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Determination of Physiological Traits for Growth Analysis in some Bread Wheat (Triticum aestivum L.) Cultivars

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ABSTRACT: *The purposes of this study are to determine the growth parameters using in growth analysis of late period of wheat and to estimate the correlation coefficient between growth parameters and yield and yield components. In six bread wheat varieties suitable for Aegean Region, growth parameters were determined between flag leaf just visible (zadox 37-39) and ripening (zadox 85-91). The total dry matter increased until the milk and dough development period and then decreased, while leaf area index continuously declined after beginning of anthesis. A decreasing second-degree polynomial was described for net assimilation rate and relative growth rate due to dry matter and leaf area index. The positive and significant correlation coefficients were estimated between yield and leaf area index. It should be concluded that the (LAR) confirms the positive and significant relation of the duration of greenness on the yield and yield components during further development periods.*

Keywords: *Wheat, yield, net assimilation rate, relative growth rate, leaf area index.*

Bazı Ekmeklik Buğday (Triticum aestivum L.) Çeşitlerinde Büyüme Analizine Yönelik Fizyolojik Özelliklerin Saptanması

ÖZ: *Çalışmanın amacını, büyüme analizinde kullanılan parametrelerin buğdayın geç döneminde zamansal eğilimini belirlemek ve büyüme parametreleri ile verim arasındaki korelasyon katsayılarını saptamak oluşturmuştur. Ege Bölgesi'ne uygun 6 ekmeklik buğday çeşidinde bayrak yaprağı çıkışı (zadoks 37-39) ile olgunlaşma (zadoks 85-91) arasında büyüme parametreleri saptanmıştır. Toplam kuru maddede tane dolum dönemine kadar sürekli artış ve sonrasında azalış; yaprak alanı indeksinde ise çiçeklenme başlangıcından sonra sürekli azalış gözlenmiştir. Bu iki parametreye bağlı olarak net asimilasyon oranı ve oransal büyüme oranında ikinci dereceden polinomial azalan eğilim çizgisi elde edilmiştir. Yaprak alanı indeksi ile verim arasında tüm gelişme dönemlerinde pozitif ve önemli korelasyon katsayıları saptanmıştır. Yaprak alanı oranının (LAR) ileri gelişme dönemlerinde yeşil kalma süresinin verim ve verim komponentleri üzerindeki olumlu ve önemli ilişkisini doğrular nitelikte olduğu sonucuna varılmıştır.*

Anahtar Kelimeler: *Buğday, verim, net asimilasyon oranı, oransal büyüme oranı, yaprak alanı indeksi.*

INTRODUCTION

The productivity of the crop canopies is explained by the efficiency of the light energy used, the conversion of this energy to the dry matter and the distribution of this dry matter in the crop. Growth analysis is based on total dry matter and leaf area analysis.

The relative growth rate (RGR; g g^{-1} day^{-1}), the most basic component of growth analysis, is used as a measure of dry matter distribution along with physiological and morphological differences in the crop (Shipley, 2006). The net assimilation rate (NAR; g cm^2 day^{-1}) is the main component of RGR, and is defined as the ability to make dry matter in the unit leaf area by the effect of photosynthesis and respiration rates (Li *et al*., 2016). The NAR is largely dependent on leaf area index (LAI; m^2 m^{-2}). In growth analysis and agronomic evaluations, it is desirable to reach the maximum value of LAI in the early period. This has an important role in increasing photosynthesis as well as reducing evaporation losses. The other most important measure in growth analysis is the normalized difference vegetation index (NDVI), which is the ratio of functional reflection to other reflectance in terms of photosynthesis in the spectrometric way (Cabrera-Bosquet *et al*., 2011).

Aegean Region Wheat cultivation and varieties used in the conditions of Aydın are suitable for growing coastal zone, temperate and rainy regions. Despite heavy rains in the middle of December-February, high temperatures and drought are experienced from the middle of March. In this respect, significant changes are observed in growth parameters such as dry matter synthesis, proportional distribution and leaf area index (Ghosh and Singh, 1998) and that plant biomass and NAR values have high inheritance rates (Karhizi *et al*., 2010).

