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Influence of water application on photosynthesis, growth and biomass characteristics in *Jatropha curcas*

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Abstract
The effect of CO_2 assimilation, stomatal conductance, transpiration rate, water use efficiency, growth and biomass productivity were studied in *Jatropha curcas* under different moisture levels of water (100, 75, 50 and 25% of field capacity). CO_2 assimilation, stomatal conductance, transpiration, growth and biomass were reduced in response to decreasing moisture content of water. The decreased CO_2 assimilation during irrigation stress was found largely dependent on stomatal closure, which reduced available internal CO_2 concentration and restricted water loss through transpiration based on leaf gas exchange hypothesis linked with stomatal limitation for photosynthesis to reduce carbon uptake followed by loss in leaf area expansion which declined total carbon uptake, growth and biomass in *Jatropha curcas* seedlings.

Keywords: Biomass, CO_2 assimilation, growth, stomatal conductance, transpiration rate, water use efficiency

INTRODUCTION

Fossil fuel reserves over the globe are decreasing and global prices soaring continuously putting tremendous pressure on developing economies. Therefore, alternate sources of fossil fuel are being searched by the researchers (1). *Jatropha curcas* has drawn much attention for producing biodiesel (2,3,4,5) being an energy plant, also shown drought- tolerance with good growth on poor quality of land (5,6). The plant parts have been used for various purposes such as animal feeding, medicine production and restoration of disturbed ecosystem (7,8,9). The seeds contain viscous oil used in soap industry, cosmetics and as a bio-diesel to substitute kerosene (8,9).

Water is essential for various metabolic activities. Its deficiency induces water stress on vegetation in combination with soil, plant and climate. All these factors interact to determine the water absorption and loss by the plants (10). In arid and semi-arid regions, plants are often exposed to water deficit stress, also known as moisture stress which negatively influence plant growth and biomass productivity (11,12,13). The plants can avoid moisture stress by maximizing water uptake (i.e., absorbing ground water by deep roots) or minimizing water loss through stomatal closure – small thick leaves, etc. (14). The occurrence of morphological and physiological responses may lead to some adaptation to moisture stress may vary considerably among species (15). The apparent consequences of moisture stress is the progressive decline in photosynthetic capacity though photosynthetic system found to be resistant to irrigation levels linked with stomatal closure (16). The reduced leaf water reserve in relation to the limiting transpiration rate (10) eventually impairs biomass accumulation (17). The aim of this study was to be evaluate the responses of CO_2 assimilation, stomatal conductance, transpiration rate, water use efficiency, growth and biomass in *Jatropha curcas* subjected to different irrigation levels.

MATERIALS AND METHODS

Plant material and experimental design

One year old *Jatropha curcas* plants were chosen for obtaining their stem cuttings (18- 20 cm). These cuttings were shifted in polybags filled with 2 kg normal soil for 15 days to ensure sprouting (March, 2009). After two weeks, they were transplanted in earthen pots (30cm diameter and 30cm depth, filled with fertile soil and humus 3:1). The pots were watered daily to the field capacity to ensure that the plants did not experience drought. Fifty days old uniform plants were chosen for the study purpose and subjected to four moisture regimes (100, 75, 50 and 25% field capacity) in a glass house at Botany Department, Lucknow University, Lucknow. Microclimatic parameters such as temperature, relative humidity, rainfall and sunlight intensity were not controlled but recorded weekly (Fig. 1). The soil moisture content measured by calculating weight of 100gm of the soil from each pot under:

$$\text{Soil moisture content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

The average soil moisture content was retained ca. 40, 33, 21 and 10% in the pots during irrigation regimes viz., 100, 75, 50 and

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25%, throughout.

