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Research Article

Different Levels of Imposed Water Stress Conditions on the Growth and Morphological Changes in *Oryza sativa* L. and *Zea mays* L.

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Abstract

This earthen pots study assessed the effect of water stress on the growth and morphological changes of *Oryza sativa* L. (C3 Plant) and *Zea mays* L. (C4 plant) seedlings. Different types of soils were selected for different types of treatments namely Treatment A (watered daily), Treatment B (watered 3 d once) and Treatment C (watered weekly once) were carried out to assess the growth and morphological measurements in the third leaf of *Oryza sativa* (rice) and *Zea mays* (maize). After 10 d of germination, water stress treatment was started and after 15 d of seed germination, a comparative study was conducted. Third leaf was collected from tender stage to senescence stage for 7 times once in 5 d and morphological analysis was carried out. Plant responses to water scarcity are complex, involving deleterious and/or adaptive changes and under earthen pot experiments conditions. On consolidation of the findings from the present work, it could be concluded that water stress adversely affect the growth in C3 and C4 plants because of reduced photosynthesis in the leaves. Decreased shoot length and leaf area in stressed plants than control is also noted. The growth and development is very fast in maize than in rice plant during water stress conditions.

Keywords: Growth parameters, morphological changes, water stress, *Oryza sativa* L., *Zea mays* L.

Introduction

Rice (C3) (*Oryza sativa* L.) is the only cereal that can grow in wetland conditions. Depending on the hydrology of where rice is grown, the rice environment can be classified into irrigated lowland rice (79 million ha), rain fed lowland rice (54 million ha), flood-prone rice (11 million ha) and upland rice (14 million ha). Lowland rice is also called 'paddy rice'. Lowland rice fields have saturated (anaerobic) soil conditions with ponded water for at least 20% of the crop's duration. In irrigated lowlands, the availability of irrigation assures that ponded water is maintained for at least 80% of the crop's duration. In rain fed lowlands, rainfall is the only source of water to the field and no certain duration of ponded water can be assured. In flood-prone environments, the fields suffer periodically from excess water and uncontrolled, deep flooding (>25 cm for 10 d or more). Deep-water rice and floating rice are found in these environments. Upland rice fields have well-drained, non-saturated (aerobic) soil conditions without ponded water for more than 80% of the crop's duration. Although water is required all over the growth periods of rice plant, there are some critical growth stages when drought stress impacts seriously and create a massive reduction in quantity and quality of yield.

Maize C4 (*Zea mays* L.) is the third most important cereal after wheat and rice all over the world. Maize is the world's largest grain crop in total production on a MT basis (FAOSTAT, 2010). Given the reliance on maize for food, fiber and fuel, continued improvement in maize grain yields is a substantial challenge. Maize, however, is highly sensitive to drought, specifically two weeks prior and post-silking (Banzinger *et al.,* 2000; Tollenaar and Lee, 2011). Maize had its origin in a semi-arid area but it is not a reliable crop for growing under dry land conditions, with limited or erratic rainfall (Arnon, 1972).

Water stress refers to scarcity or limited supply of water. The major reasons for water scarcity are population growth, increasing urban, industrial demand for water, water pollution and water resource depletion. Water stress adversely affects crop growth and yield in many regions of the world (Teulat *et al.,* 1997). One of the most important constraints for agriculture is water limitation. Most recently, global warming may be worsening this situation in most agricultural region. Water stress is an abiotic stress, it is multidimensional in nature, and it affects plants at various levels of their organization (Yordanov *et al.,* 2003; Chaves *et al.,* 2003; Wentworth *et al.,* 2006).

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When water availability is reduced, plants changes itself to retain as much water as possible and take up whatever water they can. During water stress, plants produce and accumulate compatible solutes such as sugars and amino acid to lower the osmotic potential in the cells to facilitate water absorption and retention (Xiong and Zhu, 2002). Some of the compatible solutes also contribute to maintain the conformation of macromolecules by preventing misfolding or denaturation (Xiong and Zhu, 2002). Water stress affects morphological, physiological, enzyme production and biochemical contents of plants. All plants are capable of perceiving and responding to stress (Bohnert *et al.,* 1995; Bartels and Sunkar, 2005). To overcome the effect of stress, plants have evolved adaptive mechanisms which may be classified into four categories. Water stress not only affects plant water relations through the reduction of watercontent, turgor and total water, it also affects stomatal closure, limits gaseous exchange, reduces transpiration and arrests carbon assimilation rates. Negative effects on mineral nutrition (uptake and transport of nutrients) and metabolism leads to a decrease in the leaf area and alteration in assimilate partitioning among the organs. Alteration in plant cell wall elasticity, disruption of homeostasis and ion distribution has been reported (Yordanov *et al.,* 2003). Water stress adversely affects crop growth and yield in many regions of the world. Maintaining high water stress plays an important role in tolerance to water stress and in yield stability of crop plants (Teulat *et al.,* 1997). Considering the above facts in view, the effect of water stress on the growth and morphological changes of *Oryza sativa* L. (C3 Plant) and *Zea mays* L. (C4 plant) seedlings was evaluated.

