NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 28, 2011
Print ISSN 1222-4227; Online ISSN 2067-5720

SIGNIFICANT DIFFERENCES IN CROP ALBEDO AMONG ROMANIAN WINTER WHEAT CULTIVARS

Gabriela Şerban[1], Daniel Tudor Cotfas[2], Petru Adrian Cotfas[2]

[1] National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania.
E-mail: gabyatbsg@yahoo.com

[2] Transylvania University of Brasov/Physics Department, 500036 Braşov, Bd. Eroilor, no. 29,
Braşov County, Romania

ABSTRACT

Increased reflectance (higher albedo) of solar radiation by the wheat canopy 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. The measurements of albedo were made on twenty four Romanian winter wheat cultivars and one Russian cultivar as historical check, using an albedometer based on solar cells, and found significant differences among cultivars, both between and within earliness groups. These differences can be used in a breeding program aimed at increasing crop albedo, for improving wheat performance under water and high temperature stress.

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

INTRODUCTION

A large part of the incoming net radiation reaching the crop canopies is not used for photosynthesis, but dissipated mainly by transpiration, leading to increased non-productive use of water. A reduction in transpiration can be achieved by reducing net radiation by way of reflection, namely increasing crop albedo (Blum, 2005).

Albedo is defined as the ratio of reflected radiation from the surface to global solar incident radiation upon it, and is measured on a scale from zero for no reflecting power of a perfectly black surface, to 1 for perfect reflection of a white surface. Being an important parameter of the global energetic budget, determining the albedo is useful in studying microclimates and macroclimates (Song, 1998; Diner and Kahn, 2001; Fujimaki et al., 2003; Muneer, 2004).

Genetic variation in crop albedo was reported in several crops. At the canopy level, albedo variations of up to 0.01 and 0.08 have been observed between several different commercial varieties of barley (Febrero et al., 1998) and maize (Hatfield and Carlson, 1979), respectively. Piggin and Schwerdtfeger (1973) reported daily albedo values ranging from 0.13 to 0.25 for wheat, while for individual leaves, Uddin and Marshall (1988) reported differences of up to 0.05 (abaxial surface) and 0.16 between varieties of wheat.

This variability appears to be mainly governed by differences in the thickness and characteristics of leaf waxes (Uddin and Marshall, 1988), but is also influenced by the "hairiness" of leaves or the morphology (arrangement) of the leaves in the canopy (Hatfield and Carlson, 1979).

The cropland albedo was considered to have played a role of primary importance for determining the magnitude of the global temperature change (Matthews et al., 2003). Ridgwell et al., 2009 calculated that increasing canopy albedo by 20% drives a >1ºC reduction in summertime surface air temperatures in a wide latitudinal band spanning North America and Eurasia. During the northern hemisphere summer months the introduction of increased crop canopy albedo with lighter varieties reduced local temperatures in these regions by 0.5 to 2ºC. During European summer, the higher albedo crops would help keep soil moisture at relatively high levels. This could be beneficial to agricultural productivity, while the current climate trends, with increasing temperature

Received 10 June 2011; accepted 01 July 2011

and swift drying-out during the crucial first phase of the summer has detrimental effects on European agriculture.

Using a coupled ocean – atmosphere – vegetation model (HadCM3), Singarayer et al. (2009) confirmed that increasing crop canopy albedo by 0.04 would have a regionally and seasonally specific effect, with the largest cooling of ~1°C for Europe in summer. Potentially important positive impacts of increasing crop canopy albedo on soil moisture and primary productivity in European cropland regions, due to seasonal increases in precipitation were identified, making crop albedo bio-geoengineering an attractive alternative for climate change mitigation.

Increasing the fraction of incoming photosynthetically active radiation (PAR) reflected back by the canopy does not necessarily imply a reduction in total photosynthesis and by inference, productivity. Indeed, it has been observed that, at least in some environments, glaucous („waxy”) lines of wheat exhibit higher grain yield (Merah et al., 2000).

It appears therefore that an increased albedo could contribute to improved performance under drought and heat, by reducing transpiration and canopy temperature. This could justify breeding for increased albedo, especially having in mind expected climate changes.

