http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 6 (5): 441-444, 2003
ISSN 1028-8880

Drought Stress Effects on Water Relations of Rice Grown in Nutrient Film Technique

K. P. Halder and S. W Burrage
Imperial College of Science, Technology and Medicine, University of London, UK

Abstract: Rice plants grown in nutrient film technique (NFT) to evaluate the effect of intermittent water stress on water relations, transpiration rate and leaf temperature. It was observed that the total water uptake by the plant, leaf relative water content (RWC), leaf water potential and rate of transpiration were decreased with increasing water stress. The transpiration rate was also decreased with increasing water stress but the leaf temperature increased. There was a positive correlation between (R^2=0.81) leaf temperature and RWC and between leaf temperature and transpiration (R^2= 0.68).

Keywords: Drought stress, NFT, *Oryza sativa* L. and water relations

Introduction

Drought stress in the growing medium leads to water deficit in leaf tissue, thus affecting many physiological processes with ultimate consequences on the growth and yield of crop (Kramer, 1983; Samuel and Paliwal, 1993). A physiological approach would be the fair way to develop new cultivars rapidly but breeding for specific, suboptimal environments involves a deeper understanding of the yield developing processes (Blum, 1983; Turner and Nicolas, 1987).

Some plant species can adapt to water stress by adjusting osmotically, so that, the physiological activity is maintained at low leaf water potential (Kramer, 1983). Leaf water potential is considered to be a reliable parameter for quantifying plant water stress response (Siddique *et al*., 1999). Cruz *et al*. (1986) reported that the photosynthetic rate of rice leaves is highly susceptible to drought stress and it is decreased by 60% when leaf water potential decreased from -0.6 to -1.3 MPa. Tanguilig *et al*. (1987) observed that the high transpiration rate in rice leaves may have caused the rapid decline in leaf water potential if proper amount of water is not supplied to the growing medium. Sinclair and Ludlow (1985) noted that leaf relative water content (RWC) is a better indicator of water status than leaf water potential.

To know the better understanding about drought stress effects on water relations in rice, this experiment was conducted in nutrient film technique (NFT) and stressed period was considered until the plant received a set amount of solar radiation.

Materials and Methods

The experiment was carried out in the glasshouse unit of the Department of Agricultural Sciences, Imperial College of Science, Technology and Medicine (Wye- Campus), University of London, UK during May to October, 1998.

Rice (*Oryza sativa* L. *cv*. BR 24) seeds were germinated in an incubator at constant temperature of 30^{0}C for 48 hours. After germination, the individual germinated seeds (with radicles emerged already) were placed in small wetted rock wool cubes (2.54 x 2.54 x 3.80 cubic mm). The cubes were placed in trays in a glasshouse at a temperature of 26 ^{0}C day and night. After 5 days, when the seedlings had reached 3 - 4 cm height, they were given equal amount of the mixture of 1% stock solution A and 1% stock solution B of Wye nutrient solution (Varley and Burrage, 1981). After 10 days when the seedlings had reached 15-16 cm height, they were chosen for uniformity and transferred to larger rock wool cubes (10 x 10 x 6.5 cubic mm). Then the larger rock wool cubes were transferred to the NFT system.

Each gully contained 12 plants. The end two plants in each gully were considered as guard row plants. Tap water was circulated through the gullies for three days to encourage root growth and development before adding the nutrient solution. The electrical conductivity (EC) of the nutrient solution was maintained 3.0 mS cm^{-1}. The solution P^H was maintained at 5.5-6.5 by using 5% acid mixture of nitric and orthophophoric acid (3:1). The plant spacing was 20 cm within the row and 20 cm between rows. Day and night temperatures were set at 27 and 21^{0}C respectively. Ventilation of the cubicle was set at 29 ^{0}C.

During the vegetative phase the nutrient solution was circulated continuously in all treatments. Intermittent water stress treatments were applied from 15 days after panicle initiation (PI) to maturity of the crop.

Water stress was imposed in relation to solar radiation received by the plant because the water loss by a plant through transpiration depends upon the availability of solar energy received. To develop a controlled stress on plants, water was withheld from the plant according to the amount of radiation it received. The greater amount of

Table 1: Detail of treatments

Treatments	From 15 days after PI to panicle emergence	From panicle emergence to maturity
T_1 = minimal stress	Continuous circulation (Control)	Continuous circulation (Control)
T_2 = low stress	0.30 MJ m^{-2} solar radiation received then 15 minutes nutrient solution circulation.	0.60 MJ m^{-2} solar radiation received then 15 minutes nutrient solution circulation.
T_3 = medium stress	0.60 MJ m^{-2} solar radiation received then 15 minutes nutrient solution circulation.	1.20 MJ m^{-2} solar radiation received then 15 minutes nutrient solution circulation.
T_4 = high stress	1.20 MJ m^{-2} solar radiation received then 15 minutes nutrient solution circulation.	2.40 MJ m^{-2} solar radiation received then 15 minutes nutrient solution circulation.

