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Effect of intermittent water stress and nutrient solution electrical conductivity on nutrient uptake by rice plant

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Abstract

Rice plants were grown using nutrient film technique (NFT) to evaluate the effect of intermittent drought stress in terms of solar radiation (0.60 MJm^{-2}) received by the plant and electrical conductivity (EC) of nutrient solution on nutrient uptake by different parts of plant. Water stress and solution EC had significant effect ($P<0.05$) on nutrient uptake but their interaction effect was not significant. In whole plant, irrespective of water stress and solution EC, the nutrient (P, K and Mg) uptake gradually increased reaching maximum at the final harvest but N and Ca decreased at the final harvest. Plants grown in the EC 3.0 solution had a significant ($P<0.01$) increased in the amount of N, P, K, Ca and Mg than EC 2.0. The same trend also observed in leaves and stems. In roots, water stress decreased the uptake of N and K at DATI (days after treatment imposed) 15 and 30 and; Mg at DATI 15. Water stress had no significant effect on P uptake. There was no consistent trend on uptake of Ca. Plants grown in EC 3.0 solution had significantly ($P<0.05$) greater P uptake at DATI 0 and 30, Mg at DATI 0 and 15 and; K at all the sampling dates. The uptake of N increased in EC 2.0 plants at DATI 45. In panicles, regardless of water stress and solution EC, the uptake of nutrients increased from flowering to final harvest.

Keywords: Water stress, Solution EC, Nutrient uptake and *Oryza sativa* L

Introduction

Many workers reported that water stress reduced nutrient uptake by plants (Gates, 1955; Hsiao, 1973; O'Toole and Baldia, 1982; Yambao and O'Toole, 1984). They found this was due to one or more of the following factors such as reduced transpiration, less active nutrient absorption or impaired transport mechanisms in the roots. But, Tanguilig *et al.,* (1987) reported another possible cause that water stress inducing reduced dry matter accumulation, thereby decreasing the demand for nutrients. Mederski and Wilson (1960) observed that the uptake of phosphorus (P), potassium (K) and magnesium (Mg) by the plants decreased linearly with the decreasing of soil water content. Greenway and Klepper (1969) found that the amount of nutrients that can be transported to the shoots depends on the capability of the roots to absorb nutrients from the soil and transport them through the transpiration stream. O'Toole and Baldia (1982) reported that water stressed rice plants continued taking up nutrients but the uptake rates were not as high or as responsive to changes in evaporative demand and transpiration rate as in the control plants.

There is no available information on water stress and nutrient solution EC on nutrient uptake by different plant parts of rice grown using nutrient film technique (NFT). Therefore, this experiment was undertaken for better understanding about water deficit and nutrient solution EC effect on nutrient uptake by different plant parts of rice plant.

Materials and Methods

This trial was conducted in the glasshouse unit of the Imperial College at Wye, University of London, UK, during 1999-2000. Rice (*Oryza sativa* L), cultivar BR 24 was used in this experiment. Seeds of rice were germinated in an incubator at a constant temperature of 30^0C for 24 hours. The germinated, individual seeds 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 plants 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. After that half of the plants were grown in a nutrient solution of EC 3.0 mS cm^{-1} and other half of the plants in a nutrient solution of EC 2.0 mS cm^{-1}. The solution pH was maintained at 5.5-6.5 by using 5% acid mixture of nitric and orthophosphoric acid (3:1). The nutrient solution EC and pH were measured and adjusted daily. The nutrient solution EC was adjusted as EC 3.0 mS cm^{-1} and EC 2.0 mS cm^{-1} by mixing equal amounts of Wye solution A and B with water, as per required (Varley and Burrage, 1981). The plant spacing was 20 cm X 20 cm. Day and night temperatures of the cubicle were set at 27 ^{0}C and 21 ^{0}C respectively. Ventilation of the cubicle was set at 29 ^{0}C.

Water stress was applied in relation to solar radiation received by the plant since the water loss by a plant through transpiration depends upon the availability of solar energy received. To develop water stress on plants, water was withdrawn from the plant until the plant received 0.60 MJ m^{-2} solar radiation. 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 0.60 MJ m^{-2} solar radiation received by the plant within the glasshouse.