Materials and methods

Experimental design: This study was conducted in earthen pots using different varieties of soil. Healthy viable seeds of paddy (C3) and maize (C4) were surface sterilized with 0.01% mercuric chloride solution and rinsed several times in distilled water. The seeds were soaked in distilled water for 24 h. Soaked seeds were buried under the earthen pots below 2 cm depth. In each pot, 15 seeds were sowed and C3 (rice) and C4 (maize) plants were grown in 60 pots separately (Rice-30 pots and maize-30 pots).

Types of treatments: Three types of treatments were employed in this study namely:

a. Treatment A (Control) watered daily.
b. Treatment B (Moderate water stress) watered 3 d once.
c. Treatment C (Heavy water stress) watered weekly once.

Different types of soil samples were collected from botanical garden of Chikkaiah Naicker College, Erode. Every pot was filled with 10 kg soil. Each treatment had ten pots of different soil proportions:

1. Red soil
2. Red soil + Manure
3. Red soil + Vermi compost
4. Red soil + Sand
5. Red soil + Black soil
6. Red soil + Clay soil
7. Red soil+ Loamy soil
8. Red soil + Loamy soil + Manure + Black soil
9. Red soil + Manure + Vermi compost + Fertilizer (NPK+DAP)
10. Red soil+ Fertilizer (NPK +DAP) (NPK-Nitrogen, phosphorus and potassium and DAP-Diammonium phosphate).

Growth parameters: The experiment was conducted for a period of 45 d. After 10 days of seed germination, water stress treatment was started, and after 15 d of germination a comparative study was conducted. From each pot, one sample was uprooted (total number of samples are 60 (rice 30 and maize 30) and analysis of the growth performance and morphological structure was carried out from the 3rd leaf. From every treatment, 3rd leaf sample was collected from tender stage to senescence stage for 7 times, once in 5 d (15 d, 20 d, 25 d, 30 d, 35 d, 40 d and 45 d).

Morphological measurements of rice and maize plant root and shoot length: Root length was measured from root collar region to the root tip region. Shoot length was measured from the root collar region to the shoot tip region. The root and the stem length were expressed in centimeters per plant.

Total leaf area: Leaf area of 3rd leaf of rice and maize plant was measured and recorded from tender stage to senescence stage for 7 times, once in 5 d (15 d, 20 d, 25 d, 30 d, 35 d, 40 d and 45 d). The total leaf area of the plants was measured using LICOR Photo Electric Area Meter (Model 11-3100, Lincoln, USA) and expressed in cm^2.

Results and discussion

This study was undertaken to study the biochemical changes in *Oryza sativa L.* (C3) and *Zea mays L.* (C4) plants under water stress conditions. In this study, rice and maize plants are selected because they are main staple food crops. They contain high nutritive level, high demand throughout the world, easily cultivable and their life cycle is very short. These crops are more economic and viable to farmers.

Root length: This study clearly shows that root length is developed in water stressed plant of rice and maize compared with control. Root length is high in maize than rice plant. Water stress increased the root length of rice and maize plant (Table 1 and 2).

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Table 1. Water stress induced changes in the root length (cm) of *Oryza sativa* L. rice plants (150 d old) under water stress conditions.

Types of soil	Treatment A (watered daily)	Treatment B (watered 3 d once)	Treatment C (watered weekly once)
Red	20	28	30.9
Red + Manure	21.9	29	31.5
Red + Vermi	25	32.2	34.5
Red + Sand	29	33.9	36
Red + Black	23	28.2	31.5
Red + Clay	26.9	31.7	36
Red + Loamy	24	31.2	35.5
R+L+M+B	26.8	35.1	37.2
R+M+V+F	28	36.2	39.5
Red+Fertilizer	24.8	30.6	34.9

R-Red soil; M-Manure; B-Black soil; L-Loamy; V-Vermicompost; F-Fertilizer (NPK+DAP).

Table 2. Water stress induced changes in the root length (cm) of *Zea mays* L. maize plants (150 d old) under water stress conditions.

Types of soil	Treatment A (watered daily)	Treatment B (watered 3 d once)	Treatment C (watered weekly once)
Red	28	30	42
Red + Manure	30	36	44
Red + Vermi	27	40	45
Red + Sand	34	46	55
Red + Black	35	41	49
Red + Clay	32	45	49
Red + Loamy	40	54	67
R+L+M+B	38	45	57
R+M+V+F	42	44	59
Red+Fertilizer	35	38	45

Table 3. Water stress induced changes in the shoot length (cm) of *O. sativa* L. rice plants (150 d old) under water stress conditions.