First step in initiating a breeding program for a specific trait is to evaluate the genetic variation available in adapted germplasm. This paper presents data on genetic variation of crop albedo among several Romanian winter wheat cultivars.

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 Braşov, were used for determining the albedo. At the date of the readings cultivars were between decimal stages 43 (boots just visibly swollen) and 59 (inflorescence completed) (Zadoks et al., 1974). Therefore, cultivars were classified into three classes of earliness according to the phenophase at the date of readings (early – stages 43 to 47, mid-early – stages 51 to 55 and late – stage 57 to 59).

An albedometer based on solar cells was used to estimate wheat crop albedo (Cotfas et al., 2008a).

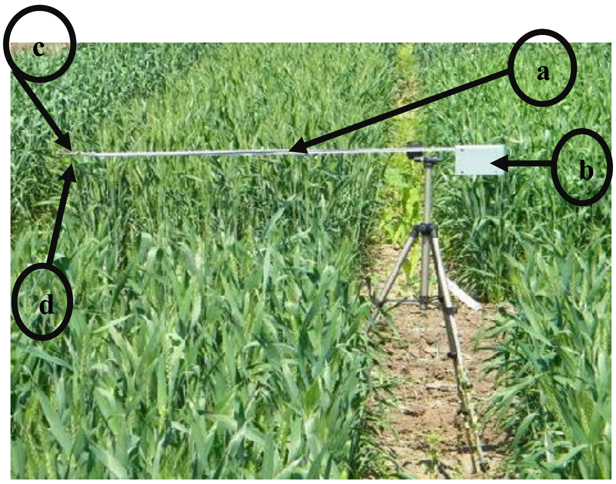

Figure1. The albedometer based on solar cells

The albedometer (figure 1) is composed of:

- two monocrystalline silicon solar cells made of mono-crystal silica (with the spectral response of 380 nm – 1200 nm) with a 3 cm^2 area, placed back to back. The solar cell (c) facing the sun measures the global solar horizontal radiation, while the solar cell (d) directed down measures the reflected radiation (Cotfas et al., 2008b).
- a system for temperature compensation including 2 temperature sensors
- a support for the sensor, ensuring the horizontality of the measurement system (a)
- the acquisition plate (b) - a wireless device Tag4M was used for the data acquisition; one of the best characteristic of this board is its coverage distance of up to 800 m in open field, making it useful tool for stand alone devices.

The software created using the graphical programming language LabVIEW allows data acquisition, correction according to the temperature of the solar cells and calculation of the albedo values. The silicon solar cells were initially calibrated, and the calibration line was introduced in the software. For each scoring a ratio between reflected radiation and global radiation given by the solar cells was calculated, corrected and averaged by the soft. Each such scoring is a point on figure 2.

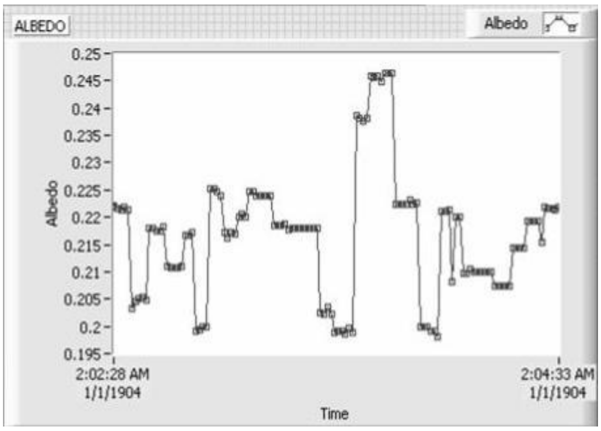

Figure 2. The value of albedo for different wheat cultivars

Measurements were performed on May 27, 2011 between 11am and 15pm hours, when the sky was cloudless, in three replications, each replication including the average of least three readings.

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).

RESULTS AND DISCUSSION

ANOVA shows that cultivars had a significant effect on the variation of albedo (Table 1). Subdividing the cultivar variance into variation between and within earliness groups reveals significant effects of both sources of variation.

