Net CO_2 uptake rates for *wheat* (*Triticum aestivum* L.) under Cukurova field conditions: Salinity influence and a novel method for analyzing effect of global warming on agricultural productivity

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Goal: Investigation of crop factors that are influenced by global warming

Effect of increased temperature on agricultural productivity

Effects on water availability and salinity

Impact of CO_2: Physical measurements of daily CO_2 change under natural and greenhouse conditions

Methodology Simultaneous and continuous measurements of photosynthesis and transpiration rates of wheat leaves (*Triticum aestivum* L.) were carried out automatically at 30 min intervals under Mediterranean field conditions, using a Photosynthesis and transpiration Monitor system (PTM-48M). The coupled dynamics of net photosynthetic rate (P_N), transpiration rate (E_T), water use efficiency (WUE), light use efficiency (LUE), stomatal conductance (g_s), photosynthetically active radiation (PAR), air temperature (T), relative humidity (RH), and atmospheric CO_2 concentration (C_{atm}) were quantified at five rainfed wheat sites with the same stages of development (midflowering) along south-to-north and east-to-west transects for eight days in April.

Key results

Net CO_2 uptake rates (P_N) were measured under relatively moderate climatic conditions in Cukurove basin Turkey.The higher temperatures and lower relative humidity in the field led to a rapid response to salinity.

Fig.1

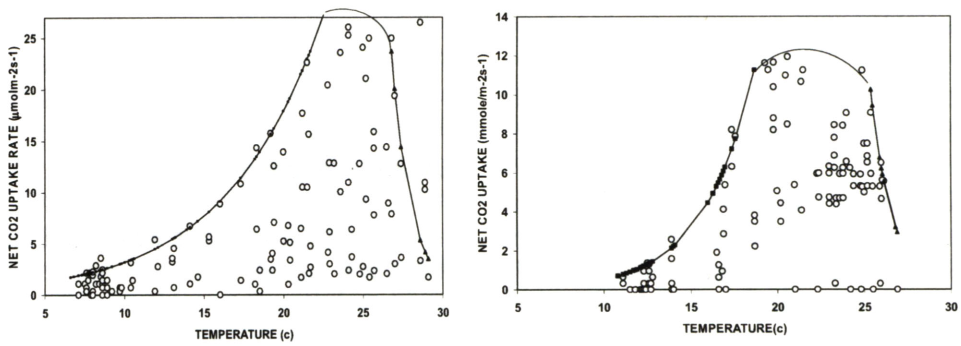

Fig.1. Temperature dependence of the net CO_2 uptake rate, P_N for salin conditions (right) andnon saline conditions (left): Data were obtained at 30 min intervals under various temperatures and degrees of water stress;

The envelopes for the rising portions were analyzed using Arrhenius equation (Eq1), and the envelopes for the falling portions were analyzed using enzymes inactivation equation (Eq 2 and 3);

$$\text{Rate}=Be^{-A/RT} \quad (1)$$

where B is a constant, A is the apparent activation energy [kJ mol^{-1}], R is the gas constant (8.314 J mol^{-1} K^{-1}), and T is the absolute temperature [K]. Using an Arrhenius plot [$\ln P_N$ *vs.* $1/T$], A, which represents the minimum energy for the reaction, was estimated for both species.

Above the optimum temperature, P_N values declined with increasing temperature, presumably representing inactivation (or deactivation; Bernacchi *et al.* 2002, Sharkey 2005) of the catalytic properties of the enzymes involved. The decline in rate with increasing temperature was assumed to be proportional to the rate:

$$d(\text{Rate})/dT=-C\times\text{Rate} \quad (2)$$

where C represents the relative fraction of inactivated molecules per unit increase in temperature. Reorganizing Eq. 2 and integrating leads to:

$$\text{Rate}=De^{-CT} \quad (3)$$

where D is a constant of integration that incorporates the particular units used. Eq. 3 was used to fit the upper envelopes of P_N above the optimal temperatures.
Parameter values are summarized in Table 1.

Table 1. Parameters for equations describing the upper envelopes of the responses of net CO_2 uptake to temperature for saline and non-saline conditions. Rising portions (below the optimal temperature) were described by Eq. 1 and falling portions (above the optimal temperature) were described by Eq. 3.