Two water stress treatments [CC= Continuous circulation of nutrient solution throughout the life cycle, RS= Water stress was imposed from panicle initiation (PI) to maturity of the crop] and two level of nutrient solution EC (3.0 mS cm^{-1} and EC 2.0 mS cm^{-1}) were used. The treatments were replicated four times and laid out in a randomized complete block design (Factorial).

Plant sampling were made at 15 days intervals from water stress imposed until final harvest of the crop. Details of the growth phases, sampling days and the times at which different water stress treatments were applied are given in Fig. 1.

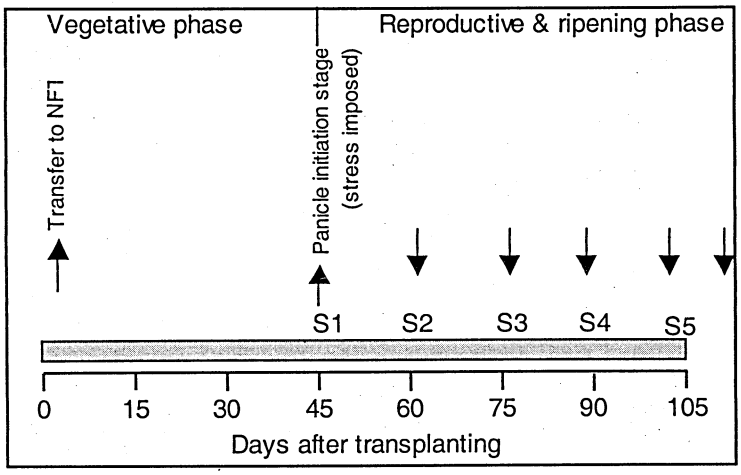

Fig. 1. Growth phases of rice indicating water stress imposed and different sampling days. (S1 to S5 represents sampling days). S1= 0 Days after treatment imposed (DATI), S2= 15 DATI, S3= 30 DATI, S4= 45 DATI and S5= 60 DATI.

The collected plants were separated into leaf, stem (stem + leaf sheath), panicle, grain and root. The plant material was oven dried at 75 ^{0}C to a constant weight. Dry plant material was stored in a dry place at room temperature. Before chemical analyses, the samples were placed in the oven overnight at 75^{0}C and then ground using a ball mill. The plant material was treated by wet (Kjedhal) digestion (Allen, 1989). Digestion was performed in boiling tubes containing 0.2 g of dried, ground plant sample and 4 ml of digestion reagent. The tubes were subsequently placed in a block heater at 150 ^{0}C for the first 2 hours and at 350 ^{0}C for another 4 hours. The tubes were allowed to cool; the digest was then filtered, made up to 50 ml with de-ionised water and stored in polythene bottle.

Analyses for the concentration (%) of N and P were carried out with an auto analyser (Burkard SFA2) and for K using a flame photometer (Corning 410). The concentration (%) of Ca and Mg was determined by atomic absorption (Pye Unicam, model SP9 with air acetylene flame).

The nutrient uptake was calculated by the following formulae; nutrient uptake= % Nutrient X Dry weight of plant.

Analysis of variance was carried out on the results followed by the use of the least significant difference to compare the differences in treatment means using Genstat Computer Software Program.

Results and Discussion

Water stress and nutrient solution EC had significant ($P<0.05$) effect on nutrients (N, P, K, Ca and Mg) uptake by the plant but the interaction effect between water stress and EC was not significant. Therefore, only main effects (water stress and nutrient solution EC) are presented and discussed below:

Nutrient in the whole plant: The accumulated nutrient in the whole plant is presented in Fig.2 (a-j). Irrespective of water stress and nutrient solution EC the nutrients (P, K and Mg) uptake by the whole plant gradually increased during the experiment, reaching maximum at final harvest with exception of N and Ca. The uptake of N and Ca reached a maximum at DATI 45.