Measurement of CO_2 assimilation, stomatal conductance, transpiration and water use efficiency

CO_2 assimilation, stomatal conductance and transpiration were measured with an open system CIRAS-1 portable Infra Red Gas Analyzer photosynthesis system (IRGA, PP System, England). Measurements were made in natural sunlight (1500- 2000 µmol m^{-2} s^{-1}) between 10:00- 11:00am by using mature and fully expanded leaf (6- 8th) from control and moisture stress seedlings. Water use efficiency (WUE) was calculated (WUE=CO_2 assimilation/ transpiration rate) as described by (18). All measurements were made in the forenoon to avoid high temperature and low humidity in the afternoon.

Growth and biomass characteristics

At the end of experiment, plants (n= 10) were harvested to analyse the pattern of growth and biomass i.e., height of plants, collar diameter, number of leaves, leaf area expansion, root length and their biomass. The height of plants were measured from the apex to the starting point of the basal leaf (19). The stem - collar diameter measured at ~15 cm above from the soil surface by using calliper. The leaf area expansion measured by using Leaf Area Meter CI- 202 (CID Inc., USA). The biomass measured by using different plants' parts of the each plant, separated and washed to remove debris and then dried (68 ±2 ^{0}C, 72 h) until constant weight achieved.

Statistical analysis

Data management and statistical analysis were performed using SPSS 16.0 software (SPSS Inc., Chicago. Il USA).

RESULTS

The water stress as imposed by maintaining various irrigation levels compared to field capacity reduced CO_2 assimilation, stomatal conductance, transpiration and water use efficiency. The water stress (75, 50 and 25%) induced decline trends 15 days after the on-set of water stress. The loss in CO_2 assimilation did occur in the range of 20 - 78%, incase *Jatropha curcas* subjected under water stress i.e., 75, 50 and 25% respectively (Fig. 2A).

The stomatal conductance, transpiration rate and water use efficiency were found down-regulated ca. 45- 63%, 30-51%, and 31-53% respectively. *Jatropha curcas* seedlings after the application 60 days of various irrigation levels i.e., 75, 50 and 25% compared to 100% (upto field capacity) for stomatal conductance, transpiration and water use efficiency. The optimal reduction values of stomatal conductance, transpiration and water use efficiency was observed ca. 63, 51 and 53% incase irrigation level 25% of the field capacity ensured throughout (Fig. 2B, C and D).

Table.1. Growth and biomass characteristics of *Jatropha curcas* seedlings grown under different irrigation levels (75, 50 and 25 %). The control plants were irrigated to the level of field capacity (100%). Data are the mean (±) standard error of 8- 10 individuals.

Characteristics	% irrigation of water in relation to field capacity			
	100	75	50	25
Plant height (cm)	50.5 ±3.3	47.7 ±3.8	38.1 ±3.0	31.0 ±2.0
Loss (%)	-	5.54	24.55	38.61
Collar diameter (cm)	7.3 ±0.54	7.0 ±0.18	5.4 ±0.32	4.4 ±0.19
Loss (%)	-	4.11	26.03	43.84
Number of leaves	34 ±4	30 ±2	26 ±2	19 ±3
Loss (%)	-	11.76	23.53	44.12
Leaf area expansion (m^{-2} $plant^{-1}$)	10.0 ±1.3	8.9 ±0.31	6.1 ±0.5	4.53 ±0.23
Loss (%)	-	10.97	38.68	54.84
Specific leaf area (g m^{-2})	1.97 ±0.02	1.8 ±0.02	1.32 ±0.01	1.19 ±0.02
Loss (%)	-	8.63	32.99	39.59
Biomass of leaf (g)	10.71 ±1.1	9.99 ±1	7.84 ±1.3	5.94 ±0.89
Loss (%)	-	6.72	26.8	44.54
Biomass of stem (g)	15.38 ±1.1	14.44 ±0.9	13.02 ±0.98	11.33 ±0.06
Loss (%)	-	8.06	15.34	26.33
Biomass of root (g)	4.19 ±0.3	4.02 ±0.42	3.13 ±0.04	2.82 ±0.03
Loss (%)	-	4.06	25.30	32.70
Total biomass (g)	30.28 ±1.4	28.15 ±1.1	23.99 ±0.2	20.09 ±1.9
Loss (%)	-	7.03	20.77	33.65
Length of root (cm)	37.5 ±2.1	35.8 ±1.7	25.8 ±1	21 ±1.8
Loss (%)	-	4.53	31.2	44.0
Leaf moisture content (%)	84.83 ±6	84.08 ±4.3	82.47 ±3.7	81.9 ±4.3
Loss (%)	-	0.88	2.78	3.40
Leaf weight ratio	0.57 ±0.006	0.55 ±0.008	0.47 ±0.003	0.41 ±0.002
Loss (%)	-	3.51	17.54	21.05

