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Relationship Between Rapid Canopy Closure and Grain Yield in Wheat

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Abstract: In order to determine the relationship between rapid canopy closure and grain yield in wheat and to identify the traits that affect rapid canopy closure, a research was conducted using 5 wheat cultivars (Atrak, Tajan, Zagros, Golestan and Viniak). A field experiment with randomized complete blocks was carried out at the Gorgan University of Agricultural Science and Natural Resources, in 2003-2004. Rapid canopy closure had significant effect on grain yield, cultivars with faster canopy closure produced comparatively more grain yield per unit area. Leaf area index and seedling dry weight at the beginning of the exponential growth phase; relative leaf area development rate and relative growth rate during the exponential phase and the average of individual leaf area and leaf area ratio were detected as the effective traits in rapid canopy closure. It was concluded that the RCC is an appropriate way especially in the environment where growing season is limited and there is little scope for lengthening the growing season in order to increase dry matter production and yield.

Key words: Dry matter, growth, leaf area, seedling, trait

INTRODUCTION

Rapid Canopy Closure (RCC) is one of the physiological attributes that may enhance genetic yield potential of wheat (*Triticum estivum* L.), particularly in a short growing season. RCC could confer several greater advantages. Firstly, under irrigated condition and in the absence of biotic and abiotic stresses, wheat yield is related to the amount of solar radiation captured by the crop. In this condition, RCC maximizes light interception and consequently increases yield potential (Hay and Walker, 1989). Secondly, under rain-fed conditions, greater yield may arise mainly from faster growing leaf canopy that shades the soil surface, thereby reducing evaporation of water from the soil surface and increasing water availability for the crop (Lopez-Castaneda *et al*., 1995). However, in some situations, RCC may result in rapid water use, especially in environments with severe terminal droughts followed by severe water deficits at the critical stages, leading to reductions in grain yield (Ludlow and Muchow, 1990). Thirdly, a greater ground cover and growth in the early season results in greater CO_2 fixation per unit transpirational water loss than if growth occurred later when temperatures are high (Tanner and Sinclair, 1983; Condon *et al*., 1993). Fourthly, greater ground cover early in the season could also reduce light availability beneath the crop canopy and improve the crop's competitiveness with weeds (Rebetzke and Richards, 1999).

The development of crop canopies (in terms of dry weight and leaf area index) in the early season before canopy closure is called exponential phase. In this phase, growth rates of seedlings are limited by leaf area and light interception and exponential growth results from positive feedback of expanding leaf area on growth rates. It continues up to the time when the foliage canopy closes in complete cover of the land area and thus complete light interception (Loomis and Connor, 1992). During exponential phase, crop dry weight (W) and Leaf Area Index (LAI) versus time or thermal time (t) can be described by Eq. 1.

$$y = \alpha \exp(\beta t) \qquad (1)$$

where, y is W or LAI and α and β are the parameters of the model. The parameters can be interpreted in a biologically meaningful way. α is W or LAI at the beginning of the exponential growth and related to seed size and seed vigor. Complete, rapid and uniform emergence of vigorous seedlings (components of seed vigor) may result in greater a and hence, RCC. The second

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parameter of the model (β) is relative growth rate of crop (g/g/day or g/g/°Cday) or LAI (m^2/m^2/day or m^2/m^2/°Cday). RCC is somewhat different from the Early Vigor (EV) used by Lopez-Castaneda *et al.* (1995, 1996) and Rebetzke and Richards (1999). EV deals with crop dry matter and LAI production during the early part of the exponential phase of the crop growth. However, RCC covers crop growth during the whole period of exponential phase. For example, Lopez-Castaneda *et al.* (1995, 1996) and Rebetzke and Richards (1999) limited EV to 300°C day from sowing (2-4 leaf numbers on main stem), compared to 800°C day after sowing considered in this study.