Types of soil	Treatment A (watered daily)	Treatment B (watered 3 d once)	Treatment C (watered weekly once)
Red	60	54	42
Red + Manure	68	61	48
Red + Vermi	76	68	53
Red + Sand	58	52	41
Red + Black	63	56	44
Red + Clay	69	62	48
Red + Loamy	71	64	50
R+L+M+B	75	68	53
R+M+V+F	80	72	56
Red+Fertilizer	73	65	51

Table 4. Water stress induced changes in the shoot length (cm) of *Z. mays* L. maize plants (150 d old) under water stress conditions.

Types of soil	Treatment A (watered daily)	Treatment B (watered 3 d once)	Treatment C (watered weekly once)
Red	135	121.5	94.5
Red + Manure	145	130.5	101
Red + Vermi	156	140	109
Red + Sand	130	117	91
Red + Black	144	129	100.8
Red + Clay	140	126	98
Red + Loamy	148	133.2	104
R+L+M+B	151	135.2	105
R+M+V+F	158	142	111
Red+Fertilizer	150	135	105

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Table 5. Water stress induced changes in the 3rd leaf area (cm^2) of *Oryza sativa* L.

Types of soil	Treatment A (watered daily)	Treatment B (watered 3 d once)	Treatment C (watered weekly once)
Red	2.2	1.98	0.84
Red + Manure	3.2	2.4	2.2
Red + Vermi	3.84	2.61	2.28
Red + Sand	2.23	1.79	1.6
Red + Black	5.7	3.3	2.79
Red + Clay	2.4	1.9	1.6
Red + Loamy	1.75	1.6	1.3
R+L+M+B	3.3	2.6	2.1
R+M+V+F	2.8	2.3	1.8
Red+Fertilizer	4.5	3.1	2.1

Table 6. Water stress induced changes in the 3rd leaf area (cm^2) of *Zea mays* L.

Types of soil	Treatment A (watered daily)	Treatment B (watered 3 d once)	Treatment C (watered weekly once)
Red	21.45	19.15	12.5
Red + Manure	31.2	26.8	18
Red + Vermi	32.5	29.4	23
Red + Sand	30.5	26.5	20
Red + Black	22.5	18.5	11
Red + Clay	22.68	19	12.6
Red + Loamy	18.24	15.4	8.9
R+L+M+B	21.2	18	11
R+M+V+F	27.17	24	17
Red+Fertilizer	17.5	14	9.8

Root length of some species was reduced as a result of water stress. Similar results were observed in soybean treated with paclobutrazol (Sankhla *et al.,* 1985), *Dianthus caryophyllus* (Banon *et al.,* 2002) and in wheat (Berova *et al.,* 2002). However, the rice and maize plant had the ability to survive under water stress because of very long root length. In all the ten different types of soil, root length was unique.

Shoot length: In general, shoot length of plant gradually decreased in water stress condition. This study proved water stress inhibiting the shoot length to a large extent in both treatment C (watered weekly once) and treatment B (watered 3 d once) types when compared to Treatment A (watered daily) control (Table 3 and 4). Similar results were observed in Avocado (Chartzoulakis *et al.,* 2002), soybean (Ohashi *et al.,* 2002).

Leaf area: Water stress reduced the leaf area to a great extent in both treatments C and B as compared to control (Table 5 and 6). The leaf growth was more sensitive to water stress in rice and maize plants. Water stress decreased total leaf area in rice and maize plants. Similar results were observed under water stress in *Eucalyptus globules* (Pita and Pardos, 2001), wheat (Gong *et al.,* 2003), cowpea (Anyia and Herzog, 2004), maize (Nayyar and Gupta, 2006). Stress level gradually increased shrinkage of leaf cells, curling of leaf and reduced leaf area are seen.

Conclusion

The results obtained in the present study showed that rice and maize cultivars significantly differed in their response to drought and hence drought tolerance. The degree of drought tolerance depends on the interactions between the rice and maize cultivars, the levels of water stress and the type of soil. The results suggest that maize is the most drought tolerant one followed by rice plant and red soil + sand soil composition is the most drought sensitive one followed by red soil. The plant morphological and physical changes determined not only on the basis of water stress but also with the types of soil. Red soil and sand soil are not suitable for rice and maize cultivation under stress condition but, red soil + manure + vermicompost + fertilizer and red soil + vermicompost type of soil is significant even under water stress condition, and recorded higher level of growth and development when compared with other soil proportions.

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