In this study, firstly, the function of the growth parameters investigated in the process from the pre-spawning period to the maturing stage was presented. The number of studies about the period in which the growth parameters are temporal and the effect on yield and yield components is high is negligible. For this reason, the correlations of the growth parameters of different zadox development periods with the yields were examined and the growth parameters which could be the selection criterion were tried to be determined in the breeding studies to be performed.

MATERIALS AND METHODS

In this study, it was utilized data from the research carried out at the Research and Application Farms of Adnan Menderes University, Faculty of Agriculture during the 2009 wheat growing periods. The average temperature values of the December-June period when the experiment was conducted were found to be higher than the average of long years except February. Although there was less rainfall in December, May and June compared to the average for many years, the total of 697.6 mm rainfall during the experiment year was higher than the 471.5 mm rainfall, which is the average for many years. The soil properties of the test area are defined as loamy, alkali, low lime and organic matter, and moderate levels of phosphorus and potassium.

The bread wheat varieties, Negev, Pamukova 97, Sagittario, Adana 99, Golia and Meta 2002 which find commonly sowing area in Aegean Region were used as materials. The sowing was done in the first week of December in the order of 600 seed m^{-2} planting intervals and 0.2 m between rows.

The experiment was laid out in Randomized Complete Block Design with four replications. The parcels were 6 rows (1.2 m) in length of 6 m. 25 kg da^{-1} 20-20-0 in sowing as fertilizer; 15 kg da^{-1} Urea and 18 kg da^{-1} Ammonium Nitrate (33%) were applied during the sibling period.

Samples for growth parameters were drawn at seven Zadox growth stages (from Zadox 37; flag leaf visible to Zadox 85-91; Maturation) in four replications from each variety (Zadox *et al*., 1974). The numbers of sample plants were 5 for each treatment and each growth stages. These plants were dried at 70 ° C for 72 hours to detect dry matter (g). In the same plants, leaf area index (LAI) was found by using the leaf area and plant density according to the leaf size x leaf width x 0.79 formula. The NDVI values were determined in each parcel using flag Chlorophyll Spectrometer NDVI 300 instrument. The growth parameters used in the study are Sandeep *et al*. (2016) and determined according to the following formulas;

Leaf Area Index (LAI; m^2 m^{-2}) = Total leaf area / soil area

Relative Growth Rate (RGR, mg mg day^{-1}) = $(\ln W_2 - \ln W_1) / (t_2 - t_1)$

Net Assimilation Rate (NAR: mg cm^{-2} day^{-1}) = (Ln L_2 - Ln L_1 / t_2 - t_1) × (W_2 - W_1 / L_2 - L_1

Leaf Area Ratio (LAR) = A / W

Here; L_1 and L_2 leaf area at times t_1 and t_2

W_1 and W_2 dry weight at times t_1 and t_2

A: leaf area

W: weight

Grain yield (kg da^{-1}) and yield traits such as thousand kernel weight (g) and the number of kernel per ear (K/E) were also recorded for all the treatment. Grain yield was determined by harvesting one 1 x 4 m strip down the center of each parcel.

The curve fitting were performed in the Microsoft Office Excel program using replication values for each growth parameters. Here, the most suitable curve function is selected to the highest R^2. Correlation coefficients between the characters were estimated in the TARIST Statistical Package Program by using the same data (Acikgoz *et al*., 1994).

RESULTS AND DISCUSSION

The changes in dry matter (DM) were described by the second-degree polynomial according to R^2 (0.9913). When the dry matter accumulation (g m^{-2}) in the period from the flag leaf emergence period (Zadox 39) to the ripening (Zadox 85-91) was evaluated, it was seen that DM reached from 197 g m^{-2} to 784 g m^{-2} and then it decreases to 705 g m^{-2} with drying and leaf abscission (Figure 1).

