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CROP ALBEDO MEASUREMENTS AFTER ANTHESIS REVEAL SIGNIFICANT DIFFERENCES AMONG ROMANIAN WHEAT CULTIVARS

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ABSTRACT

Increased reflectance of solar radiation by the wheat canopy (higher albedo) can contribute to reducing canopy temperature and transpiration, and therefore to improved performance under drought and heat, and to mitigating the effects of climate changes. Albedo is known to vary during the vegetation period, increasing from the emergence to heading and flowering, and decreasing after anthesis to ripening stage. We measured albedo after anthesis, on twenty five winter wheat cultivars, on which albedo had been previously measured before anthesis, using an albedometer based on solar cells. We found significant differences among cultivars, after anthesis, and a significant, but not very close correlation between albedo measurements before and after anthesis. These differences can be used in a breeding program aimed at increasing crop albedo, all along the vegetation period, for improving wheat performance under water and high temperature stress, and to reduce the impact of climate changes.

Key words: wheat, spectral reflectance, albedo, anthesis, drought, heat, climate change.

INTRODUCTION

The albedo is the ratio between the reflected radiation from the target surface and the global horizontal solar radiation. Taking into account the climatic changes and the importance of the surface reflectivity for various domains, such as the atmospheric sciences, the building energy, the photovoltaic domain, the forestry and the agriculture, the albedo becomes a very important parameter.
Albedo measurements can be performed using the following methods:

- In the lab for small samples using solar simulators (Berdahl and Bretz, 1997);
- From the top of the atmosphere using planes or meteorological balloons. This method is not recommended for small surfaces (Pinty et al., 2001).
- In field conditions using albedometers with one or two pyranometers (Sailor et al., 2006). The pyranometers can use thermal sensors or photovoltaic sensors. Using two pyranometers, positioned back to back the cost is higher, but the accuracy is very good. The field albedo measurement is the most common method.

Crop albedo, defined as the ratio of radiation reflected from a crop canopy to global solar incident radiation upon it, can play an important role in determining the amount of water used by plants for transpiration (Blum, 2005), and can have a potential to mitigate climate changes by reducing surface air temperatures in summertime (Ridgwell et al., 2009; Singarayer et al., 2009). Increased albedo could therefore contribute to improved performance under drought and heat, by reducing transpiration and canopy temperature and have a contribution to mitigation of climate changes. This could justify breeding for increased albedo, especially having in mind expected climate changes.

Genetic variation in crop albedo was reported in several crops (Febrero et al., 1998; Hatfield and Carlson, 1979). Large cultivar differences have also been reported in wheat (Piggin and Schwerdtfeger, 1973; Uddin and Marshall, 1988; Saulescu et al., 2011).

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Şerban et al. (2011) identified significant genetic differences among several Romanian winter wheat cultivars, by measuring crop albedo just before anthesis. It is known that wheat crop albedo varies during the vegetation period, increasing from the emergence to heading and flowering, due to the rapid rise of leaf area index and decreased influence of the soil background, and showing an uninterrupted decrease from peak green to ripening stage (Song, 1999; Huawei et al., 2004). However, little is known about cultivar behaviour regarding the changes in albedo during the vegetation period.

Taking into account the fact that grain filling period represents a large part of the wheat vegetation during the warm time of the year, this paper reports data on genetic variation of crop albedo after anthesis, in the same set of Romanian winter wheat cultivars, on which measurements of albedo were made before anthesis by Şerban et al. (2011).

MATERIAL AND METHODS

Twenty four Romanian winter wheat cultivars, including released cultivars and new lines from the breeding programs of the National Agricultural Research & Development Institute (NARDI) Fundulea and the Agricultural Research & Development Station (ARDS) Turda and one older Russian cultivar as historical check, grown in a yield trial at NIRDPSB-Braşov, were used for determining the albedo after anthesis. At the date of the readings all cultivars were in the decimal stages 7-8 (Zadoks et al., 1974).

An albedometer based on solar cells was used to estimate wheat crop albedo (Cotfas et al., 2008). The albedometer is composed of: two solar cells, a system for temperature compensation, a support for the sensors, the acquisition system.

The solar cells are placed back to back, with a small distance between them. This space assures an air flow and their temperature does not influence each other. The area of solar cells is minimized, 3 cm^2, to reduce the shadowing area of the albedometer. Monocrystalline solar cells are used. Their spectral response is very good and covers the necessary spectral response. The solar cell directed down measures the reflected radiation, while the solar cell facing the sun measures the global solar horizontal radiation. The solar cells were previously calibrated.