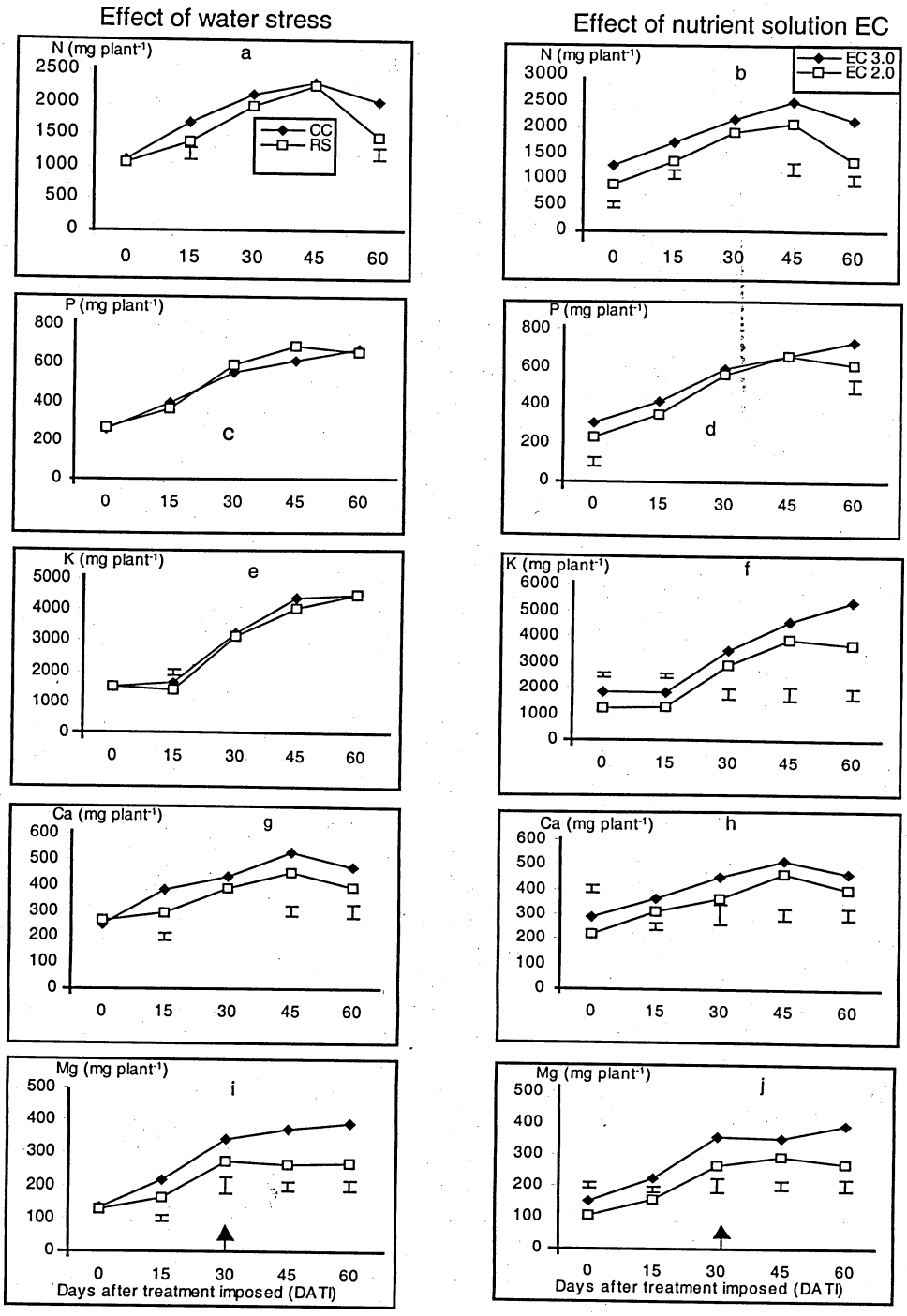

Fig. 2(a-j). Nutrient uptake by the whole plant of rice as influenced by water stress and nutrient solution EC grown in NFT. Vertical bar represents the LSD (0.05) value for comparing water stress and comparing EC. CC=Minimal stress, RS= Reproductive & ripening phase stress. Arrow at 30 DATI indicates the flowering stage

Water stress significantly (P<0.01) decreased the N accumulation at DATI 15 and at final harvest (DATI 60). There was no significant effect of water stress on the uptake of P. The uptake of K was significantly (P<0.05) decreased when the plants were water stressed at DATI 15. The uptake of Ca and Mg was significantly (P<0.05) decreased at all the sampling dates with the exception of Ca at the flowering stage (DATI 30). In this experiment, circulation of nutrient solution to the roots were stopped periodically, affected the nutrient uptake by the roots in the water-stressed plants as a result decreased the amount of nutrient in different parts of the plant. This is an agreement of Mederski and Wilson (1960); Begg and Turner, (1976); Tanguilig *et al.* (1987). They reported that water stress reduces the uptake of N, P, K, Mg and other elements with the reduction of water content in the growth medium might be due to reduced growth caused by water stress resulting in a reduced demand by the plant. The other possible causes of reduced uptake of nutrients are reduced transpiration, less active nutrient absorption or impaired transport mechanisms in the roots (Gates, 1955; Hsiao, 1973; O'Toole and Balida, 1982; Yambao and O'Toole, 1984).

