Evolution of chlorophyll fluorescence parameters in durum wheat as affected by air temperature

Elhani S., Rharrabti Y., García del Moral L.F., Roca L.F.

in

Royo C. (ed.), Nachit M. (ed.), Di Fonzo N. (ed.), Araus J.L. (ed.).
Durum wheat improvement in the Mediterranean region: New challenges

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 40

2000
pages 275-277

Evolution of chlorophyll fluorescence parameters in durum wheat as affected by air temperature

S. Elhani*, Y. Rharrabti*, L.F. Roca and L.F. García del Moral***
*Dpto. Biología Vegetal, Facultad de Ciencias, Universidad de Granada, Avda. Fuentenueva s/n, 18071 Granada, Spain
**Dpto. de Mejora y Agronomía, Centro de Investigación y Formación Agraria, Camino de Purchil s/n, Aptdo. 2027, 18080 Granada, Spain

SUMMARY – Twenty-five genotypes of durum wheat differing in drought resistance were grown both under rainfed and irrigated conditions in southern Spain during 1999. At the middle of the grain-filling period, chlorophyll fluorescence measurements on flag leaves were recorded in a growth chamber in the laboratory after varying the temperature from 20-60ºC at intervals of 5ºC. Significant differences were found between genotypes in the sensitivity to high temperatures. The inverse relationship found between the Fv:Fm ratio at 60ºC and the grain yield, indicate that this measurement could be of value to identify genotypes of durum wheat which are especially tolerant to heat stress.

Key words: Chlorophyll fluorescence, grain yield, durum wheat.

RESUME – *"Evolution des paramètres de fluorescence de la chlorophylle chez le blé dur affectés par la température de l'air". Vingt-cinq génotypes de blé dur différant dans leur résistance à la sécheresse ont été cultivés sous des conditions sèches et irriguées au sud de l'Espagne. Les paramètres de fluorescence ont été déterminés au laboratoire dans une chambre de croissance à un intervalle de température de 5ºC entre 20 et 60ºC. Des différences significatives ont été trouvées entre génotypes dans la sensibilité à des hautes températures. De plus une relation inverse significative a été trouvée entre Fv:Fm mesuré à 60ºC et le rendement en grains, ce qui indique que cette mesure pourrait être intéressante pour identifier les génotypes de blé dur résistants au stress thermique.*

Mots-clés : *Fluorescence chlorophyllienne, rendement en grain, blé dur.*

Introduction

In vivo chlorophyll fluorescence provides a rapid and easy method for assessing the effects of temperature stress on photosynthesis. In effect, with the chlorophyll protein complexes embedded in the thylakoid membrane, change in chlorophyll fluorescence may be considered to be a sensitive indicator for alterations in membrane fluidity, stability and organization induced by heating (Schreiberg and Berry, 1977). The ratio Fv:Fm has been demonstrated to be proportional to the quantum yield of photochemistry (Genty *et al.,* 1989) and shows a high degree of correlation with the quantum yield of net photosynthesis in intact leaves (Björkman and Demmig, 1987). The present study investigates the response of fluorescence parameters to increased temperature in flag leaves obtained from plants grown under field conditions.

Materials and methods

During 1999, 25 genotypes of durum wheat differing in drought resistance were grown both under irrigated and rainfed conditions in southern Spain. Crops were sown at an adjusted rate of 350 viable seeds/m^2 in 12 m^2 plots with four replications. To investigate their temperature tolerance, 3 plants per genotype were sampled from each environment. Later, in the laboratory, chlorophyll fluorescence parameters on flag leaves were measured with a HANSATECH Plant Efficiency Analyser P02.002, after varying temperature from 20-60ºC at intervals of 5ºC in a plant growth-chamber. Each thermal treatment was applied during 20 min and fluorescence was measured after 5 min at room temperature. To avoid secondary water stress, plants were amply watered throughout the experiment.

Results

Basal fluorescence (Fo) remained relatively stable to a temperature of 40ºC, increasing later on, especially above 45ºC. Between genotypes, significant differences appeared for all the temperatures studied, particularly above 40ºC. Similarly, significant differences appeared in the emission of basal fluorescence between the flag leaves of plants grown under rainfed or irrigated conditions. Thus, leaves from irrigated conditions consistently presented lower Fo values than those sampled from rainfed conditions. In the present study, a critical temperature of 30ºC for the beginning of the increase in Fo was found for the plants grown under rainfed conditions, while under irrigated ones, the critical temperature was 35ºC. This indicates a higher temperature sensibility of the plants grown under rainfed conditions, possibly due to a greater influence of water and temperature stresses during crop development.

The Fv:Fm ratio remained relatively stable to a temperature of 30ºC, diminishing later on, mainly above 50ºC. Again, the Fv:Fm ratio differed significantly both between genotypes and environments, differences being particularly pronounced above 45ºC. Under high temperatures, the Fv:Fm ratio was lower in leaves grown under rainfed conditions, indicating a stronger inhibition of photosynthesis for the high temperatures in this environment. In this study, a significant inverse relationship between the degree of inhibition of photosynthesis (estimated by the Fv:Fm ratio at 60ºC) and the grain yield was found (Fig.1), indicating that this measurement could be of value to identify genotypes especially tolerant to heat stress.