At the end (60 days) of the experiment, height of plants, collar diameter, number of leaves, leaf area expansion, specific leaf area, leaf water content, leaf weight ratio, root length and plant biomass monitored and found significantly reduced alongwith loss in the levels of applied irrigation levels compared to control which was experienced irrigation level to field capacity (100%) throughout. The height of plants and collar diameter was reduced 5- 39% and 4- 44% (Table 2). The withdrawal of irrigation to the level of 25% severely impaired plant height, collar diameter ca. 39 and 40%. It has also declined number of leaves, leaf area expansion and specific leaf area ca. 12- 44%, 11- 55% and 8- 40%. Similarly, root length, leaf water content and leaf weight ratio also found affected to the level of 4 - 44%, 0.8 - 5% and 4 - 21% along with loss in biomass yield i.e., leaf, stem, root and total dry weights to the levels of 7- 45, 8- 26, 4-

33 and 7-34% (Table 1).

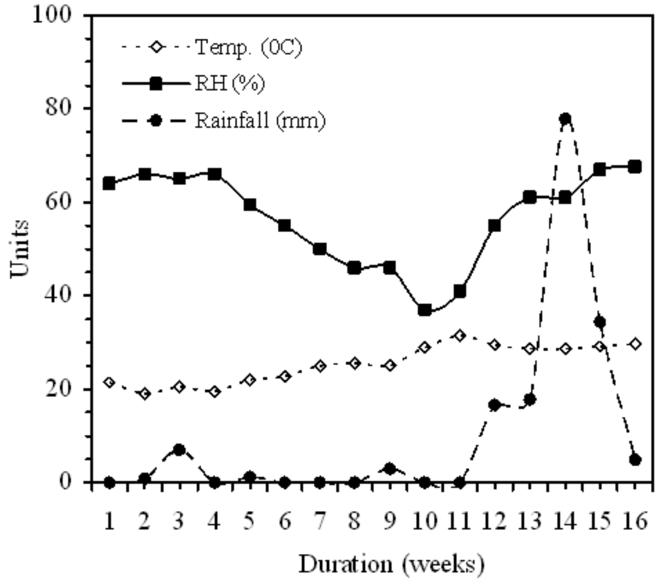

Fig 1. Environmental variables viz., average temperature (°C), relative humidity (%) and rainfall (mm) during the cultivation period (Feb. - June, 2009) of *Jatropha curcas*. (The seedlings- plants were grown in the range of PFDs ca. 1500 – 2000µmol m^{-2} s^{-1}).

