LEAF PHOTOSYNTHESIS IN KENAF (*HIBISCUS CANNABINUS* L.) IN RESPONSE TO WATER STRESS*

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ABSTRACT: The high biomass yield and fibre content of kenaf justify the growing interest on this multipurpose crop (biomass for energy, natural fiber for industrial uses) for its potential role in agroecosystems involving biomass production as substitute of non-renewable resources. The high assimilation capacity of this C3 plant has also suggested to study the environmental performance of kenaf in term of carbon storage potential and capacity to act as carbon dioxide sink.

However few literature references report experimental results on the physiology of this multipurpose crop especially in term of assimilation rate and its relation with environmental and agronomic factors.

In order to asses the physiological, biological and agronomic response of kenaf cv. Tainung 2 to different environmental conditions, a field experiment have been conducted in internal hilly areas of Sicily during summer 2003 studying four different soil water contents (100%, 50%, 25% of Etm restoration during the whole crop cycle and irrigated only at sowing treatment). In the present work net photosynthesis response to soil water and temperature conditions are reported. In well watered condition P_{max} (maximum photosynthetic activity resulted 37.75 μmoles $m^{-2}s^{-1}$ and ε (apparent quantum efficiency) 0.0583. Both indices were negatively affected by water stress and leaf temperature.

Keywords: Irrigation, CO_2 balance, Kenaf,

1 INTRODUCTION

The high biomass yield and the elevated fibre content of Kenaf (*Hibiscus cannabinus* L.) justify the growing interest on this multipurpose crop (biomass for energy, natural fiber for industrial uses) for its potential role in agroecosystems involving biomass production as substitute of non-renewable resources[1]. The high assimilation capacity of this C3 plant has also suggested to study the environmental performance of hemp based natural fiber material in term of carbon storage potential for its capacity to act as carbon dioxide sink [2].

However few literature references report experimental results on the physiology of this multipurpose crop especially in term of assimilation rate and its relation with environmental and agronomic factors.

Aiming at studying carbon dioxide assimilation capacity in relation to different environmental condition, a field experiment have been conducted in internal hilly areas of Sicily during summer 2003 and in the present work net assimilation rate data obtained and photosynthesis response in kenaf to soil water conditions will be stressed.

2 MATERIALS AND METHODS

Carbon dioxide assimilation rate at leaf level have been measured in kenaf crop on a field experiment conducted in internal hilly areas of Sicily during summer 2003. Adopting cv Tainung 2, four different soil water contents (100%, 50%, 25% of Etm restoration during the whole crop cycle and irrigated only at sowing treatment, respectively I_3, I_2, I_1 and I_0) have been evaluated.

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The crop was sown on June 24th and harvested on December the 4th.

A randomised block experimental design with three repetitions was applied. Using the open system IRGA of the Analytical Development Com. LTD (LCA4) gas exchange at leaf level has been measured at noon on five dates (August 6th, 12th, 21st and 28th and September 6th) during vegetative phase on the last fully expanded leaf three time replicated for each plot.

Using all the assimilation rate data collected during the whole measurement period, relations have been plotted with leaf temperature (linear relation) and with photosynthetic photon flux density on leaf surface according to the widely used exponential regression curve with he following formula:

$$\mathbf{P_n = [P_{max}+R][1 - exp(-\varepsilon I/(P_{max} + R))] - R}$$

Where P_n is the actual net photosynthesis (μmoles CO_2 $m^{-2}s^{-1}$), P_{max} is the highest net photosynthesis value potentially reachable by the crop representing an asymptotic constrain, R is the respiration rate (μmoles CO_2 $m^{-2}s^{-1}$), I is the photosynthetic photon flux density on leaf surface (μmoles $m^{-2}s^{-1}$), and ε is the apparent quantum efficiency (PAR moles CO_2 $moles^{-1}$) representing the slope of the initial part of the exponential curve.

Apparent quantum efficiency obtained for each data collected have been plotted against leaf temperature as well, aiming at verifying the response of the assimilation capacity of the crop to temperature in the different adopted soil water content treatments.