Two LM precision sensors are used to measure the solar cells temperature and to make the temperature compensation possible. The sensor support consists of a tripod, an arm, 1m long, and the box of the acquisition board. The acquisition system consists of a USB acquisition board or Tag4M and a laptop with dedicated software. The software was created using the graphical programming language LabVIEW. It allows the calculation of the albedo value. For each wheat cultivar the measurement takes 10s and the average albedo value with temperature compensation is shown.

Measurements were performed on June 7, 2012, between 11:30 am and 2:00 pm hours, when the sky was cloudless, in three replications.

ANOVA was used for statistical analysis of the data and significance of differences between cultivars was established using the Newman - Keuls test for $P<0.05$ (Dagnelie, 1975).

Correlation was analysed between the measurements made in 2011 on plots before anthesis (Zadoks stages 43-59) and those made in 2012 after anthesis.

RESULTS

ANOVA shows that cultivars had a significant effect on the variation of albedo after anthesis (Table 1). This indicates that significant differences among the analysed wheat cultivars existed, not only before anthesis (Şerban et al. 2011), but also during the grain filling period.

Albedo after anthesis varied from 0.21103 in cultivar Delabrad 2 to 0.24373 in line T55-01 (Table 2). Most cultivars originated from ARDS Turda breeding program had higher albedo than cultivars originated from NARDI Fundulea breeding program. A certain influence of the difference in earliness between the cultivars originated from the two breeding centres cannot be excluded, despite the fact that they were all in largely the same growth stage. Also, differences in disease attacks (mostly caused by *Septoria* sp.) might have influenced the differences in albedo.

On average for all cultivars, crop albedo after anthesis was 0.22607, which is lower than the average of 0.247335 calculated from measurements before anthesis reported by Şerban et al. (2011). This supports the results of Song (1999) and Huawei et al. (2004) who reported an uninterrupted decrease from peak green at anthesis to ripening stage. The amplitude between the highest and lowest albedo after anthesis was 0.0327, which is smaller than the amplitude of 0.03667 found in 2011 in crop albedo measured before anthesis. Consequently, there are more chances of detecting genetic differences in albedo by measurements made earlier, when wheat is still in vegetative stage. Nevertheless, the amplitudes observed after anthesis can be also considered large enough to provide a basis for genetic progress in a breeding program.

Table 1. ANOVA for albedo readings after heading in a winter wheat yield trial

Source of variation	SS	df	MS	F	P-value	F crit
Between cultivars	0.009437	24	0.000393223	27.04	6.3E-21	1.74
Within cultivars	0.000727	50	1.45396E-05			
Total	0.010164	74				

Table 2. Crop albedo after heading in several Romanian winter wheat cultivars

Nr	Cultivar	Status	Origin	Average	Significance
1	T55-01	New line	ARDS Turda	0.24373	a
2	T265-01	New line	ARDS Turda	0.24300	a
3	T181-01	New line	ARDS Turda	0.24280	a
4	T67-02	New line	ARDS Turda	0.24236	a
5	T136-03	New line	ARDS Turda	0.24006	a
6	Pitar	New line	NARDI Fundulea	0.23720	ab
7	T66-01	New line	ARDS Turda	0.23476	abc
8	Glosa	Released cultivar	NARDI Fundulea	0.23446	abcd
9	Litera	Released cultivar	NARDI Fundulea	0.23260	abcd
10	Dumbrava	Released cultivar	ARDS Turda	0.23113	abcde
11	T96-97	New line	ARDS Turda	0.22783	bcdef
12	T9-01	New line	ARDS Turda	0.22753	bcdef
13	Partener	New line	NARDI Fundulea	0.22613	cdefg
14	Nikifor	New line	NARDI Fundulea	0.22203	defgh
15	T150-03	New line	ARDS Turda	0.22200	defgh
16	Boema 1	Released cultivar	NARDI Fundulea	0.21910	efgh
17	Izvor	Released cultivar	NARDI Fundulea	0.21813	fgh
18	Otilia	New line	NARDI Fundulea	0.21643	fgh
19	Dropia	Released cultivar	NARDI Fundulea	0.21576	fgh
20	Faur	Released cultivar	NARDI Fundulea	0.21496	gh
21	Miranda	Released cultivar	NARDI Fundulea	0.21306	gh
22	Noroc	New line	NARDI Fundulea	0.21260	h
23	Ostrov	New line	NARDI Fundulea	0.21183	h
24	Bezostaya 1	Old cultivar	Russia	0.21136	h
25	Delabrad 2	Released cultivar	NARDI Fundulea	0.21103	h
	Average			0.22607	
			LSD 5%	0.01083	

