Global Research in Environment and Sustainability
July 2023, Vol. 1, No. 5, pp. 20-27.

Photosynthetic Traits of Rice Landraces (*Oryza sativa L.*) Under Drought Condition

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Abstract:
Drought stress is mainly a serious limiting factor for rice production, which creates huge economic losses by becoming more serious issue with respect to global climate change. In the view of the current situations and forecasted global food demand, it is necessary to enhance the crop productivity on the drought prone rain fed lands with utmost priority.Rice is a main staple cereal crop in the world.Climate change mainly alters the plant phyllosphere and its resource allocations. The main aim of this experiment was to evaluate the “Photosynthetic attributes on drought tolerance of rice landraces” (Oryzasativa L.). A laboratory screening, hydroponic studies and pot culture experiments were conducted in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, during 2020-2021 to investigate the Photosynthetic attributes. Rice land races, namely Anna(R) 4, 337- IC116006, 224 - IC463809 were studied. The present findings showed that drought stress reduced the photosynthetic parameters and enhanced the chlorophyll index and soil temperature in all the land races. Among the land races, Anna(R) 4 performed better under drought stress conditions when compared to other.

Keywords: Photosynthesis, chlorophyll, tolerance, landrace, leaf temperature.

INTRODUCTION

Rice is a widely consumed stable food crop in the world after wheat crop for larger part of world’s human population, particularly in Asia to meet out the daily calories of a growing population (Samal et al., 2018). The consumption and cultivation of rice in worldwide is about 509.87 million metric tonnes in the year 2021 (Shahbandeh *et al.*, 2021). It is estimated around 515.35 million tonnes represent an increase of 4.18 million tons i.e., 0.82 % in rice production is required around the globe for the year 2022.

Rice is positioned best among the foremost inundated crops within the world since it requires more water to grow (Kumar *et al.*, 2019). At the physiological, metabolic and molecular levels, drought influences the growth and development of rice by causing numerous changes (Liu *et al.*, 2017a). Rice is suited to a wide extend of settings, in spite of the fact that is semi-aquatic nature makes paddy production more efficient at high soil moisture content. However, it is necessary to adopt the rice production in the rainfed ecosystem to meet out the need of the growing world population (Gleason *et al.*, 2017).

Among the abiotic stress, drought is one of the most obvious factors that limits rice yield of existing rice cultivars which do not fare well in drought-stricken circumstances. India is a home to the diverse range of rice cultivars and landraces which are lesser-known by the farmers (Biswajit *et al*., 2017) have greater potential to tolerate the water scarcity by sustaining the optimum yield. Exploring the potential of rice landraces towards the drought tolerance could be the viable alternative for increasing food production in the coming years under rainfed ecosystem (Manikavelu *et al*., 2006).

Drought can occur at any stages of the growth and development of rice. At early growth stages such as seedling stage, drought occurs results in poor crop establishment and reduced yield (Pandey *et al*., 2021). Drought stress decreases reduced growth and development of rice by negatively affecting seedling vigour, germination, leaf membrane stability, photosynthetic rate and osmolyte content (Pandey *et al*., 2015; Mishra *et al*., 2018).

Though all the stages of rice crop are sensitive to water stress conditions, the degree of sensitivity of growth stage on drought stress decides the proper growth and development and reproductive efficiency of rice crop (Binodh *et al*., 2019; Vikram *et al*., 2016). Particularly rice at reproductive stage is a critical causing yield loss up to 40 % to 60 % under drought stress (Venkatesan *et al*., 2005). Hence, it is imperative to screen the germplasm to find out the drought tolerant traits at various stages in growth like seed germination, seedling and maturity of rice (Sarkar *et al*., 2011).

PHYSIOLOGICAL RESPONSES TO DROUGHT STRESS

The chlorophyll meter (SPAD) is portable, simple, quick and non-destructive tool that measures the intensity of green colour in plants instantly and it has the potential to provide insight to the nitrogen status of crops (Makhdum *et al*., 2002). A significant correlation was obtained between SPAD readings and photosynthetic rate in soybean (Uma *et al*., 1995) and wheat species (Burke, 2010). In rice, Sivakumar *et al*. (2016) reported that SPAD readings positively correlated with chlorophyll content, photosynthetic rate and chlorophyll fluorescence (*Fv/Fm*).