3 RESULTS AND DISCUSSIONS

3.1 Meteorological data

During the growing season, maximum air temperature ranged between 35 and 42°C and minimm air temperature between 16 and 25°C. No rainfalls occurred between sowing and the end of September.

3.2 Leaf Net Photosynthesis during the whole measurement period

For all the measuring dates (Fig. 1), in the best water conditions (I_3) the crop maintained the highest net photosynthesis level (28.4 μmoles CO_2 m^{-2} s^{-1}, in the average of the five measurements), compared to I_2 (21.3 μmoles CO_2 m^{-2} s^{-1}), I_1 (17.8 μmoles CO_2 m^{-2} s^{-1}) and I_0 (15.5 μmoles CO_2 m^{-2} s^{-1}).

From the first measurement onward, a slight reduction in net assimilation activity was observed in all water treatments. The last field measurement occurred just few hours after a rainfall, which determined a relevant increase in Pn, irrespective of the water regime.

Kenaf is a C3 crop but the observed net assimilation rate resulted quite high especially during the first measurement (36 μmoles CO_2 m^{-2} s^{-1} for I_3 and 29 μmoles CO_2 m^{-2} s^{-1} for I_1); this contribute to explain the high growth rate, which makes this crop very interesting in term of biomass production and carbon sequestration.

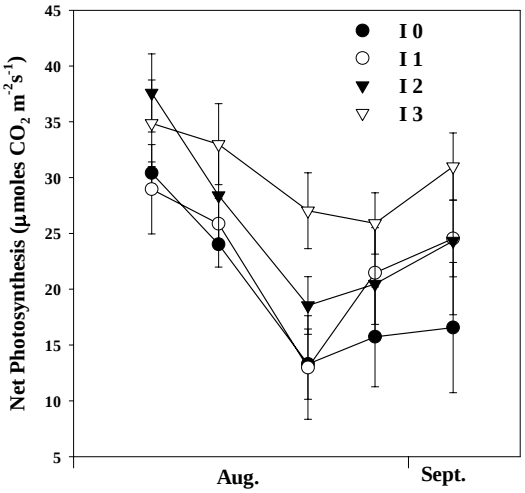

Figure 1: Net photosynthetic rate variation during the field measurement period in the different soil water content treatment

3.2 Relation between net photosynthesis and photosynthetic photon flux density

In order to define the maximum photosynthetic activity (P_{max}) and the apparent quantum efficiency (ε), the equation previously reported was considered adopting the values of respiration measured during night measurement as reported in a note in the same issue [3].

Plotting net photosynthesis data *vs* light intensity (PAR in terms of Photosynthetic Photon Flux Density-PPFD), the exponential regression curve applied allowed to individuate P_{max} and ε (apparent quantum efficiency in each treatment).

In well watered conditions P_{max} was 37.75 μmoles $m^{-2}s^{-1}$. This index decreased, with the reduction of water supplied, to 31.89, 29.96 and 33.82 μmoles $m^{-2}s^{-1}$ have been respectively obtained in I_2, I_1 and I_0 treatment (Fig. 2).

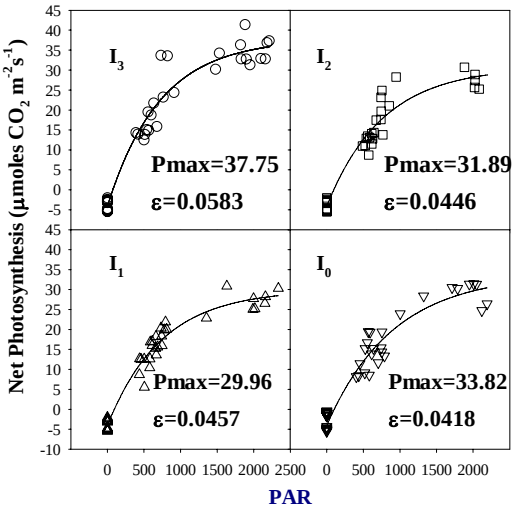

Figure 2: Net photosynthetic rate in relation to photosynthetic photon flux density in the different soil water content treatments

Apparent quantum efficiency, equal to 0.0583 in well water water conditions, diminished as well with reduction of soil water content (0.0446, 0.0457 and 0.0418 respectively for I_2, I_1 and I_0).