Relative growth rate (RGR, g g day^{-1}) expressed the rate of dry matter synthesis in terms of the period. A rapid change from 32 g g day^{-1} value to 56 g g day^{-1} value between flag leaf emergence (39) and booting (43-49) was recognized (Figure 1). The rapid increase was attributed to with photosynthesis at the generative and vegetative organ surfaces by Mondal and Paul (1994). From this period, the rate of dry matter synthesis tends to decrease and is constantly decreasing. In the maturation period, 9.36 g of day^{-1}ve and 7.62 g of day^{-1} are reduced to -9.84 g of day^{-1} in the ripening period (R^2 = 0.7912). Similar decreases were reported by Spitters and Kramer (1986) and Zaman *et al*. (2016) by decreasing leaf area and decreasing photosynthesis capacity due to aging.

Dry matter and relative growth rate during zadox growth stages are directly related to LAI (Figure 1). LAI reached a value of 8.24 m^2 m^{-2} (Mujdeci *et al*., 2005) at the beginning of the flowering period of 50-55 period and gradually tended to decrease with leaf age and leaf loss during maturation period (Mondal and Paul, 1994). Especially in the last two growing stages, it decreased to 4.40 and 2.82 m^2 m^{-2} value. The largest indicator of this is the reduction in leaf area ratio (LAR) values (R^2 = 0.9918). The dry matter accumulation and leaf area index (LAI) appears as a function of net assimilation rate (NAR), and the changes in all three growth parameters must be considered together (Anonymous, 2019). Growth and decline in growth in DM and LAI may not be consistent. In contrast to DM, which showed a steady increase until the maturation period, LAI reached maximum in the flowering period of zadox 50-55 period and then decreased rapidly. A NAR graphic similar to that of LAI was formed (R^2 = 0.8056). NAR has reached values of about 48-52 g cm^2 day^{-1} in the flowering period (zadox 50-55) together with flag leaf formation (zadox 39 and 43-49). NAR tended to decline after this period and declined to 38 g cm^2 day^{-1} after maturity - 60 g cm^2 day^{-1} in the period of zodox 76-81 (end of grain filling). Similarly, the decreasing tendency of NAR and RGR over periods was determined in rice (Araujo, 2003) and wheat (Hasan *et al*., 2016).

The NDVI values in our study are the values for the development period of the flag leaf (Figure 1). Cabrera-Bosquet (2011) found significant relationships between NDVI values and total dry matter and green area. The initial NDVI values of 65 declined to 25 with grain filling and maturation (R^2 = 0.8944). It is seen that the trend of decrease in NDVI is similar to the tendency of RGR, in particular LAI and accordingly RGR.

