to determine spectral reflectance from canopy expressed as NDVI. The sensor has self-illumination system in red (656 nm) and near infrared (774 nm) wavelengths. The NDVI value (-1 to 1) is calculated from the measured ambient and reflected light [(%Near Infrared - %Red) / (%Near Infrared + %Red)] where NIR and Red are the fractions of near infrared and red radiation reflected back from the crop canopy to the sensor, respectively. The NDVI values were measured by passing the sensor above the canopy at 1 m height at slow walking speed. Leaf measurements were taken during anthesis and milk stage. The relationship between the measured variables was subjected to analysis of variance. When a significant correlation was found ($p<0.05$), the coefficients of determinations were also estimated. Regression analyses were performed following linear, on the pooled data of both growing stage using JMP 10.

Result and Discussion

Values of chlorophyll content of leaf measured with three chlorophyll measuring devices at anthesis and milk stage of barley and analysis of variance are given in table 1.NDVI, SPAD and CM-1000 readings mean values and the mean squares from analysis of variance given in Table.1. Genotypic differences were significant ($P\leq0.05$and $P\leq0.01$) for all the parameters studied except NDVI-M.

Maximum values of NDVI were observed in Kendal (0.58) and minimum values were showed in Onder (0.69) at anthesis stages. The NDVI measured during the milk stage period varied between 0.43 and 0.69. During the anthesis stage the SPAD readings varied between 30-47.3 values. SPAD reading values varied from 27.6 to 46.7 in the milk stage. The chlorophyll value measured with CM-1000 at the anthesis stage had values in the range of 217 to 548. The amount of chlorophyll in the leaf, measured by CM-1000 chlorophyll meter, varied between 121-370 values during the milk stage. In the study, it was observed that as the plant growth stage improved, a decrease occurred in the chlorophyll content measured with all three measuring instruments.

Table 1.Analysis of variance and NDVI, SPAD and CM-1000 readings the mean values in seven barley genotypes during anthesis and milk stage

Genotypes	NDVI-(A)	NDVI-(M)	SPAD-(A)	SPAD-(M)	CM-1000(A)	CM-1000(M)
Altıkat	0.67ab	0.61	45.5a	39.65ab	339b	302a
DZ12-1	0.61bc	0.54	39.8b	35.875abc	357.25ab	214.25bc
Kendal	0.58c	0.53	33.3c	31.275c	283.75b	305.25a
Önder	0.69a	0.55	37.1bc	37.65ab	438.75a	238.25abc
TBT16-13	0.68a	0.57	38.8b	34.625bc	298.75b	184c
TBT16-14	0.62abc	0.53	38.7b	41.25a	324.75b	273.25ab
TBT16-15	0.68a	0.60	38.3b	34.95bc	309.5b	209bc
Means	0.65	0.56	38.8	36.5	336.0	246.6
Min. - Max.	0.51-0.75	0.43-0.69	30-47.3	27.6-46.7	217-548	121-370
Mean Square (ANOVA)	*		**	*	*	*

A:Anthesis, M: Milk stage *,** $p < 0.05$ $p < 0.01$ significant respectively

It was determined that there was a positive relationship between SPAD and NDVI, CM-1000 and NDVI, and SPAD and CM-1000 with chlorophyll measuring devices at anthesis stage (Figure 1).