3.3 Relation between net photosynthesis and leaf temperature

Using all the data collected, the relation between leaf temperature and net photosynthesis was also studied in each treatment (Fig. 3). Irrespective of soil water conditions, a negative correlation was described, being the assimilation capacity reduced by increasing of leaf temperature (r= -0.76*, -2.0***, -1.35** and -1.82***, in I_3, I_2, I_1 and I_0 respectively).

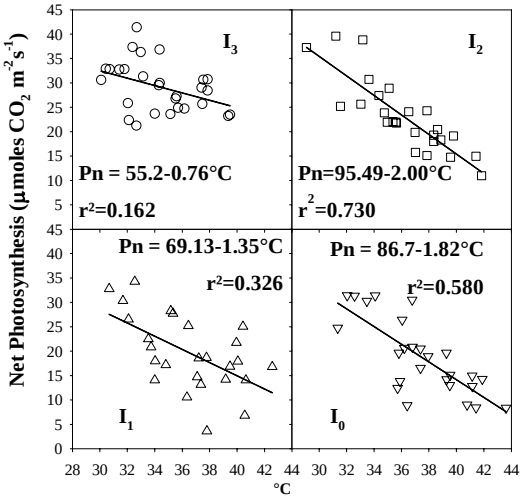

Figure 3: Net photosynthetic rate in relation to leaf temperature in the different soil water content treatments.

3.4 Relation between apparent quantum efficiency and leaf temperature

Regarding quantum efficiency (CO_2 μmoles m^{-2} s^{-1} assimilated *v*s μmoles m^{-2} s^{-1} PPFD) using all the data reported, negative relations with leaf temperature have been observed for all the soil water content treatment (Fig. 4).

The assimilation capacity for each incident light unit (photon), steeply decreased when leaf temperature increased from 26° to 40°-42°C. Regression coefficient (-0.0017***, -0.0014***, -0.0014*** and -0.0013** for I3, I2, I1 and I0 respectively) showed that, for each incrementing °C degree, almost the 4% of quantum efficiency was lost.

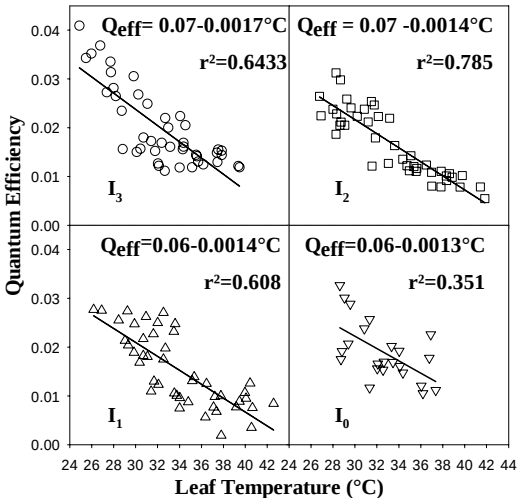

Figure 4: Apparent quantum efficiency rate in relation to leaf temperature in the different soil water content treatments.

These relations demonstrate as, at high thermal conditions the kenaf, as a C3 species, reduces its photosynthetic efficiency, probably due to photorespiration losses.

4 CONCLUSIONS

Kenaf is a C3 crop but the observed net assimilation rate resulted quite high and contributes to explain the high crop growth rate that make this crop very interesting in term of biomass production and carbon sequestration.

Moreover, the definitions of maximum photosynthetic rate (Pmax) and apparent quantum efficiency (ε) and their relations with air temperature and soil water content may help to develop simulation models of the growth of the crop to be used for wide territorial studies.

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6 REFERENCES

[1] S.L. Cosentino, V. Copani, Agroindustria, (2003), 2, 2/2:137-145

[2] M. Pervaiz, M.M. Sain, Resources, Conservation and Recycling (2003), 39: 325- 340

[3] E. Riggi, S.L. Cosentino, M. Mantineo, II World Conference on Biomass (2004). Roma 10-14 Maj.