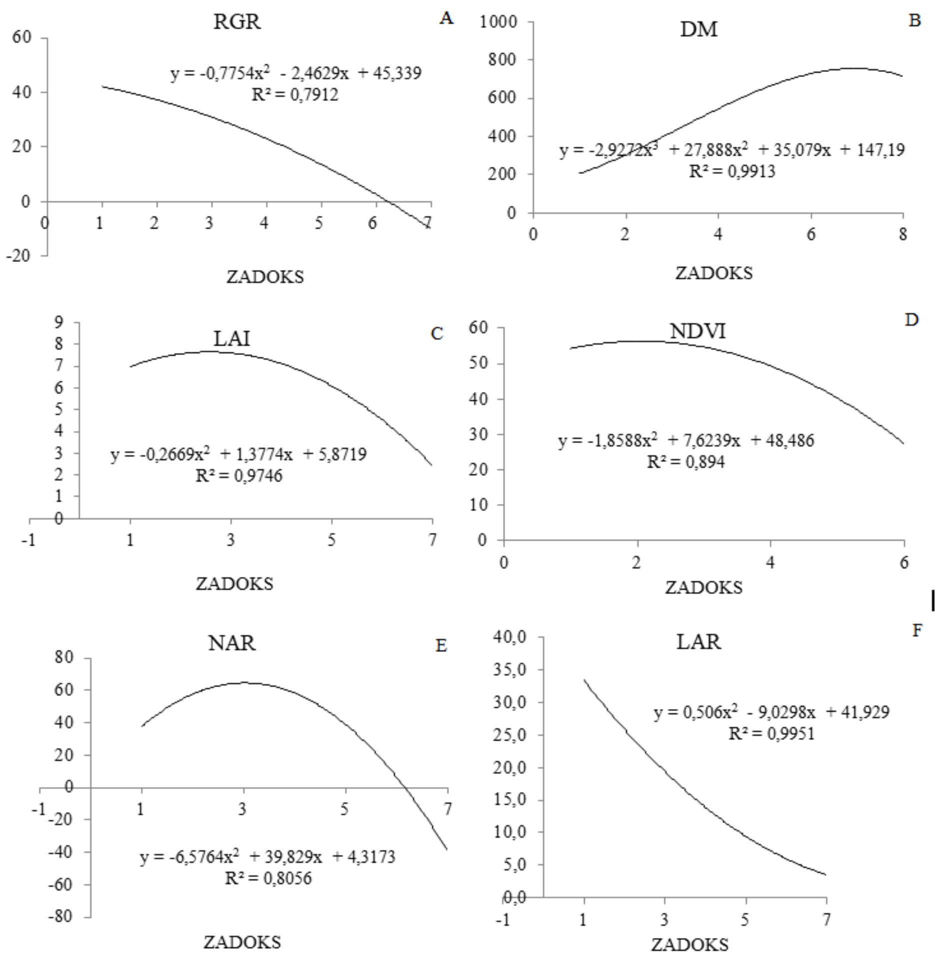

Figure 1. The changes at zadox growing stages of (A) RGR: Relative Growth Rate; (B) DM: Dry Matter; (C) LAI: Leaf Area Index; (D) NDVI: Normalized Differences Vegetation Index;, (E) NAR: Net Assimilation Rate; (F) LAR: Leaf Area Ratio. Zadox Growing Stages; 1:39, 2:43-49, 3:50-55, 4:56-61, 5:66-71, 6:76-81, 7:85-91 and 8:harvest.
Şekil 1. Zadox büyüme aşamalarındaki değişiklikler: (A) RGR: Oransal Büyüme Oranı; (B) DM: Kuru Madde; (C) LAI: Yaprak Alanı İndeksi; (D) NDVI; Normalleştirilmiş Vejetasyon İndeksi Farklılığı; (E) NAR: Net Assimilasyon Oranı; (F) LAR: Yaprak Alanı Oranının zadoks dönemlerindeki zamansal değişimi. Zadoks Büyüme Dönemleri; 1:39, 2:43-49, 3:50-55, 4:56-61, 5:66-71, 6:76-81, 7:85-91 ve 8:hasat.

The correlation coefficients between the yield (kg da^{-1}), the number of seeds per head and the seed weight (g) characteristics and the growth parameters are given in Table 1. Leaf area index positive and significant correlated with yield in every growing period except zadox 76-81. This result of the present study was found the similar to the findings of Yadav and Sing (1984) in canola and Sandeep *et al*. (2016) in rice. Especially, Sandeep *et al*. (2016) found positive and significant between LAI and yield components during the ripening period of rice, but detected negative correlation coefficients between yield and growth parameters such as RGR and NAR and. In contrast, Kahrizi *et al*. (2010) found non-significant correlations between growth parameters and yield and yield components, although there were significant relationships between growth parameters in durum wheat. At the same time, the positive and significant correlations between LAI and the number of kernel per ear in zadoxs 50-55, 76-81 and 85-91 periods were found. In the period of zadox 76-81, correlation coefficients of LAI with thousand kernel weight were positive and significant. These findings indicate that the leaf area index increases efficiency over the number of kernel per ear in particular.

Table 1. The correlation coefficients between yield, thousand kernel weight (TKW), the number of kernel per ear (K/E) and growth parameters at different zadox stages.
Çizelge 1. Verim, bin tane ağırlığı ve başakta tane sayısı ile büyüme parametreleri arasındaki korelasyon katsayıları.