Plants grown in the EC 3.0 solution had a significant (P<0.01) increase in the amount of N uptake at all the sampling dates except at the flowering stage (DATI 30). Increased P uptake by EC 3.0 plants was significantly greater (P<0.01) at the DATI 0 and at the final harvest (DATI 60). The uptake of K, Ca and Mg increased significantly (P<0.05) in the EC 3.0 plants at all the sampling dates.

Nutrient in leaves: The nutrient uptake by leaves is presented in Fig.3 (a-j). Irrespective of water stress and nutrient solution EC, the uptake of N, P and Mg reached a maximum level at the flowering stage (DATI 30). The uptake of K and Ca reached a maximum level 15 days after flowering stage i.e. at DATI 45.

Water stress significantly (P<0.001) decreased the uptake of N at DATI 15. The uptake of P significantly (P<0.001) decreased in the water-stressed plants at DATI 15. Water stress had no significant effect on uptake of K and Ca. The uptake of Mg significantly (P<0.05) decreased in the water -stressed plants at DATI 15 until final harvest.

Plants grown in the solution EC 3.0 had a significant (P<0.05) increase in the uptake of N, K and Mg. There was no significant effect of EC on the uptake of P and Ca.

Nutrient in stems: The ion uptake by stems is presented in Fig.4 (a-j). Irrespective of water stress and nutrient solution EC, the uptake of N, P and Mg reached a maximum level at the flowering stage (DATI 30) whereas the uptake of Ca reached a maximum level 15 days after flowering stage (i.e. at DATI 45) and uptake of K increased during the experimental period.

Water stress had no significant effect on uptake of N and K. Water stress significantly (P<0.05) decreased the uptake of P at the final harvest and the uptake of Ca at DATI 30 & 45. The uptake of Mg significantly (P<0.05) decreased in the water -stressed plants at DATI 15 until final harvest.

Plants grown in the solution EC 3.0 had a significant (P<0.05) increased in the uptake of N and P at DATI 0 and; K at DATI 0, 15 & 60. The level of Ca and Mg was greater in EC 3.0 plants at all sampling days except Mg at DATI 45.

Nutrient in roots: The nutrient uptake by the roots is given in Fig.5 (a-j). Water stress significantly (P<0.05) decreased the uptake of N and K at DATI 15, DATI 30 etc and; Mg uptake at DATI 15. Whereas water stress had no significant effect on uptake of P. There was no consistent trend on the uptake of Ca.