radiation received before irrigation (nutrient solution circulation) was applied. The water stress treatments were adjusted by controlling the period between recirculation of the nutrient solution by means of a computer connected to a tube radiometer. The total radiation received within the glasshouse was integrated and the pumps were switched on for fifteen minutes after a fixed amount of energy according to the treatment inside the glasshouse had been received. T_1 plants received continuous circulation of nutrient solution during day and night. The other treatments did not receive any circulation of nutrient solution at night. The treatments were laid out in a randomized complete block design with each treatment replicated four times.

Total water uptake by the plants, leaf water potential, relative water content, and net photosynthetic rate were measured during the experimental period (Table 1).

Water uptake: The water uptake per plant was measured from the treatment applied to the final harvest of the crop by the depletion of the water in the nutrient solution each day and was calculated for the number of plants present in each gully as follows:

$$\text{Water uptake (ml plant}^{-1}) = \frac{\delta V}{n}$$

where

δv = volume of water added each day (ml),

n = number of plants

Leaf water potential: Leaf water potential was measured by using pressure chamber. It was measured between 1100 and 1400 h, because Fischer and Sanchez (1979) reported that leaf water potential was reasonably stable during noon. Three topmost fully expanded leaves in each replication were collected. Leaves were covered with a plastic bag, then excised 1 cm below the collar, and carried to the pressure chamber. A clip was attached near the cut end of the leaf so that the leaf remained attached with the plastic bag. The chamber was sealed, air tight and pressure inside the chamber was increased slowly and gradually with compressed N_2 gas until sap droplets appeared on the cut end of the leaf. Small droplets were detected with a hand lens and reading was taken immediately on the pressure gauge.

Relative water content of leaves (RWC): The water content relative to that at full saturation and expressed, as relative water content was determined. For the estimation of RWC 10 leaf blades (discs), 10mm in diameter were punched with a borer from a set of leaves into a reweighed sealed vial. After the fresh weight (FW) had been obtained, the discs were floated for 24 h on distilled water in covered perti dishes kept at low light intensities and in a constant temperature room (20°C), until they became fully turgid. The discs were surface dried, returned to the same vial and reweighed to obtain the turgid weight (TW). Finally, the leaf discs were oven dried at 80°C to a constant weight (almost 12 hours) and weighed again to obtain the dry weight (DW). The RWC on a percentage basis was calculated using the equation of Schonfeld *et al.* (1988).

$$\text{RWC} = \frac{\text{FW-DW}}{\text{TW-DW}} \times 10$$

Measurement of photosynthetic rate: Net photosynthetic rate, transpiration rate and leaf temperature were measured on the second top most fully expanded leaf non-destructively at 5 to 7 days intervals from the initiation of treatment to the maturity of the crop by using a portable carbon dioxide leaf chamber analysis (IRGA), type LCA-3, supplied by the Analytical Development Company (ADC), Hoddesdon, Herts, UK. The unit incorporates a controlled air supply for a Parkinson leaf chamber (PLC), an auto-zeroing, solid state carbon dioxide analyzer and also data processing and storage.

Results and Discussion

Water uptake, relative water content and leaf water potential: Water stress significantly decreased the water uptake by the plant and relative water content in the plant leaves (Table 2).

During the non-circulation period (1-4 hours, depending upon the intensity of solar radiation) of nutrient solution,

Table 2: Water uptake, relative water content (RWC) and leaf water potential (LWP) of rice plant as affected by intermittent water stress grown in NFT

Treatment	Total water uptake (ml plant $^{-1}$)	Relative water content (%)	Leaf water potential (MPa)
T1	26634a	78.68a	-0.1452a
T2	20750b	76.63b	-0.1488b
T3	16400c	72.55c	-0.1526c
T4	13370d	70.70d	-0.1601d
LSD (0.05)	2680.26***	0.443***	0.0041***

Mean followed by different letters in the same column differs significantly at the 5% level by Lsd test.
*** = significant at P <0.001

Table 3: The effect of intermittent water stress on transpiration and leaf temperature of rice grown in NFT. Photosynthetically active radiation (PAR)= (595.3 ± 51.4) µmol m^2 s^{-1}

Treatments	Transpiration (µmol m $^{-2}$ S $^{-1}$)	Leaf temperature (0^c)
T1	185.6a	30.4d
T2	156.8ab	31.0c
T3	123.4bc	31.5b
T4	87.4c	31.9a
LSD (0.05)	40.7***	0.40***