The chlorophyll index is a measure of a plant's stress tolerance capabilities (Mohan *et al*., 2000). The CCM200 meter is based on the ratio of Near Infrared (NIR) to red wavelengths determines the nonlinear relationship between radiation transmission and the quantity. Radiation transmission is nonlinearly proportional to the amount of absorbing chemical in leaf tissue and linearly proportional to the compound's absorbance (Parry *et al*., 2014). The uptake of red radiation is aided by an expanded chlorophyll focus. Because these wavelengths are not consumed by photoreceptors, all plants transmit a large amount of NIR light, which is used as a form of perspective wavelength (Parry *et al*., 2010). Leaf chlorophyll meters examine how thylakoid chlorophyll communicates with incident light, and several studies have found strong links between extractable chlorophyll and non-damaging chlorophyll meter readings (Jifon *et al*., 2005).

Rice photosynthetic rate decreased due to drought stress has been thoroughly established (Ji *et al*., 2012; Lauteri *et al*., 2014; Yang *et al*., 2014). The CO_2 diffusional constraint owing to early photosynthesis is one of the key factors limiting photosynthesis. The major components restricting the photosynthesis are the CO_2 diffusional limitation due to the early stomatal closure, decreased photosynthetic enzyme activity and biochemical changes are the components linked to the synthesis of triose phosphate and a reduction in photochemical efficiency of PSII. Drought drastically reduces PSII activity in the flag leaf of rice plant (Pieters and Souki, 2005). This may be due to drought induces degradation of D1 polypeptide which lead to the inactivation of PSII reaction centre (Huseynova *et al*., 2016). Drought effect decreased the photosynthetic rate of rice has been reported (Yang *et al*., 2014).

Drought induced reduction in photosynthetic rate has been well documented (Lauteri *et al*, 2014; Yang *et al*, 2014). Extreme drought conditions limit photosynthesis because of a decreased in RuBisCO movement, which could be the component of Calvin cycle (Zhou *et al*., 2007) by advancing the ATP subordinate conformational changes, improves under the drought stress as a defensive treatment. Drought stress decreases the photosynthetic rate, water contents and transpiration rate and increases the stomatal resistance (Zhang *et al.*, 2018).

Several studies that differing in stress conditions causes difference in transpiration rate and stomatal conductance (Kamphorst *et al*., 2022). Decrease in transpiration, there is a reduction in stomatal conductance and also limits photosynthesis in rice (Sikuku *et al*., 2010). Mingchi *et al*., (2010) reported the photosynthetic rate, stomatal conductance and transpiration rate were decreased under drought stress. Drought stress hampers the plant net photosynthesis in rice genotypes (Centritto *et al*., 2009; Yang *et al*., 2014) stomatal conductance (Ji *et al*., 2012)., transpiration rate, intercellular CO_2 concentration and this might be because of decreased leaf expansion, disabled photosynthetic machinery, irregular leaf senescence, change in structure of the pigments and proteins and oxidation of chloroplast lipids (Singh *et al*., 2013).

Meena *et al*, (2004) reported that there was significant decrease in transpiration rate in maize lines under severe drought stress condition compared to control. Ramchander *et al*. (2014) observed a significantly higher transpiration rate in the rice variety Mahamay, when drought was induced at flowering stage.

Stomatal conductance is a good indicator of leaf water status (Suresh *et al*., 2012). Photosynthetic rate, stomatal conductance and transpiration rate were significantly decreased under drought stress. While at the initiation of stress treatments, the intercellular CO_2 concentration was slightly changed as observed by Ohashi *et al*. (2006) in soybean. The response pattern of gas exchange parameters and crop yield in rice imposed under drought stress at different growth stages might provide basis for selecting the drought tolerant variety to solve food crisis and stabilize yield (Sikuku *et al*., 2012). Photosynthetic rate and transpiration rate were reduced, while leaf temperature and stomatal resistance were increased under drought stress in all cultivars (Rajasekar *et al*., 2020). Reduced photosynthetic rate and stomatal conductance were observed under 100 per cent and 50 per cent drought stress over control in tomato (Bhatt *et al*., 2020).