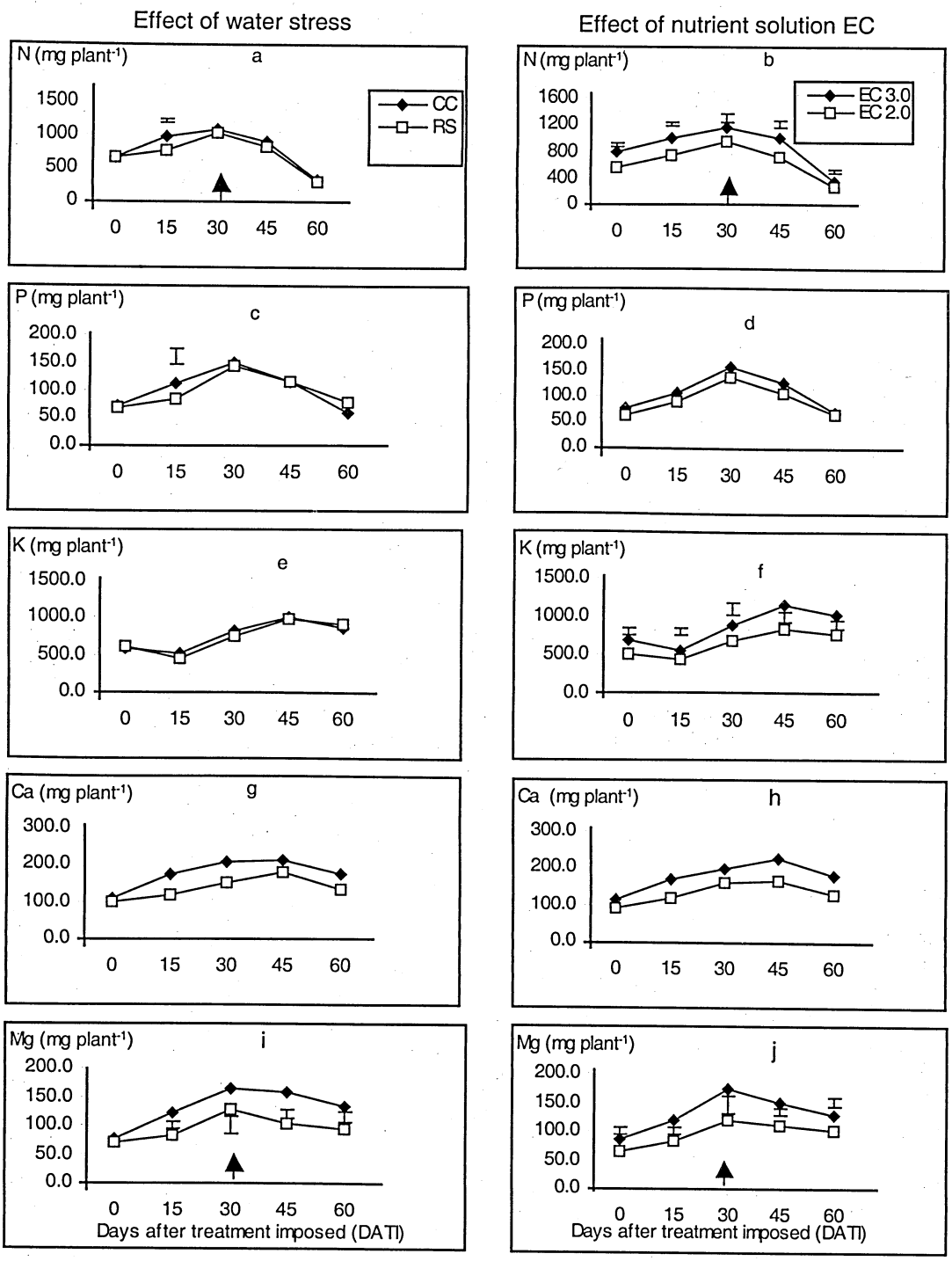

Fig.3(a-j). Nutrient uptake by rice leaves as influenced by water stress and nutrient solution EC grown in NFT. Vertical bar represents the LSD (0.05) value for comparing water stress and comparing EC. CC=Minimal stress, RS= Reproductive & ripening phase stress. Arrow at 30 DATI indicates the flowering stage