Conditions	*A*	ln *B*	*C*	ln *D*
	[kJ mol^{-1}]		[K]	
Saline (3dS/m)	240	101.7	0.83	250
Non saline (1dS/m)	118.4	51.2	0.83	252

The upper envelopes of scatter diagrams for P_N *versus* temperature which indicate the maximal rates at a particular temperature, were determined . As leaf temperature increased above 10 °C, for wheat under saline conditions (near Karatash on the easterm mediterranean) the maximal P_N increased exponentially, reaching maxima of 12 μmol m^{-2} s^{-1}near 24 °C. For wheat under more favourable conditions near Adana Turkey, as leaf temperature increased above 5 °C, the maximal P_N increased exponentially, reaching maxima of 26 μmol m^{-2} s^{-1} also near 24 °C. Based on the Arrhenius equation, the apparent activation energies of enzymatic metabolism were 118 and 240 kJ mol^{-1}, for wheat under favourable and saline conditions respectively. These values are within the range determined for a diverse group of species using different methodologies. Above the temperature of maximal P_N it decreased by an average of 55 % per 1.00 °C for the two cases. Such steep declines with temperature indicate that irrigation then may lead to only small enhancements in net CO_2 uptake ability. Global warming with only several fractions of a degree may therefore be associated with signifcant yield reduction.

Diurnal dynamics of leaf P_N and E_T were strongly coupled and highly correlated with PAR (P<0.001). The diurnal course of P_N exhibited a peak at mid-morning, and a photosynthetic midday depression under the limiting effects of low soil moisture and high evaporative demand (Fig 2)

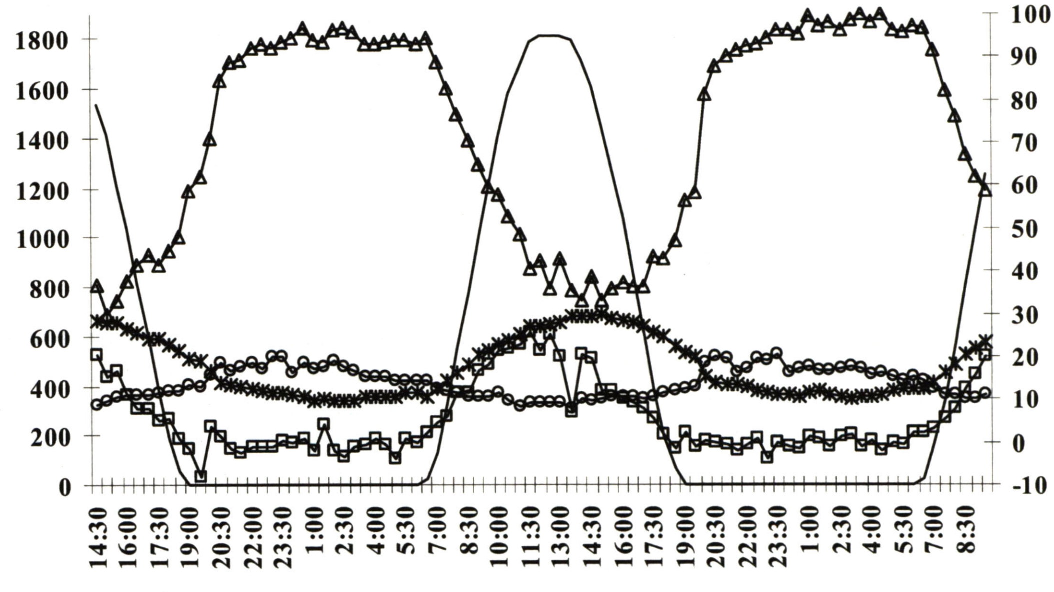

Fig. 2. Diurnal patterns of leaf net photosynthetic rate (P_N, □), photosynthetically active radiation (PAR, –), air temperature (T, ∗), relative humidity (RH, △), and atmospheric CO_2 concentration (C_{atm}, O) measured at a wheat field of the experimental station of the Department of Agricultural Structures and Irrigation of the Çukurova University in the north on April 9 to 11, 2005

Diurnal variations in WUE and LUE showed a bimodal behavior with the maximum values in early morning and late afternoon. Reductions in E_T and P_N at noon through biological control of transpiration via stomatal sensitivity were associated with decreases in g_s.

Outlook for the last year of the project

Enhanced agricultural activity may serve as an excellent agent for global carbon sequestration.Climate change could improve wheat yields, but it is not necessarily so for all crops. Similar analysis should be carried on with several other crops especially with C4 pathway. Our scenario simulations indicated crop failure when rain was below a certain threshold unless supplemental irrigation was added. Thus, the improvement in wheat yield comes along with exacerbated problems of irrigation water due to increased consumption. In the long run it is expected that soil quality and water availability continue to deteriorate while agroproductivity may be better in the short run. Thus production is still likely to decline with global warming. Water management could become a problem in the Cukurova Basin. Finally, because climate change is a long-term global environmental issue, assessing adaptation and mitigation strategies helps to encourage responsible sustainable water management.