Canopy profile distribution of leaf area, light and nitrogen in some Iranian winter wheat cultivars released during the last 50 years

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Abstract

Distribution of leaf area, radiation and nitrogen within the canopy of some Iranian wheat cultivars which were developed for the cold to cold-temperate region of the country within the last 50 years were studied in two separate trials during 1998 and 1999 growing seasons in Mashhad, NE Iran. In both trials 6 wheat cultivars were investigated in a complete randomized block design with 3 replicates. In the first experiment all cultivars were sown at the same date and with the same planting density and N fertilization. However, in the second experiment cultivars were sown using their recommended sowing date, plant density and N rate. Other management practices were identical in both years. Recently introduced wheat cultivars had a higher- light extinction coefficient (K) and positioned a higher proportion of their leaf area in the upper canopy layers. Such a canopy structure led to better interception of radiation at top canopy layer. A decreasing trend of specific leaf nitrogen (SLN), specific leaf area (SLA) and leaf nitrogen content (LNC) was observed moving from the top to the bottom canopy layer. A negative correlation existed between SLW and LNC.

Keywords

wheat, genetic improvements, SLN, LNC, RUE

Introduction

Analysis of the plant canopy is an interesting subject for crop physiologists working on crop yield improvement (Gardner *et al.* 1985; Russell *et al*. 1989). These researchers usually describe the geometrical structure of the canopy by spatial distribution of assimilatory organs (mainly leaves) (Nassiri 1998), leaf angle distribution (Gardner *et al.* 1985; Lee *et al.* 1987; Nassiri 1998), light absorption pattern (Nassiri 1998) and specific leaf nitrogen (Peng and Garcia 1993).

Takahashi and Nakaseko (1993) states that crop growth rate is correlated to the amount of photosynthetically active radiation (PAR) intercepted by the canopy. Many researchers have found a linear relationship between PAR intercepted by the canopy and crop growth rate (CGR) in spring wheat (Saina and Nanda 1986; Takahashi and Nakaseko 1990). The importance of leaf area for the distribution of light interception and radiation use efficiency (RUE, g DM MJ^{-1}) has also been emphasized by these researchers (Barnes *et al*, 1990; Nassiri 1998; Massinga *et al.* 2003).

Nitrogen supply strongly influences crop growth through its effects on leaf area development and photosynthetic capacity (Evans 1993). In particular, variation in leaf carbon dioxide exchange rate (CER) has been shown to be strongly associated with leaf nitrogen content expressed on a leaf area basis (Specific Leaf Nitrogen, SLN, mg N/g DM) in many species (Sinclair and Horie 1989). There are many studies that show in closed canopies of many species SLN declines with depth below the top of the canopy (Hirose and Werger 1987; Lemaire *et al.* 1991; Ellsworth and Reich 1993). Presumably, a non-uniform SLN distribution allows the crop to have greater RUE than is possible with a uniform SLN canopy (Takahashi and Nakaseko 1993). At the leaf level, a gradient in SLN within a canopy results from gradients in either specific leaf weight (g DM/m^2, SLW) or leaf nitrogen concentration (mg N/g DM, LNC) or both (Hirose and Werger 1987).

The objectives of the present study were (a) to determine whether gradients in light interception, leaf area, SLN, SLW and LNC exist in wheat and if present, how they correlated with each other; (b) to assess whether there are differences in canopy structure of some Iranian wheat cultivars released during the last 50 years.

Materials and Methods

Experiments were conducted in two separate trials during 1998 and 1999 at the research station of the College of Agriculture, Ferdowsi University of Mashhad. In both trials 6 wheat cultivars were investigated in a complete randomized block design with 3 replications. Names of cultivars, their year of release, optimum density and nitrogen requirement are listed in Table 1. In the first trial, all cultivars were sown on the same date (November 16) with the same planting density (400 seeds per m^2) and N fertilization [300 kg/ha ammonium phosphate, (110 kg/ha nitrogen)]. However, in the second trial, cultivars were sown under the recommended sowing date, plant density and N rate Table 1). Other management practices were identical in both years. In this experiment, gradients of leaf area, light absorption in the canopy (using tube solarimeter) and of SLN and its components (including SLW and LNC) were measured in 250mm height increments two week after flowering. K and RUE was also calculated for wheat canopies for the period between jointing to two weeks after flowering. Models described by Nassiri (1998) and Caldwell and Hansen (1993) were used to fit the data for LAI and radiation distribution within canopy.

Table 1. Name of cultivars, year of releasing, optimum density and nitrogen requirement

Year of release	Optimum density (Seeds/m^2)	N fertilizer recommended ((kg/ha	Cultivars
1956	300	50	Omid
1969	410	100	Bezostaya
1979	325	100	Azadi
1989	325	100	Ghods
1995	365	115	Alamot
1995	350	115	Alvand

Results and discussion

Vertical distribution of leaf area was different in 1998 and 1999. These differences were mainly related to agronomic conditions in these two years. In 1998 cultivars were sown using the same agronomic practices which were not optimum for some cultivars, which caused some of their canopies not to close completely. In 1999, however, cultivars were sown using optimum agronomic practices for each cultivar and all canopies were closed about two weeks after flowering. In this paper we mainly discuss the results of the second year.

Leaf area and leaf area distribution

The more recently released cultivars (Ghods, Alamot and Alvand) on average had a greater LAI and shorter height and thus higher leaf area density (m^2/m^3, LAD) than older ones (Omid, Bezostaya and Azadi). The mean LAI and height were 3.3 and 117cm for new cultivars and 2.7 and 165cm for old cultivars respectively. Leaf area density (LAD) profile measurements in the canopy shows that on average the new cultivars positioned a higher proportion of their leaf area at the upper canopy layer compare to older cultivars (Figure 1).