It is known that wheat crop albedo varies during the growing 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). Then, during ripening leaves turn yellow and the albedo rises again.

Our data shows that, on average, cultivars that had later development had higher albedo (0.245) than mid early (0.233) or early (0.227) cultivars (Table 2). It should be noted however that the phenology effect was confounded with direct genetic effects on albedo, as all studied late cultivars originated from ARDS Turda breeding program, while all early cultivars originated from NARDI Fundulea breeding program. Within each earliness group there were significant genetic differences in albedo and there was considerable overlapping between earliness groups, with some early cultivars (Faur, Nikifor) having higher albedo than some mid-late and even late cultivars (Table 2).

The largest amplitude of variation was found within the late group (0.081), while within the mid-arly and early groups the amplitudes were 0.002 and 0.033 respectively. These amplitudes can be considered large enough to provide a basis for genetic progress in a breeding program. Other genetic resources are also available. Large differences in the thickness and characteristics of leaf waxes exist among wheat cultivars from the world collection.

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

Source of variation	SS	df	MS	F	F crit 5%
Cultivars:	0.00882	24	0.0003680	32.03	1.74
- between earliness groups	(0.004064)	2	(0.002032)	176.99	3.18
- within earliness groups	(0.004759)	22	(0.000216)	18.84	1.76
Within cultivars	0.00057	50	0.0000115		
Total	0.00939	74			

Table 2. Albedo of several Romanian witer wheat cultivars, grouped according to their earliness

Cultivar	Status	Origin	Average	Significance
Late cultivars				
T55-01	New line	ARDS Turda	0.25700	a
Dumbrava	Released cultivar	ARDS Turda	0.25467	ab
T67-02	New line	ARDS Turda	0.25100	ab
T265-01	New line	ARDS Turda	0.24367	cd
T181-01	New line	ARDS Turda	0.24133	cde
T9-01	New line	ARDS Turda	0.23800	de
T150-03	New line	ARDS Turda	0.22767	g
Average			*0.24476*	
Mid-early cultivars				
T136-03	New line	ARDS Turda	0.24867	bc
Bezostaya 1	Old cultivar	Russia	0.23967	de
Delabrad 2	Released cultivar	NARDI Fundulea	0.23767	de
T96-97	New line	ARDS Turda	0.23633	def
Boema 1	Released cultivar	NARDI Fundulea	0.22867	fg
Otilia	New line	NARDI Fundulea	0.22533	g
T66-01	New line	ARDS Turda	0.22467	g
Miranda	Released cultivar	NARDI Fundulea	0.22333	g
Average			*0.23304*	
Early cultivars				
Faur F	Released cultivar	NARDI Fundulea	0.23600	def
Nikifor	New line	NARDI Fundulea	0.23600	def
Partener	New line	NARDI Fundulea	0.23433	ef
Izvor	Released cultivar	NARDI Fundulea	0.22767	g
Litera	Released cultivar	NARDI Fundulea	0.22633	g
Ostrov	New line	NARDI Fundulea	0.22333	g
Dropia	Released cultivar	NARDI Fundulea	0.22100	g
Noroc	New line	NARDI Fundulea	0.22100	g
Glosa	Released cultivar	NARDI Fundulea	0.22067	g
Pitar	New line	NARDI Fundulea	0.22033	g
Average			*0.22666*	
		LSD 5%	0.00454	

Rye and Triticale generally have higher albedo than most wheat cultivars. Several lines, derived from Triticale/wheat crosses, have higher glaucousness than the wheat parents, and one line derived from a Triticale/2*wheat cross had a 16% higher albedo than the wheat cultivar Boema 1 (Saulescu et al., 2011).

CONCLUSIONS

We identified significant differences in crop albedo among Romanian winter wheat cultivars, within each earliness group. These differences were large enough to deserve attention for developing a breeding program to increase the wheat crop albedo.

Acknowledgements

This study is part of the PhD thesis named *Breeding wheat for reducing the impact of climate change* and was financed by the *Sectorail Operational Programme for Human Resources Development* 2007-2013 (Contract Code: POS- DRU/88/1.5/S/52614). The authors would like to thank all those who contributed to this article.

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