Mean followed by different letters in the same column differs significantly at the 5 % level by Lsd test.
*** = Significant at P <0.001, Air temperature (28.6 ± 0.6) 0^c

the plants of the water-stressed treatments absorbed water from the rock wool cubes as well as that water present on the root surfaces. However, during the water stress period, the water available to the root zone of the plants of water-stressed treatments was limited and deceased as the rock wool cubes and root surfaces dried out. As a result the water-stressed plants were therefore unable to absorb water as the same rate as the control plants. Hence the water uptake decreased in the water-stressed plants. This result is agreed with the findings of Fischer and Sanchez (1979). They observed that the absorption of water by the plants is governed in part by soil factors such as water content and unsaturated conductivity. When the soil dries, water uptake by the roots becomes more difficult and uptake declines.

This reduction in water used eventually results in the development of a water deficit in the shoot as a result relative water content decreased. The decreased in RWC in stressed plants might be due to decreased in plant vigour. These results are agreed with the findings of Techawongstin *et al.* (1993).

It was generally observed that the higher the leaf water potential and RWC, the higher was the photosynthetic rate. There was a positive correlation (R^2=0.64, P<0.001) between net photosynthesis rate and leaf water potential (Fig. 1) and between net photosynthesis rate and RWC (R^2=0.67, P<0.001) (Fig. 2). This result agreed with the findings of Cruz *et al.* (1986).

The leaf water potential significantly decreased from -0.1452 to -0.01601 MPa with increasing water stress (Table 2). Under drought stress condition the solute concentration in the root zone may be increased which decreased the permeability of the roots and reduced water uptake by the roots as a results declined leaf water

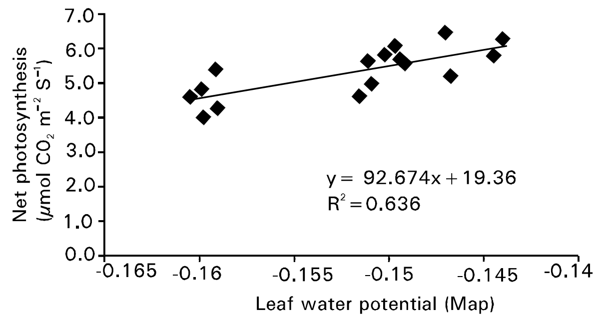

Fig. 1: Relationship between net photosynthesis rate and leaf water potential of rice

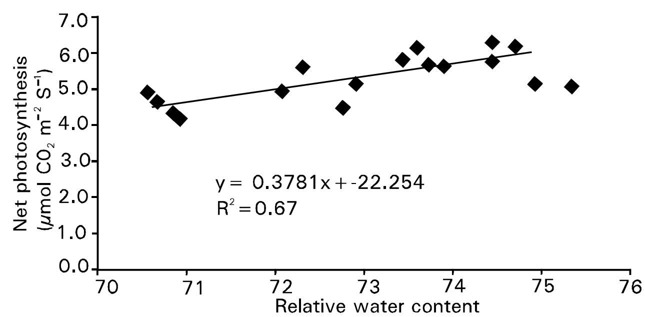

Fig. 2: Relationship between net photosynthesis rate and relative water content in rice

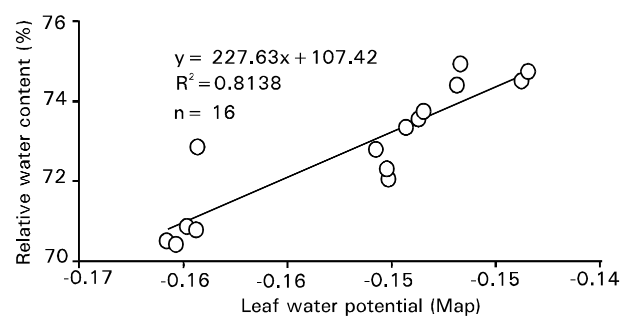

Fig. 3: The relationship between leaf water potential and relative water content

potential. Similar observation was also made by Cruz *et al.* (1986) in rice, Siddique *et al.* (1999) in wheat. Fig. 3 showed that there was a positive correlation between leaf relative water content (RWC) and leaf water potential (R^2=0.81, P<0.001) suggested that RWC is also an