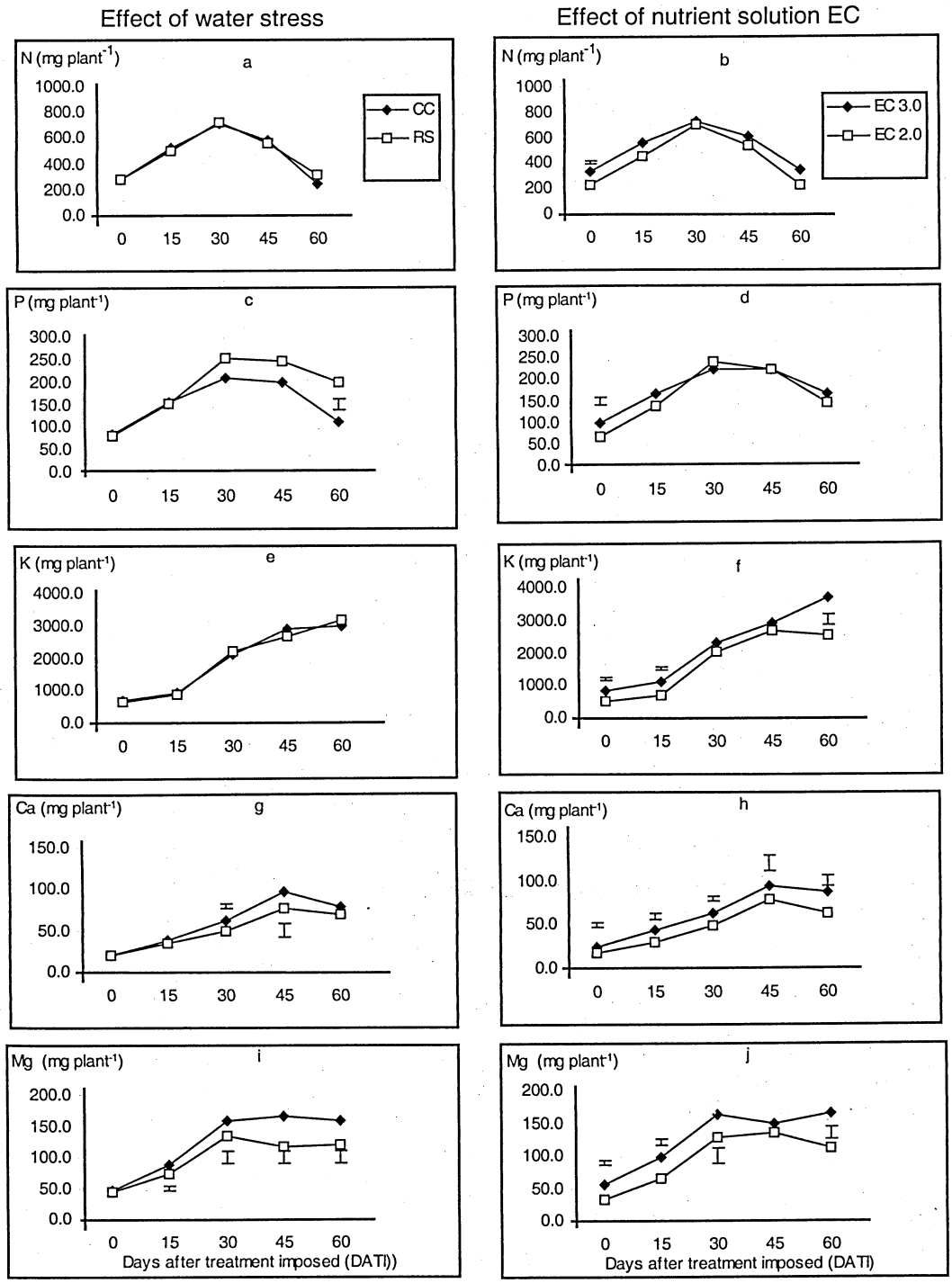

Fig. 4(a-j). Nutrient uptake by rice stems as influenced by water stress and nutrient solution EC grown in NFT. Vertical bar represents the LSD (0.05) value for comparing water stress and comparing EC. CC=Minimal stress, RS= Reproductive & ripening phase stress. Arrow at 30 DATI indicates the flowering stage