An interesting problem is the relationship between albedo measurements made before and after anthesis. As seen in figure 1, despite the fact that measurements were made in different years, the correlation between albedo data before and after anthesis was significant at P<0.01. Highest albedo was found, both before and after anthesis in the same line (T55-01). However, some cultivars showed obvious changes in their albedo after anthesis. Cultivars number 6 to 9 (Pitar, T66-01, Glosa and Litera) had relatively higher albedo after anthesis, while cultivars like number 20 (Faur), 24 (Bezostaya 1), 25 (Delabrad 2), etc. decreased their albedo very much after anthesis. This contrasting behaviour might be the result of differential expression of "waxy" genes in leaves and spikes, of differential disease attacks, or of other factors that deserve further study.

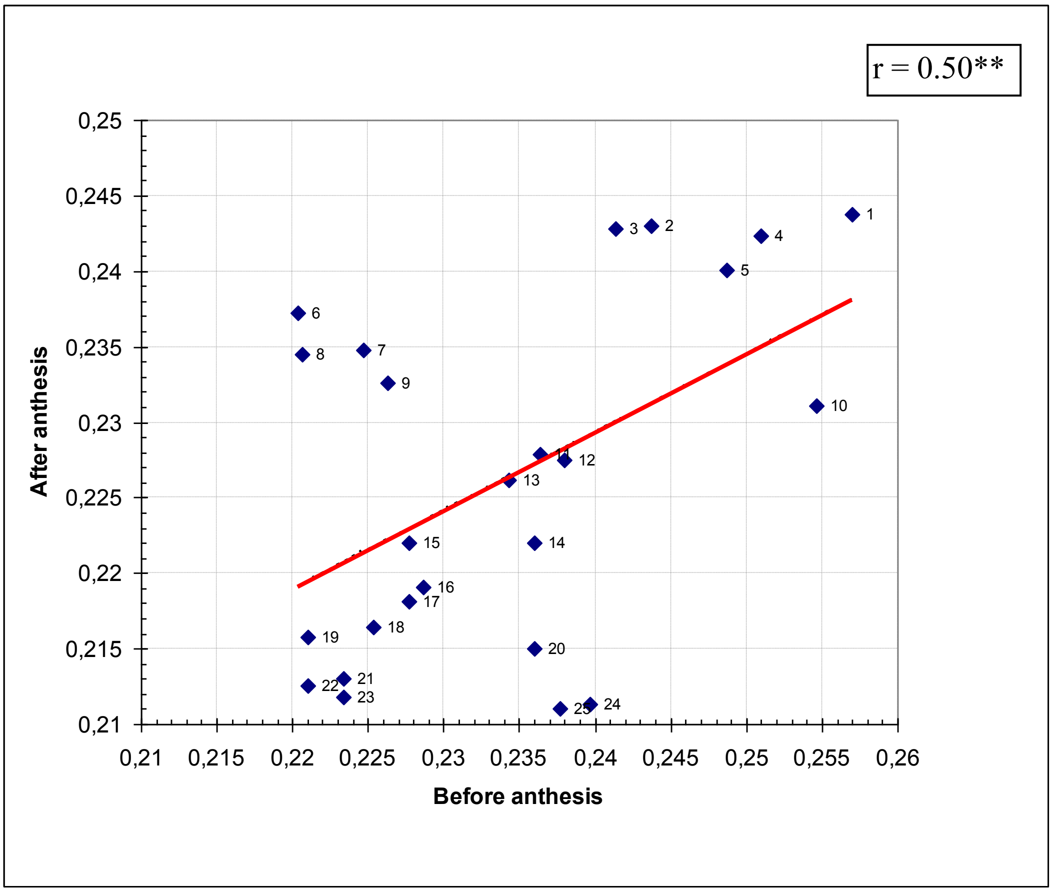

Figure 1. Relationship between crop albedo readings before anthesis (2011) and after anthesis (2012) in 25 winter wheat cultivars

Numbers in the figure correspond to the cultivar number in Table 2.

CONCLUSIONS

We identified significant differences in crop albedo among Romanian winter wheat cultivars, after anthesis. These differences were significantly, but not very closely correlated with the differences measured before anthesis, and were large enough to deserve attention for developing a breeding program to increase the wheat crop albedo, along the whole vegetation period.

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