Light distribution

Light penetration in canopy layer was inversely correlated with LAD of layers. The percentages of cumulative intercepted light in the canopy as calculated using the CropSys model (Figure 2) show that the new cultivars have intercepted the greater proportion of the light in their up most canopy layer. About 95%

PAR intercepted by Alvand, while Bezostaya intercepted only about 70% of the radiation. The mean K values (Table 2) for the old and new cultivars were 0.41 and 0.43 for 1998 and 0.52 and 0.72 for 1999 respectively. In general, K for new cultivars is a little more than old ones.

The results show that although the K values were lower in old cultivars compared with new cultivars (Table 2), the new cultivars had significantly higher grain yield. This may be due to the higher RUE in new cultivars. RUE values for new cultivars in 1998 and 1999 were calculated to be 0.82 and 1.006 g DM MJ^{-1} while in the same years the values for old cultivars were 0.67 and 0.86 g DM MJ^{-1} respectively.

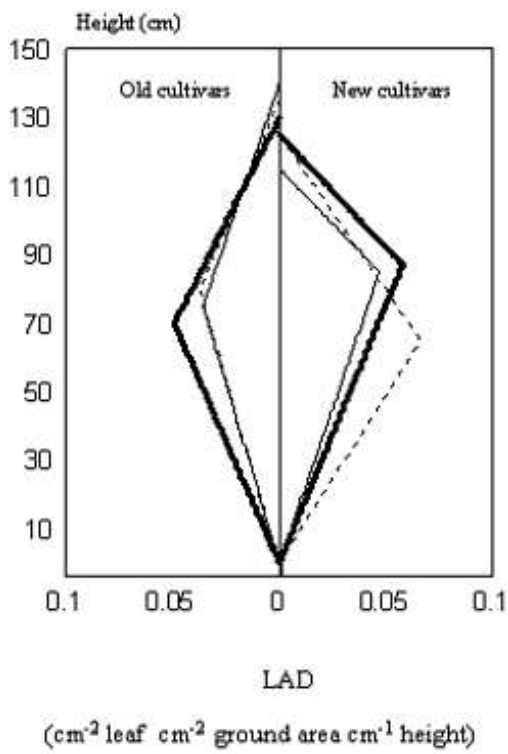

Fig. 1. Distribution of LAD of old cultivars (Omid, Bezostaya and Azadi) and new cultivars (Ghods, Alamot and Alvand) with height in the canopy two weeks after flowering (1999)

Nitrogen distribution

In 1998 none of the cultivars had closed their canopy by two week after flowering, while in 1999, their canopies did close and there was a marked decline in SLN from top to base of the canopy of both new and old cultivars. In 1998 the gradient in SLN mainly occurred due to changes in LNC, while in 1999 it mainly occurred due to changes in SLW (Table 3). Hirose and Werger (1987) measured SLN distribution for the perennial rhizomatous herb goldenrod *(Solidago altissima*). They concluded that SLN decreased exponentially as a function of relative cumulative leaf area from top to the bottom of the leaf canopy. Wright and Hammer (1994) suggested that the existence of non-uniform SLN distributions within a canopy may allow enhanced RUE compared to canopies with uniform SLN distribution.

Table 2. The extinction coefficient (K) and radiation use efficiency (RUE, g DM MJ^{-1}) of Iranian wheat cultivars two weeks after flowering during the 1998 and 1999 growing seasons and yield for the 1999 season.

	New cultivars				Old cultivars			
	Alvand	Alamot	Ghods	Average	Azadi	Bezostaya	Omid	Average
Yield Kg/Ha	7050b	6337b	8733a	7373	4271c	3041d	5237c	4183
K (1998)	0.55	0.33	0.42	0.47	0.62	0.27	0.36	0.41
RUE (1998)	0.95	0.75	0.77	0.82	0.74	0.71	0.57	0.67
K (1999)	0.92	0.82	0.44	0.72	0.52	0.53	0.53	0.52
RUE (1999)	0.74	0.95	1.13	1.006	0.8	0.65	1.06	0.86

Table 3. Correlation coefficients (r) for SLN versus LNC or SLW during the 1998 and 1999 growing season.

	SLN(1998) (mg N/g DM)	SLN(1999) (mg N/g DM)
LNC (g N / g DM leaf)	0.74*	0.20
SLW (g DM / m^2 leaf)	0.29	0.78*

* Significant at α= .05 level

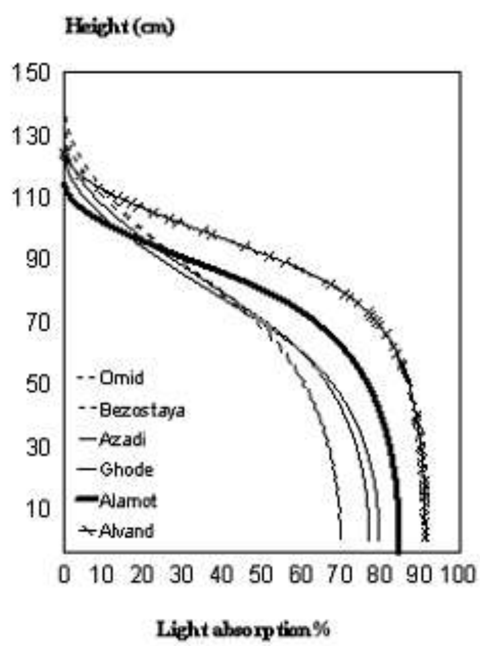

Fig. 2. The cumulative percentage intercepted light from the top of the canopy for six Iranian wheat cultivars. Interception was calculated using the CropSys model (Caldwell and Hanson, 1993) and the parameters derived in our research.

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