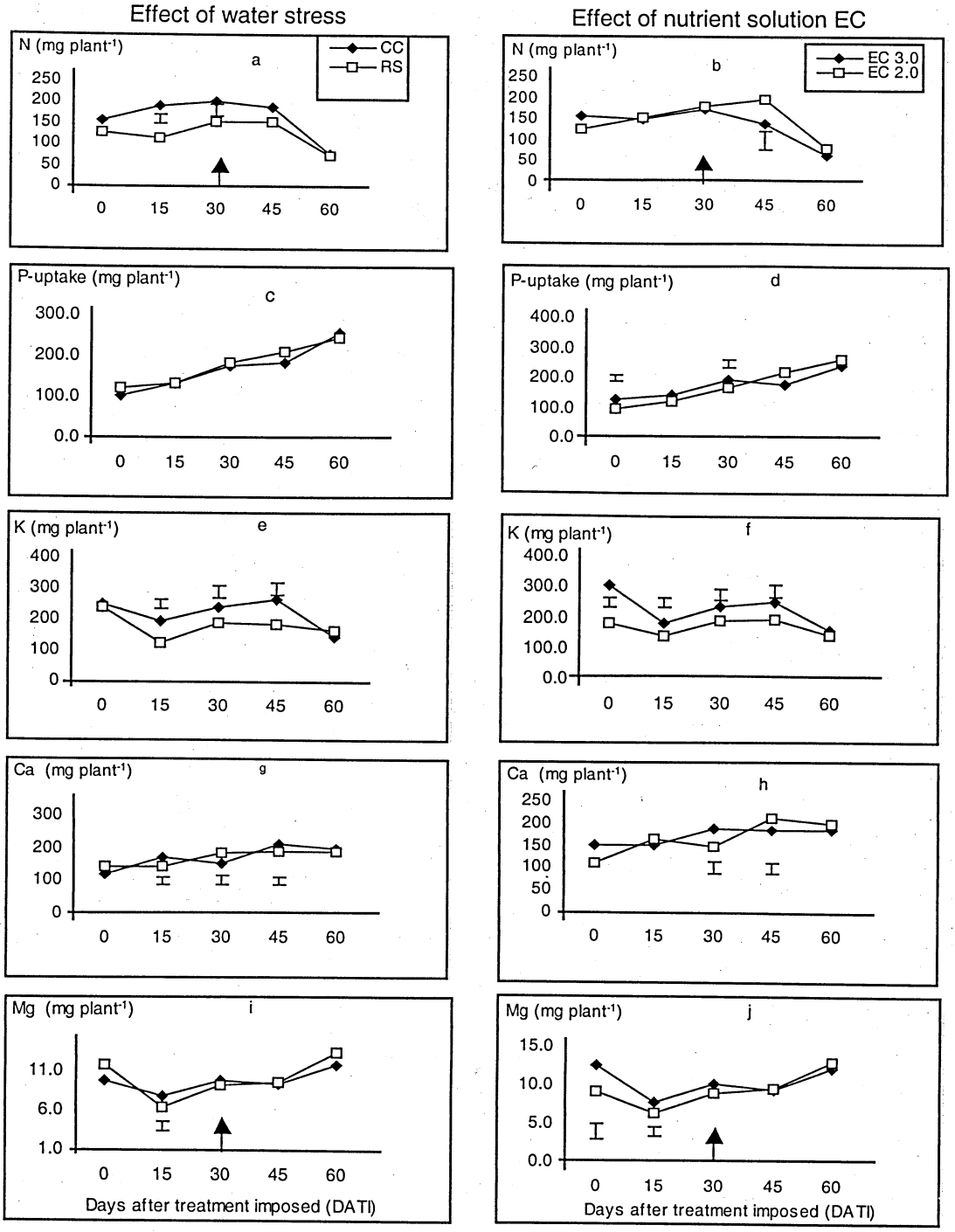

Fig. 5(a-j). Nutrient uptake by rice roots as influenced by water stress and nutrient solution EC grown in NFT. Vertical bar represents the LSD (0.05) value for comparing water stress and comparing EC. CC=Minimal stress, RS= Reproductive & ripening phase stress. Arrow at 30 DATI indicates the flowering stage