		Zadox growing stages / Zadoks büyüme devreleri						
Growth parameters Büyüme parametreleri	Yield components Verim komponentleri	39	43-49	50-55	56-61	66-71	76-81	85-91
RGR	Yield	- 0.28	0.63*	- 0.41	-0.49	- 0.63*	0.79**	0.01
	TKW	0.42	0.28	- 0.44	0.03	0.53*	- 0.66**	- 0.42
	K/E	0.11	0.87**	- 0.63*	-0.49	0.05	0.18	- 0.06
LAI	Yield	0.63*	0.53*	0.71**	0.82**	0.79**	0.32	0.59*
	TKW	- 0.08	0.06	0.17	-0.16	- 0.30	0.63*	0.48
	K/E	0.27	0.23	0.56*	0.45	0.31	0.58*	0.65*
NAR	Yield	0.22	- 0.64*	0.29	0.46	0.42	- 0.83**	0.26
	TKW	- 0.24	- 0.46	- 0.13	-0.57*	- 0.14	0.33	0.51*
	K/E	- 0.29	- 0.79**	0.19	0.13	0.25	- 0.49	0.36
LAR	Yield	0.77**	0.48	- 0.39	0.24	0.54*	0.60*	0.25
	TKW	- 0.61*	- 0.47	- 0.46	-0.81**	- 0.68**	- 0.65*	- 0.02
	K/E	0.21	- 0.07	- 0.76**	-0.65*	- 0.33	- 0.24	- 0.20
NDVI	Yield	0.39	- 0.04	0.03	-0.30	0.12	0.02	
	TKW	0.28	- 0.18	- 0.13	-0.09	0.61*	0.65*	
	K/E	0.07	0.01	0.28	-0.21	0.32	0.33	

*; 0.05, **; 0.01 significant at probability level.
*; 0.05, **; 0.01 olasılık düzeyinde önemli.

The correlation coefficients of two parameters related to dry matter (RGR and NAR) were evaluated together with yield and yield components. The correlation coefficient between RGR and yield was negative in the period 66-71 but positive and significant in the period 76-81. RGR negatively correlated with thousand kernel weight at stage of zadox 76-81 whereas correlation coefficient between mentioned characters was positive and significant at zadox 66-71. RGR, however, has a positive correlation with the number of kernel per ear in the 43-49 period and a negative and significant correlation coefficient in the 50-55 period. This shows that both growth parameters have increases and decreases within the general tendency function according to the periods. It can be said those positive periods in the periods of increase, but negative relations in the periods of decrease. Similarly, Yadav and Singh (1984) found early correlation between yield and CGR (crop growth rate), while in the late period they found negative and significant correlation coefficients.

It can be said that leaf area ratio (LAR), which is a sign of leaf area per unit dry weight, has more meaningful relationships than other characteristics. Generally, positive and significant correlation coefficients with yield and thousand kernel weight are found in terms of growth periods. Negative and significant correlation coefficients are observed between LAR and the number of kernel per ear at 50-55 and 56-61 stages. This leaf shows that the period of greenness significantly affects these properties. Therefore, when the correlation coefficients with NDVI values were examined, positive and significant coefficients were determined during adolescence periods such as 66-71 and 76-81 periods. Here, even in late periods such as grain filling periods, it means that the leaf remains green.

CONCLUSION

The results of present experiment indicated the increase of dry matter was continued even at the end of the ripening period, whereas the leaf area decreased rapidly after the flowering period. In particular, it has been observed that the growth parameters such as the net assimilation rate, which expresses the dry matter synthesis, are more influenced by the leaf area decrease, and may be reduced to minus (-) values as the assimilation value. The correlation coefficients determined in our study are the result of this. When the agro-physiological growth parameters in wheat were evaluated, it was concluded that leaf area index and leaf area ratio were determinative parameters and it would be useful to evaluate them in breeding and agronomic studies.

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