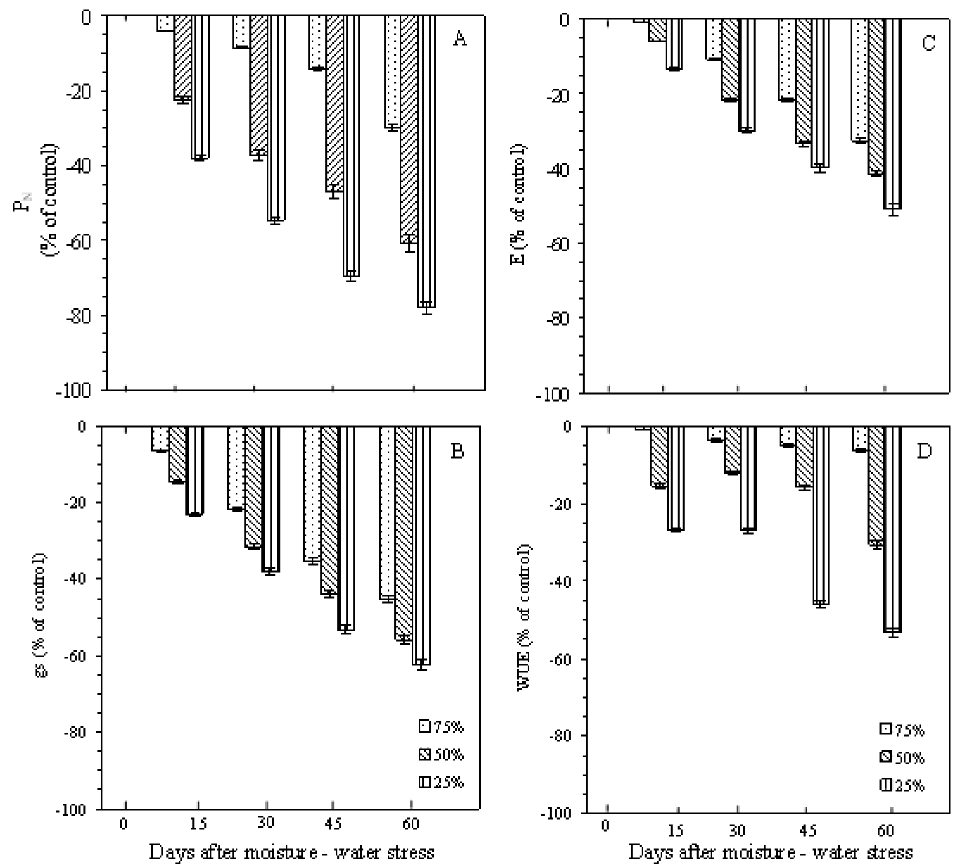

Fig 2. A - CO_2 assimilation rate (P_N), B - stomatal conductance (gs), C - transpiration (E) and D - water use efficiency (WUE) in *Jatropha curcas* influenced by various irrigation levels (75, 50 and 25%) to establish moisture/ drought stress (75, 50 and 25%). The control were irrigated to the level of field capacity (100%), throughout. Vertical bars indicate SE (n = 6).

DISCUSSION

The effect of CO_2 assimilation, stomatal conductance, transpiration rate, water use efficiency, growth and biomass productivity were monitored in *Jatropha curcas* plants as influenced by various irrigation levels (100, 75, 50 and 25%). The reduction in CO_2 assimilation (Fig. 1A) was largely found associated with stomatal closure, which decreased available internal CO_2, also restricted water loss through transpiration (15), resulted in a decline of photosynthetic capacity (20,21). Water stress induced a impaired stomatal conductance, transpiration with prevented water loss in *Jatropha curcas*. Consequently it decreased CO_2 assimilation (10) because stomatal aperture affects both photosynthesis and transpiration (17). Similar results were previously obtained in legume species (22,23,24,25,26). The sustenance of the severe moisture stress also affects integrity of photosynthetic apparatus which may result in its irripairable injuries linked with high temperature and low relative humidity (27). Hence, loss in the levels of water application which could cause rhizospheric. Moisture stress, negatively affected plant growth and biomass productivity due to availability of limited water which down- regulated leaf area expansion and carbon assimilation (21) alongwith impaired morphology – canopy i.e., plant height, collar diameter, number of leaves, leaf area expansion, specific leaf area (28,29,30). Our results are consistent with many previous studies (30,31,32,33,34).In conclusion, decreasing irrigation levels down-regulated biomass partitioning (10).

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