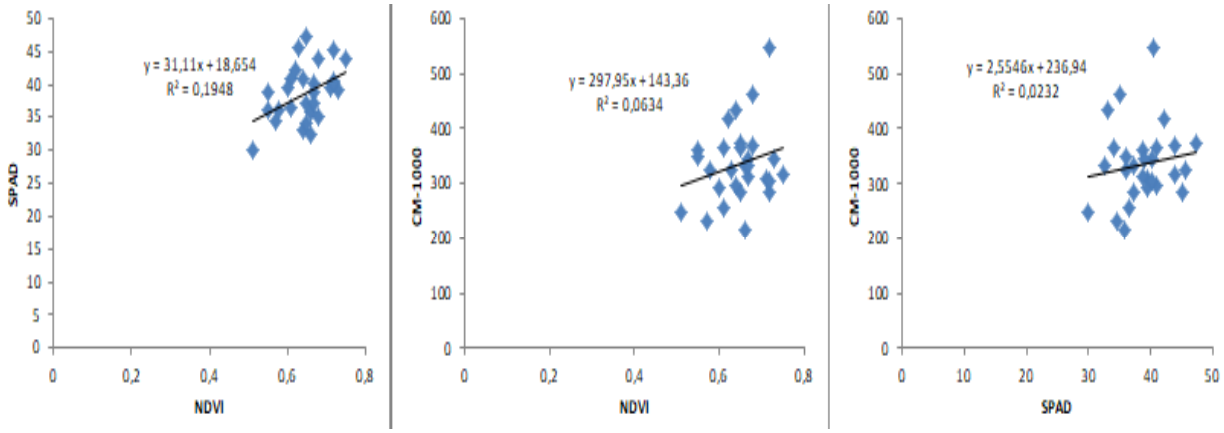

Figure 1. Relationship between NDVI, CM-1000 and SPAD readings in leaf samples taken from anthesis stage of barley genotypes.

It was determined that there was a positive relationship between SPAD and NDVI, CM-1000 and NDVI, and SPAD and CM-1000 with chlorophyll measuring devices at milk stage (Figure 2).

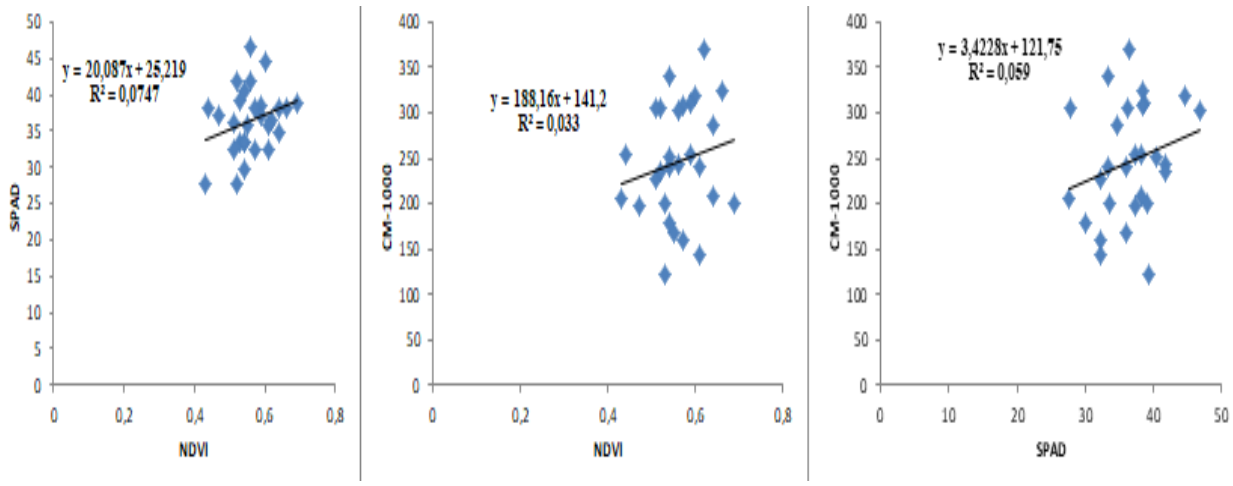

Figure 2. Relationship between NDVI, CM-1000 and SPAD readings in leaf samples taken from milk stage stage of barley genotypes.