Chlorophyll fluorescence aids in determining the impact of ecological stress on development and yield, as these characteristics are closely linked with the rate of carbon exchange (Li *et al*., 2020; Fracheboud *et al*., 2004). Light energy can drive photosynthesis can be dissipated as a heat, or remitted as light is called chlorophyll fluorescence in the chlorophyll molecules of a leaf causes a change in the efficiency of photochemistry and heat dissipation can be obtained by measuring the yield of chlorophyll fluorescence (Krishnan *et al*., 2011).

According to maximum quantum yield of chlorophyll fluorescence parameters, the water sensitivity in plant is associated with decreased photosynthetic efficiency of PSII and enhanced non – photochemical quenching (Porcel *et al*., 2015). As a result, it might be used as a reliable indicator to evaluate the metabolic or energetic imbalance of photosynthesis and yield performance across genotypes under drought condition (Araus *et al.*, 1994; Araus *et al.*, 1998). Water deficit significantly reduce the chlorophyll fluorescence attributes (Piper *et al.*, 2007).

The surface temperature of plant leaves influences the environmental conditions and transpirational cooling that means the outward latent heat flux (Peng *et al.*, 2022). A rise in leaf temperature causes a transpiration cooling (Siddqui *et al.*, 2021). When there is an increase in leaf temperature, the stomata are closed and evapotranspiration stops (Wagner *et al.*, 2021). An increase in leaf temperature hinders the enzymatic activity and other processes under drought stress. The photosynthetic mechanism becomes almost inactive when leaf temperature increases above a certain point (Perera *et al.*, 2022).

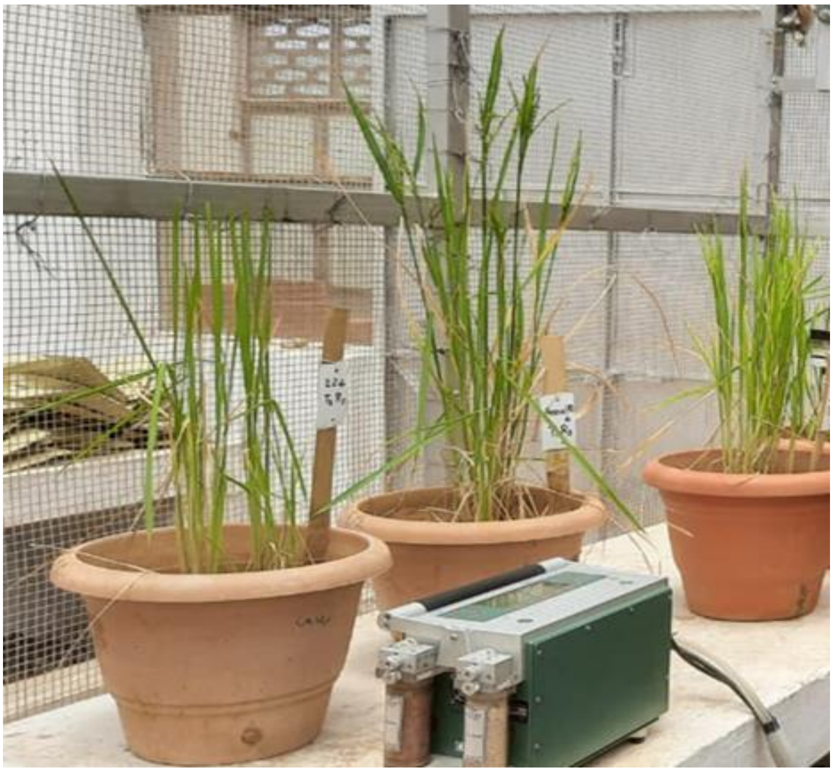
Kumar *et al.*, (2015) investigated the leaf temperature in different rice varieties under drought stress during the reproductive stage and obtained that varieties Kranti and Mahamaya maintained reduced leaf temperatures than air temperature, whereas other varieties showed increased leaf temperature under drought conditions. In brinjal, Kirnak *et al.*, (2019) reported that the water deficiencies increased in leaf temperature (34 °C) as compared to non-stressed plants (29.7 °C).