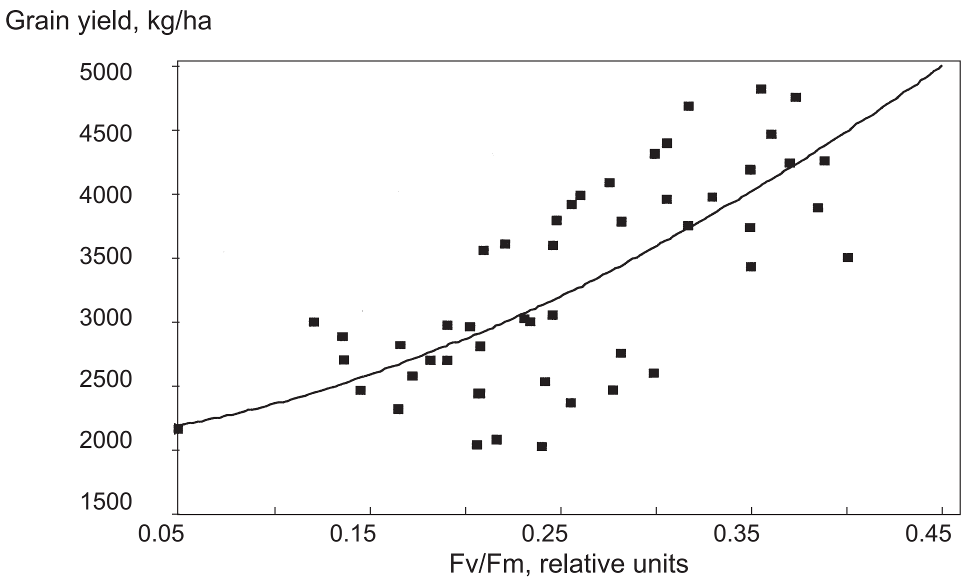

Fig. 1. Regression of grain yield on Fv:Fm values measured on the flag leaves of 25 genotypes of durum wheat subjected to 60ºC during 20 min in a growth chamber ($Y = 2070 + 10794\ X^{1.64}$, $r = 0.721^{***}$, $n = 50$).

Discussion

It is known that all of the environmental constraints affect chlorophyll fluorescence parameters (Havaux,1993; Schreiberg *et al.,*1995). Thus, Fo is affected by environmental stresses that cause structural alterations at the primary reaction centres of Photosystem II (PSII) and, therefore, thermal damage of PSII is characterised by a drastic increase in Fo (Schreiberg and Bilger, 1987). In our experiment under controlled conditions, the differences detected beteween genotypes for Fo values above the critical temperature of 40ºC indicate remarkable genotypic differences in the tolerance of Photosystem II to heat stress, especially at temperatures above 50ºC. The maximum fluorescence (Fm) and the Fv:Fm ratio decreased after exposure of leaves to high but not injurious temperatures (under 40ºC). More severe heat treatments resulted in sharp increases in Fo and decreases in Fm, accompanied by inhibition of PSII activity and lowered Fv:Fm ratios.

Conclusions

From this study, it can be concluded that the recording of Fo-temperature curves could provide a rapid means of determining heat tolerance in durum wheat. In particular, the Fv:Fm ratio measured at 60ºC could be a rapid and sensitive test to identify genotypes highly tolerant to terminal drought conditions typical of Mediterranean environments.

Acknowledgements

This work was supported by Spanish CICYT under project AGF96-1137-CO2-C2 and partially by INIA project SC97-039-C2-2. The authors wish to thank Dr. C. Royo from IRTA (Lerida) for supplying the seeds of the genotypes, Dr. J. Marinetto, M. Pelaez and A. Cabello for management of field trials, Dr. M. Nachit (ICARDA) for useful information concerning genotypic features and D. Nesbitt for correcting the English version of the text.

References

Björkman, O. and Demmig, B. (1987). Photon yield of O_2 evolution and chlorophyll fluorescence characteristics at 77K among vascular plants of diverse origins. *Planta,* 170: 489-504.

Genty, B., Briantais, J.M. and Baker, N. (1989). The relationships between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. *Biochim. Biophysisc. Acta,* 990: 87-92.

Havaux, M. (1993). La fluorescence de la chlorophylle *in vivo*: Quelques concepts appliqués à l'étude de la résistance de la photosynthèse aux contraintes de l'environnement. In: *Tolérance à la Sécheresse des Céréales en Zone Méditerranéenne. Diversité Génétique et Amélioration Variétale,* Monneveux, Ph. and Ben Salem, M. (eds). Les Colloques No. 64, Ed. INRA, Paris, pp. 19-29.

Schreiberg, U. and Berry, J.A. (1977). Heat-induced changes of chlorophyll fluorescence in intact leaves correlated with damage of the photosynthetic apparatus. *Planta,* 136: 233-238.

Schreiber, U. and Bilger, W. (1987). Rapid assessment of stress effects on plant leaves by chlorophyll fluorescence measurements. In: *Plants Response to Stress*, Tenhunen, J.D., Catarino, F.M., Lange, O.L. and Oechel, W.D. (eds). Springer, Berlin, pp. 27-53.

Schreiber, U., Bilger, W. and Neubauer, C. (1995). Chlorophyll fluorescence as a nonintrusive indicator for rapid a sessment of in vivo photosynthesis. In: *Ecophysiology of Photosynthesis*, Schulze, E.D. and Caldwell, M.M. (eds). Springer, Berlin, pp. 49-70.