The relationship between NDVI measurements at anthesis and milk stage of barley measured using GreenSeeker and grain yield followed exponential function with R^2valueof 0.15and 0.06 (Figure 3). The function was significant ($P<0.05$) and GreenSeeker measurements could explain 15% of variation in the grain yield. Grain yield of barley could be predicted from NDVI measurements at anthesis stage. Raun et al. (2001) reported that relationships between NDVI and grain yield of wheat were the highest at Zadoks 30-31 stages.

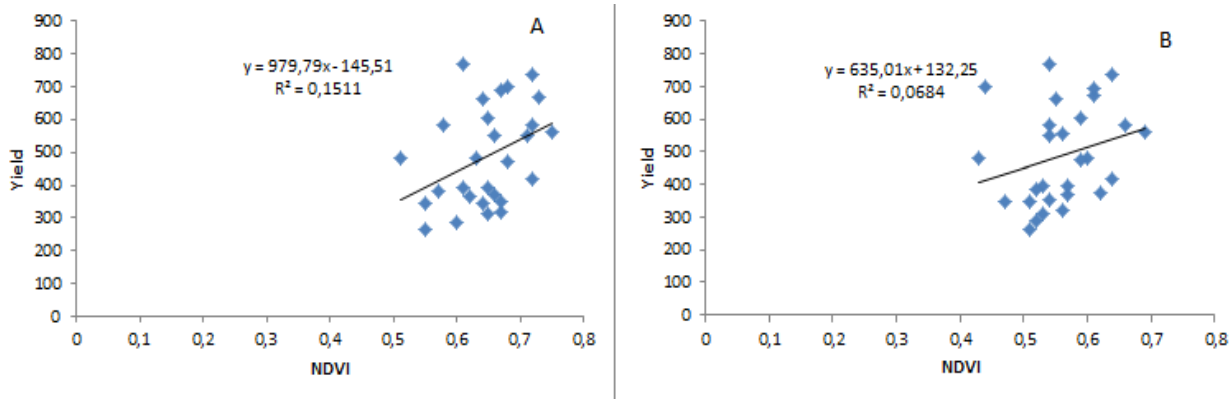

Figure 3. Relationships between grain yield and NDVI readings from leaf samples of seven barley genotypes taken in anthesis stage (A) and milk stage (B)

The relationship between chlorophyll measurements at anthesis and milk stage of barley measured using SPAD 502and grain yield followed exponential function with R^2 valueof 0.0001and 0.029 (Figure 4).

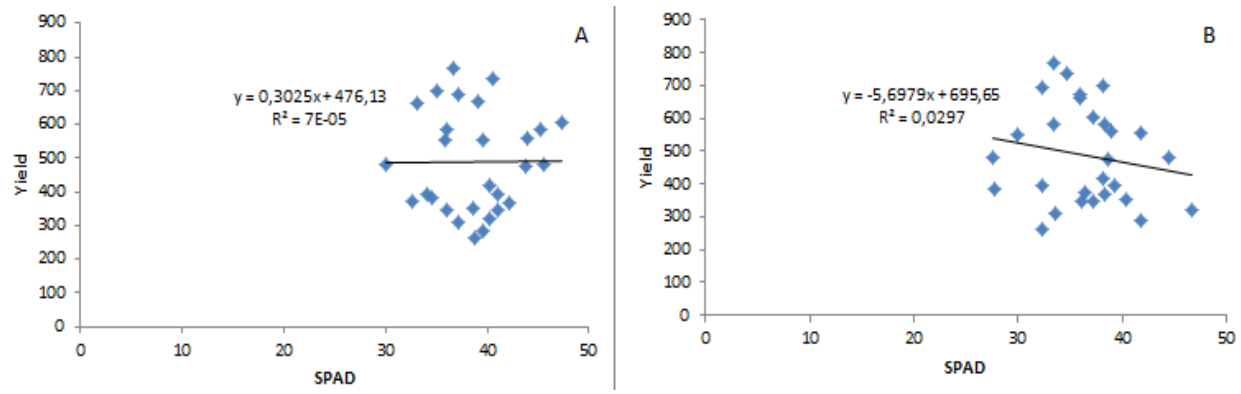

Figure 4. Relationships between grain yield and SPAD readings from leaf samples of seven barley genotypes taken in anthesis stage (A) and milk stage (B)

The relationship between chlorophyll measurements at anthesis and milk stage of barley measured using CM 1000and grain yield followed exponential function with R^2 value of 0.005and 0.078 (Figure 5).