Relative water content (RWC) is a measure of plant water status that represents metabolic activity in tissues and may be used as a useful indicator of dehydration tolerance. The RWC of leaves is greater in the early phases of leaf growth. As the leaf grows and dry matter accumulates, the RWC decrease. The RWC is closely related with the cell volume, it might intently represent the harmony balance between water supply to the leaf and transpiration rate (Farquhar *et al.*, 1989; Schonfeld *et al.*, 1988). It influences the ability of the plant to recover from the stress and subsequently affect the yield and yield attributes (Lilley and Ludlow, 1996). Under drought condition, relative water content significantly decreased. At the initial stage of leaf development, the RWC is higher. It is an important indicators of plant water balance, since it represents the relative sum of water present in the plant tissues (Cramer *et al.*, 2013).

RWC indicates the water status of the plants and have significant association with the stress tolerance of cell membrane stability and yield was reported by Lugojan *et al.* (2011). The relative water content of the leaf decreased under drought stress condition. Drought resistant cultivar ought to maintain more prominent relative water content compared to the susceptible ones. This trait is an adaptive feature that the certain plant species have been developed under the water stress conditions (Dhanda and Sethi, 2002; Zadehbagheri and Masoud, 2014). The leaves subjected to the drought exhibit the larger reductions in water potential and RWC (Nayyar and Gupta, 2006). Siddique *et al.* (2000) observed a concomitant increase in the leaf temperature with considerable decreased in the leaf water potential, transpiration rate and RWC on exposure to drought (Yang *et al.*, 2010).

The RWC was closely related to water potential, but large differences in osmotic adjustment among genotypes cause a deviation between the two measures. The RWC was negatively correlated with spikelet sterility in two of the four seasons-controlled environment (Lafitte, 2002). Tsukaguchi *et al.* (2003) suggested that increased transpiration induces water deficit in plants during day time causing a reduced water potential leading to agitation of many physiological processes. Galmes *et al.* (2011) reported that the leaf relative water content is reduced in all accessions of tomato under drought stress condition. Kumar *et al.* (2015) also reported that a significant decreased amount of RWC under drought stress condition in pigeon pea.

In the cytosol, plants accumulate different type of natural and inorganic solutes to bring down osmotic potential in this way keeping up cell turgor (Inan *et al*., 2004). Under drought stress, the maintenance of cell turgor may be accomplished by the method of osmotic adjustment because of the gathering of sucrose, proline, solvent sugars, glycine betaine, carbohydrates and different solutes in cytoplasm improving water uptake from dry soil. Under drought stress, the procedure for the accumulation of such solutes is called as osmotic adjustment that firmly depends on the rate of plant water stress (Basra *et al*., 2003). A significant physiological response of plants under drought is the capacity to maintain turgor pressure by decreasing osmotic potential as tolerance mechanism (Maisura *et al*., 2014).



CONCLUSION

The selected genotypes were categorized into tolerant, moderately tolerant and susceptible. Accordingly, the genotypes were observed for the morphological, physiological, biochemical characters and yield components. The summary of present findings is presented here under. The conclusions arrived from the present study are summarized below.

- The most significant findings from this research are the identification of tolerant rice landrace *viz.*, 337- IC116006 performed better under drought stress as compared to susceptible rice landrace 224- IC 463809.
- The physiological traits *viz.*, photosynthetic rate, stomatal conductance, transpiration rate, chlorophyll fluorescence, chlorophyll index, relative water content, leaf temperature and osmotic potential were considered as indicators of drought tolerance were observed higher in the tolerant landrace 337-IC116006 as compared to susceptible landrace 224-IC463809.
- The gas exchange parameters revealed that thephotosynthetic rate, stomatal conductance and transpiration rate were higher in the landrace 337-IC116006.

- Higher chlorophyll index (SPAD), chlorophyll fluorescence (*Fv/Fm* ratio) and Relative water content (RWC) with low leaf temperature with low osmotic potential were observed in the landrace 337- IC116006 than the landrace 224- IC463809.

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