Crop improvement programs dealing with physiological traits have three steps (Jordan *et al.*, 1983): (1) trait or traits that promote genetic yield potential must be identified; (2) genetic variation and its nature for the traits must be assessed and superior genetic resources must be identified and (3) the gene or genes governing the traits must be incorporated into the current good cultivars. Therefore, before physiological traits are proposed for inclusion in breeding programs, their importance for grain yield should be assessed in terms of the components of yield and the determinants of survival (Ludlow and Muchow, 1990). Unless they make a contribution to one or more components or determinants, there seems little use in breeding for them. Based on laboratory and field experimentations and correlations, Whan *et al.* (1991), Regan *et al.* (1992), Lopez-Castaneda *et al.* (1995, 1996), Elhafid *et al.* (1998), Rebetzke and Richards (1999) and Soltani *et al.* (2002) concluded that more vigorous early growth and greater ground cover early in the season (RCC) could result in greater yield potential. However, we did not find any report on quantitative assessing of RCC and its worth for yield increase in wheat. Thus, the main objective of this study was to perform a quantitative evaluation of RCC to wheat production in a temperate sub-humid environment.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of the Gorgan University of Agricultural Sciences in 2003-2004 growing season under rain-fed conditions. The soil was a deep silty clay. Five wheat cultivars (Atrak, Tajan, Zagros, Golestan and Viniak) from the Caspian Sea Coast of Iran were used in this study. The cultivars were sown in a randomized block design with four replications. Plots (3 m wide×4 m long) were hand-seeded on 29 October using row spacing of 15 cm. Seeding rates were calculated for each genotype using percentage germination and thousand seed weights to achieve a density of 300 plants m^2. Prior to seeding, 150 kg ha^{-1} superphosphate was broadcasted and incorporated into the soil. Plots were top-dressed at stem elongation and flowering stages with 200 kg ha^{-1} urea (46% nitrogen). Weeds were hand-controlled during vegetative and reproductive stages. Above-ground dry matter and leaf area were determined by cutting plants from the soil surface of each plot in an area of 0.25 m^2 every 10 days, from 20 DAS (days after sowing) until harvest maturity. Green leaf area was measured using a leaf area meter and expressed on a ground area basis. Dry matter was determined after drying the plants at 70°C to constant weight. At maturity (14% seed moisture content), plants were harvested from 2 m^2 of each plot and grain yield per unit area was recorded. Thermal time accumulated Growing Degree Days (GDD) was calculated using average maximum and minimum daily temperatures and the base temperature (2 °C). Equation 1, in the form of

$$\ln y = \ln \alpha + \beta t$$

was fitted to the data of crop dry matter and LAI (y) versus thermal time (t) for each cultivar at each replication. Then α and β were determined. We used W and L for crop dry matter and LAI, respectively.

RESULTS AND DISCUSSION

Table 1 shows the range, mean, standard error and coefficient of variation for RCC related traits of 5 wheat cultivars. Cultivar differences in relative growth rate during the exponential phase were not significant ($p>0.05$). However, significant differences were observed in days to 30, 60% and full canopy closure, leaf area index and seedling dry weight at the beginning of exponential growth phase, leaf emergence rate, relative leaf area development rate, and leaf area ratio during the exponential phase, average of individual leaf area and grain yield. The highest Coefficient of Variation (CV) was shown by seedling dry matter (82.7) and leaf area index (79.1) at the beginning of exponential growth phase, followed by days to 30% canopy closure (40.3). CV values for other traits ranged from 14.3 to 26.5 (Table 1). The variation observed in this study is similar to that reported by Regan *et al.* (1992), Turner and Nicolas (1987) and Whan *et al.* (1991).

Genotypic differences for RCC parameters (Table 2) show the possibility of genetic improvement for these traits. Correlation coefficients among RCC related traits and grain yield are shown in Table 3. Relative leaf area development rate during the exponential phase were highly correlated with days to full canopy closure and leaf area index at the beginning of exponential growth phase.

Table 1: Variation in RCC related traits of wheat cultivars under rain-fed conditions

Trait	Range	Mean	SE	CV	F-value for cultivars
Days to 30% canopy closure	28.8-80.4	53.1	16.4	40.3	12.29^{***}
Days to 60% canopy closure	67.1-97.9	82.3	8.7	16.5	21.36^{***}
Days to full canopy closure	91.7-135	111.00	1.5	14.3	6.87^{***}
Leaf area index at beginning of exponential growth phase	0.006-0.059	0.027	0.012	97.1	5.16^{**}
relative leaf area development rate during the exponential phase (m^2/m^2/GDD)	0.0045-0.0078	0.0059	0.0007	17.4	2.75^{*}
Seedling dry matter at beginning of exponential growth phase (g m^{-2})	0.14-1.56	0.71	0.38	82.7	3.34^{*}
relative growth rate during the exponential phase (g/g/GDD)	0.006-0.009	0.0075	0.0008	14.9	1.75^{ns}
Average of individual leaf area (cm^2)	0.08-0.12	0.09	0.01	20.3	6.03^{***}
Leaf emergence rate during the exponential phase (day)	0.12-0.17	0.14	0.01	16.1	9.68^{***}
leaf area ratio during the exponential phase (cm^2 g^{-1})	15.7-33.1	22.40	4	26.5	9.25^{***}
Grain yield (kg ha^{-1})	117.4-182.2	145.10	16.1	20.7	28.49^{***}