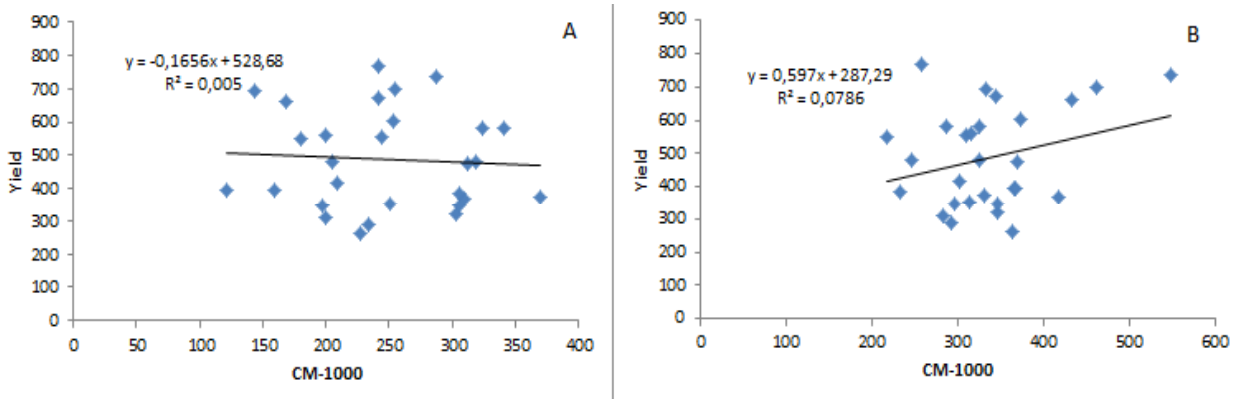

Figure 5. Relationships between grain yield and CM-1000 readings from leaf samples of seven barley genotypes taken in anthesis stage (A) and milk stage (B)

NDVI-A had positive and significant relationship with NDVI-M, SPAD-A and grain yield. NDVI-M was positively and strongly associated with SPAD-A. SPAD-A had significant correlation with SPAD-A (Table 2).

Table 2. Correlation coefficient among NDVI, SPAD, CM-1000 and grain yield in barley genotypes in anthesis and milk stage.

	NDVI(A)	NDVI(M)	SPAD(A)	SPAD(M)	CM-1000(A)	CM-1000(M)
NDVI(Anthesis stage)	1					
NDVI(Milk stage)	0.707***	1				
SPAD(Anthesis stage)	0.441**	0.523**	1			
SPAD(Milk stage)	0.416	0,273	0.603**	1		
CM-1000(Anthesis stage)	0.251	0.152	0.152	0.246	1	
CM-1000(Milk stage)	-0.031	0.181	0.171	0.242	0.09	1
Grain Yield	0.388*	0.261	0.008	-0.172	0.28	-0.07

A:Anthesis, M: Milk stage *,** $p < 0.05$ $p < 0.01$ significant respectively

Conclusion

It was observed that the amount of chlorophyll in the leaf decreased in the milk period compared to the anthesis period. Significant regression relationships were determined with SPAD and GreenSeeker during anthesis $R^2 = 0.194^*$ and GreenSeeker and grain yield at anthesis period $R^2 = 0.151^*$. As a result of the study, a significant relationship was found between only grain yield and GreenSeeker during the anthesis period under rain-based conditions. It has been observed that there is no relationship between other measuring portable devices and grain yield.

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