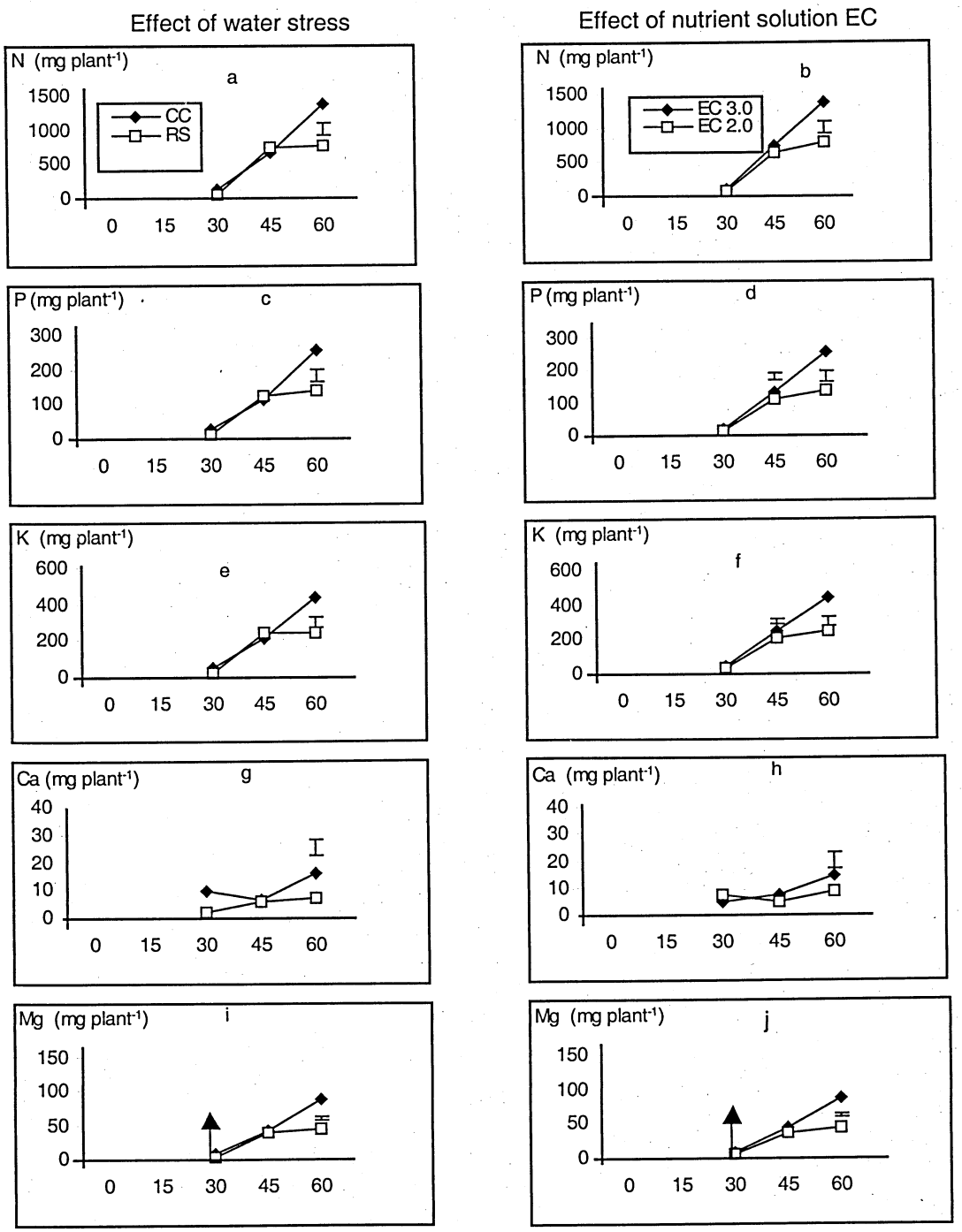

Fig.6 (a-j). Nutrient uptake by rice panicles as influenced by water stress and nutrient solution EC grown in NFT. Vertical bar represents the LSD (0.05) value for comparing water stress and comparing EC. CC=Minimal stress, RS= Reproductive & ripening phase stress. Arrow at 30 DATI indicates the flowering stage.

Plants grown in EC 3.0 had significantly ($P<0.05$) greater P uptake at DATI 0 & 30, Mg at DATI 0 & 15 and; K at all the sampling dates with an exception at the final harvest. The uptake of N significantly increased in EC 2.0 plants at DATI 45. There was no consistent trend in the uptake of Ca.

Nutrient in panicles: Regardless of water stress and EC, the nutrient uptake by the panicles increased from flowering (DATI 30) to final harvest is presented in Fig.6 (a-j).

Water stress significantly ($P<0.05$) decreased the nutrient uptake by the panicles at the final harvest. The plants grown in the EC 3.0 solution uptake significantly ($P<0.05$) more nutrients at the final harvest. At DATI 45, the EC 3.0 plants also uptake more P and K.

The uptake of nutrient by different plant parts such as leaves, stems and roots decreased after reaching a maximum level whereas in panicles it was increased up to final harvest indicating that after flowering the nutrients from the different plant parts were translocated to the panicles. This is an observation of Williams (1955), Boatwright and Hass (1961) and; Lal *et al.* (1978).

Conclusion

In this study, the application of intermittent re-circulation has limited periodically the supply of nutrient solution to the roots. The nutrient uptake was also reduced by the roots in the water-stressed plants resulting from reduced absorption and translocation of nutrients in the plant system as a result decreased the amount of nutrients in different parts of plant.

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