***, ** and *: Significant at $p \leq 0.001$, $p \leq 0.01$ and $p \leq 0.05$, respectively, ns: Not significant

Table 2: Means of RCC related traits for five wheat cultivars

Cultivar	RCC[1]	RCC[2]	RCC[3]	LAI[4]	RDR[5]	SDM[6]	RGR[7]	ILA[8]	LER[9]	LAR[10]	GY[11]
Atrak	47.2b	69.8bc	100.2c	0.112a	0.003cd	3.15ab	0.0046bc	6.2a	0.128ab	153a	4819.7b
Tajan	45.6bc	71.1b	115b	0.116a	0.0028d	3.25a	0.0043c	5.4b	0.121b	144b	4321.2b
Zagros	43.1c	66.6c	96.9c	0.102ab	0.0034bc	2.98b	0.005b	5.9ab	0.114bc	147ab	5675.8a
Golestan	58.5a	84.3a	119.7a	0.068c	0.0035ab	1.95c	0.0054a	5.1bc	0.102c	134c	3002.9c
Viniak	55.3a	80.9a	117.3ab	0.079bc	0.0039a	2.21bc	0.0052ab	4.7c	0.137a	129c	3201.6c

Different letter(s) at each column indicate significant difference at $p \leq 0.05$; RCC: Days to 30% canopy closure; RCC: Days to 60% canopy closure; RCC: Days to full canopy closure; LAI: Leaf area index at beginning of exponential growth phase; RDR: Relative leaf area development rate during the exponential phase (m^2/m^2/GDD); SDM: Seedling dry matter at beginning of exponential growth phase (g m^{-2}); RGR: Relative growth rate during the exponential phase (g/g/GDD); ILA: Average of individual leaf area (cm^2); LER: Leaf emergence rate during the exponential phase (day); LAR: Leaf area ratio during the exponential phase (cm^2 g^{-1}); GY: Grain yield (kg ha^{-1})

Table 3: Correlation coefficients of RCC related traits and grain yield in wheat

Traits	1	2	3	4	5	6	7	8	9	10	11
Days to 30% canopy closure	1.00										
Days to 60% canopy closure	0.84**	1.00									
Days to full canopy closure	0.48*	0.65**	1.00								
Leaf area index at beginning of exponential growth phase	-0.68**	-0.45*	0.25	1.00							
Relative leaf area development rate during the exponential phase	0.21	-0.10	-0.63**	-0.85**	1.00						
Seedling dry matter at beginning of exponential growth phase	-0.52*	-0.21	0.25	0.96**	-0.81**	1.00					
Relative growth rate during the exponential phase	0.21	0.14	-0.61**	-0.81**	0.95**	-0.91**	1.00				
Mean of individual leaf area	-0.75**	-0.82**	-0.45*	0.41*	-0.11	0.18	0.13	1.00			
Leaf emergence rate during the exponential phase	0.27	0.19	-0.21	-0.52*	0.31	-0.32	0.29	-0.48**	1.00		
Leaf area ratio during the exponential phase	-0.71**	-0.89**	-0.62**	0.25	0.11	0.21	0.27	0.91**	0.47*	1.00	
Grain yield	-0.79**	-0.69**	-0.65**	0.25	0.13	0.17	0.22	0.67**	-0.29	0.75**	1.00

** and *: Significant at $p \leq 0.01$ and $p \leq 0.05$, respectively

Regan *et al*. (1992) also reported a high positive coefficient between crop dry weight and LAI at 54 DAS in wheat genotypes. The lack of significant correlations of relative growth rate and relative leaf area development rate during the exponential phase with days to 30 and 60% canopy closure (Table 3) is in agreement with the findings of Lopez-Castaneda *et al*. (1995). They showed that relative growth rate and relative leaf area development rate during the exponential phase could not account for the differences in early growth (W and L) of wheat and barley during 22 DAS.

Grain yield showed a significant negative correlation with days to 30, 60% and full canopy closure (Table 3), meaning that RCC could significantly improve grain yield of wheat cultivars per unit area. In contrast, mean individual leaf area and leaf area ratio during exponential phase of growth were positively correlated with grain yield, but the correlations of other traits with grain yield were not significant (Table 3).Therefore, high grain yield is related to higher individual leaf area and leaf area ratio during the exponential growth phase and to Rapid Canopy Closure (RCC).

CONCLUSION

For several decades, progress in breeding for higher yield in wheat has been associated with a reduction in straw weight. Greater yield would be possible through breeding for higher biological yield, while harvest index remains constant. Greater biological yield depends on the amount of resource captured and the efficiency with which that resource is used to produce dry matter. The greatest scope for biomass increases probably lies in increasing the amount of resource captured. Therefore, RCC is an appropriate way especially in the environment where growing season is limited and there is little scope for lengthening the growing season in order to increase dry matter production and yield. Attempts to increase RCC and thereby yield through greater relative leaf area development rate during the exponential phase would be more beneficial than leaf area index at the beginning of exponential growth phase. The results showed that agronomic management must avoid from reduction in leaf area index at the beginning of exponential growth phase and relative leaf area development rate during the exponential phase. Application of starter fertilizers, seed quality, seedbed conditions and plant density are important aspects of cultural management with respect to RCC. More experiments and simulation studies are required to confirm the results of this study in similar and different environments. In these studies, variation for RCC related and predicted benefits from the RCC should be examined. Short time intervals for measurements of leaf characters recommended.

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