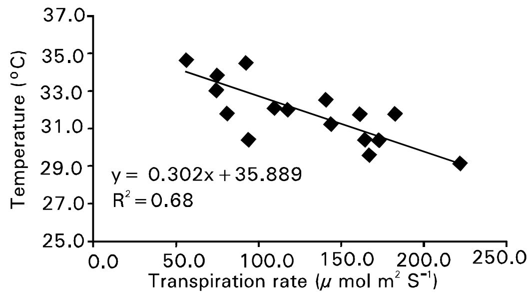

Fig. 4: The relationship between temperature and transpiration rate

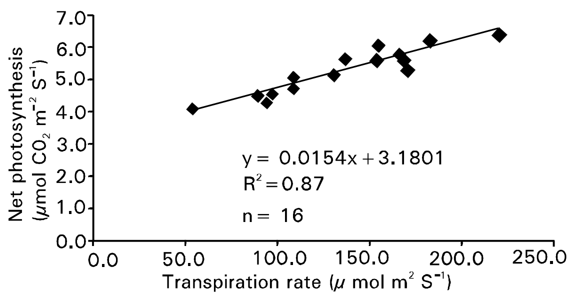

Fig. 5: The relationship between photosynthesis and transpiration

indicator of water status of plants as in found by Sinclair and Ludlow (1985).

Leaf temperature and transpiration: The leaf temperature increased significantly with increasing water stress whereas the transpiration rate decreased with increasing water stress (Table 3).

The increase in leaf temperature of the water-stressed plants is most likely due to reduction of the rate of transpiration. These results are agreed with the findings of Jackson and Volk (1970).

They reported that increases in leaf water deficits and decreases in stomatal conductance reduce the rate of transpiration, reducing the "cooling effect" of transpiration on the leaf and as a result leaf temperature increases which might be reflected in the negative relationship (R^2=0.68, $P<0.001$) between leaf temperature and transpiration rate (Fig. 4). Yoshida (1981) reported that transpiration cools the leaves, as 590 calories are required to remove 1.0 g of water transpired. Fig. 5 also showed that there was a strong positive relationship between net photosynthesis rate and transpiration rate (R^2=0.87, $P<0.001$). This result supports the findings of Tanguilig *et al.* (1987). They reported high evaporative demand increased leaf transpiration rate that decreased the leaf water potential. When leaf water potential decreased then net photosynthetic rate reduced as already mentioned earlier.

Basis on these results, it may be concluded that relative water content (RWC), leaf water potential and transpiration rate decreased with decreasing the water uptake by the plants.

References

Blum, A., J. Mayer and G. Gozlan, 1983. Associations between plant production and some physiological components of drought resistance in wheat. Plant, Cell and Environment, 6: 219-225.

Cruz, R.T., J.C. O. Toole, M. Dingkuhn, E.M. Yambao and M. Thangaraj, 1986. Shoot and root response to water deficits in rainfed lowland rice. Australian J. Plant Physiol., 13: 567-575.

Fischer, R.A. and M. Sanchez, 1979. Drought resistance in spring wheat cultivars. 11. Effects on plant water relations. Australian J. Agril. Res., 30: 801-814.

Jackson, W.A. and R.J. Volk, 1970. Photorespiration. Annual Review, Plant Physiol., 21: 385-432.

Kramer, P.J., 1983. Water relations of plants. New York, pp: 489.

Samuel, K. and K. Paliwal, 1993. Effect of water stress on water relations, photosynthesis, and element content of tomato. Plant Physiol. and Biochem., 21: 33-37.

Schonfled, M.A., R.C. Johnson, B.F. Carver and D.W. Mornhinweg, 1988. Water relations in winter wheat as drought resistance indicator. Crop Sci., 28: 526-531.

Siddique, M.R.B., A. Hamid and M.S. Islam, 1999. Drought stress effects on photosynthetic rate and leaf gas exchange of wheat. Botanical Bulletin of Academia Sinica, 40:141-145.

Sinclair, T.R. and M.M. Ludlow, 1985. Who taught plants thermodynamics? The unfulfilled potential of plant water potential. Aust. J. Plant Physio., 33: 213-217.

Tanguilig, V.C., E.B. Yambao, J.C. O. Toole and S.K. De Datta, 1987. Water stress on leaf elongation, leaf water potential, transpiration and nutrient uptake of rice, maize and soybean. Plant and Soil, 103: 155-168.

Techawongstin, S., E. Nawata. and S. Shingenaga, 1993. Recovery in physiological characteristics from sudden and gradual water stress in hot-peppers. In: C.G. Kuo (eds.), Adaptations of food crops to temperature and water stress. Proc. of an International Symposium, Taiwan, 13-18 August, 1992. AVRDC, Taiwan, pp: 140-147.

Turner, N.C. and M.E. Nicolas, 1987. Drought resistance of wheat for light-textured climate. In: Srivastava, J.P., Proceddu, E., Acevedo, E. and Varma, S (eds.), Drought tolerance in winter cereals. John Wiley and Sons, New York, pp: 203-216.

Varley, J. and S. Burrage, 1981. Nutrient film technique. New solution for lettuce. Grower, 95: 19-21.

Yoshida, S., 1981. Fundamentals of rice crop science. International Rice Research Institute, Los Banos, Laguna, Philippines, pp: 269.