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A Review of Physiological and Biochemical Aspects of drought Tolerance in Rice

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ABSTRACT: Rice (*Oryza sativa* L.) is a major food crop which is widely consumed throughout the world, it consumes alarge amount of water during its life cycle. Regarding global climate change, it is turning into a more significant concern. One of the most severe restrictions in rice production is drought situation. In this situation rice is impeded in a number of ways, including decreased germination, plant height, biomass, tiller count, and another leaf and root traits, reduced photosynthesis, transpiration, stomatal conductance, water use efficiency, relative water content, chlorophyll content, photosystem II activity, membrane stability, carbon isotope discrimination, and abscisic acid content, as well as biochemical (accumulation of osmoprotectants like proline, sugars, polyamines, and antioxidants) and molecular (altered expression of genes encoding transcription factors and defence related proteins) levels, due to drought stress condition. Rice production is severely limited by drought stress, which causes significant monetary losses. It has become imperative to improve crop productivity on the drought-prone rainfed areas with a priority in light of the current and projected world food demand. The extensive aspect of breeding for drought-tolerant rice varieties makes it a challenging endeavour, and multigenic manipulation of drought-tolerant features would be a significant bottleneck for the ongoing study. There is a need for rice varieties with drought resistance and genetic advancement for rainfed areas in order to fulfil the production target and future research should prioritise topics that are drought tolerant. We focused on the most recent developments in rice's physiological, biochemical, and molecular adaptation to drought tolerance in this review. The future crop improvement programme for the production of drought-tolerant rice varieties will be the topic of a brief discussion on the molecular genetics and breeding methodologies for rice drought tolerance.

In this review, we specifically focused on the most recent developments in rice's physiological, biochemical, and molecular adaptation to drought tolerance. For the purposes of the upcoming crop improvement programme for the creation of drought-tolerant rice varieties, a brief discussion on the molecular genetics and breeding methods for drought tolerance in rice will be made.

Keywords: Drought stress; yield attribute; morphological characteristic; physiological characteristic; biochemical characteristic.

INTRODUCTION

Moreover, two-thirds of the world's population eats rice as their primary and staple meal (Dowling *et al.*, 1998). Rice production contributes to about 7.5 percent of overall rice production. Abiotic stresses, particularly drought, were discovered in 2001 for lowland irrigation and can have a negative impact on a person's physiological state, as well as metabolism, growth, and development. Drought is an issue. Abiotic stress is a sort of stress that has a variety of effects on plants. Their life span levels and epoch. This abiotic stress also affects the quantity of water utilised, not just in terms of content, turgor, and total water, but also in terms of restricting gas flow by affecting stomata closure exchange, decreasing transpiration, and causes disruption the process of photosynthesis. Water deficiency has negative impacts on mineral nutrition and metabolism. Reduce leaf area and change assimilate partitioning between plant organs (Zain *et al.*, 2014). Drought is a meteorological term that refers to a lack of water, particularly during periods when there is no rain. Significant rainfall has a negative influence on the crop and soil. When a person's moisture storage capacity is surpassed, this happens.

The amount of water that may be accessed in the soil is dwindling, and Water loss due to transpiration or evaporation as a function of meteorological conditions The major cause of death has been recognised as drought. Rainfed rice output is constrained. Drought stress occurs when the soil's available water is depleted, and atmospheric conditions promote continual water loss through transpiration or evaporation. Drought stress tolerance is seen in almost all species, and even within species. A slight loss of water causes drought stress, which shuts the stomata and inhibits air passage. Significant water loss is possible. It's probable that this will affect metabolism, cell structure, and, eventually, the end of enzyme-catalyzed reactions, resulting in a response (Jaleel *et al*., 2007). Drought Water loss is a symptom of anxiety. turgor loss, stomata closure, and a decrease in turgor in cell expansion and proliferation A person's heart can stop beating if they are under a lot of water stress. metabolic disruption, photosynthesis (Jaleel *et al.,* 2008). A primary abiotic stressor is drought. Has a deleterious impact on rice growth, especially in rain-fed ecosystems, which has an impact on the, which in turn has an impact on biomass output and yield. Rice must adopt a complex regulatory network and a set of physiological systems to combat and cope with the unfavourable conditions caused by drought stress. Drought stress manifests itself in lower water content, reduced leaf water potential, turgor pressure, stomatal activity, and a reduction in cell expansion and proliferation. Severe water stress can interrupt photosynthesis, alter metabolism, and finally kill plants (Jaleel *et al.,* 2008). Photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrition metabolism, and growth promoters are among the physiological and biochemical processes that are harmed (Farooq *et al.*, 2008). Water stress is a limiting factor in agricultural productivity because it inhibits a crop from attaining its genetically specified theoretical maximum yield (Begg and Turner 1976). A deeper knowledge of the morphological and physiological underpinnings of variations in water stress resistance might be utilised to select or develop novel crop types that are more productive under water stress (Nam *et al*., 2001). Plant responses to water stress vary greatly at different organisational levels, depending on the severity, length, plant species, and development phases (Jaleel *et al.,* 2008).

Effects of drought stress in rice production. Rice crops are unable to attain their maximum grain yield due to drought stress, limiting their potential to produce commercial amounts of grains. Water stress has an impact on rice grain output and quality (Mostajeran and Rahimi-Eichi 2009). Rice is more susceptible to drought stress than other crops because of its shallow and compact root structure (lowland/aquatic root system), which is insufficient for water extraction, and the grain set is lower. Rice is particularly sensitive to stress, and the timing of stress is important (Serraj *et al*., 2009). Drought-affected area in the world has almost doubled in size from the 1970s to the 2000s, resulting in lower grain output and quality of food crops, resulting in food shortages (Akram *et al.,* 2013). Rain-fed rice covers 45 percent of the world's rice field and produces 25% of all rice. A large portion of the rain-fed region, including East India, Northeast Thailand, Central Myanmar, Laos, and Northeast India, is threatened by drought. Due to increased water demands, drought is affecting both rain-fed and irrigated areas in Asia. Drought affects rice physiological processes such as growth, development, and grain production, as well as crop insects and illnesses, and ultimately grain yield (Babu, 2010). Drought stress has different degrees of influence based on factors including variety, drought intensity, drought length, and crop growth stage. These parameters might assist you in determining how to improve the drought resistance of a crop. Drought stress causes rice crops to exhibit a range of reactions, including cellular responses, stress detection, physiological and developmental stages, and signal transduction (Babu, 2010). Drought stress has a variety of effects on rice plant physiology, including pigment destruction, stomatal conductance reduction, transpiration and photosynthetic rates reduction, plant growth reduction, reduced relative water content, and lower PAR (Hasanuzzaman *et al.*, 2013).

Drought stress reduces the number of panicles per unit during the vegetative, reproductive, or grain production phases, resulting in a yield reduction of up to 30%. location Drought stress delayed anthesis and reduced the number of spikelets per panicle by up to 60 percent , according to Nokkoul and Wichitparp (2014). According to their findings, drought stress reduced grain filling, resulting in a 40 percent decrease of filled grains and a 20 percent fall in grain weight. When compared to rice plants grown under well-watered conditions, mild drought stress during the reproductive period resulted in a 31 percent to 64 percent loss in grain output. When compared to rice plants grown under well-watered conditions, mild drought stress during the reproductive period resulted ina 31 percent to 64 percent loss in grain output. Drought stress impairs flower initiation during the vegetative phase, leading in reduced grain filling and increased spikelet sterility, resulting in a reduction in grain weight (Akram *et al.,* 2013). Rice is water-sensitive throughout reproductive stages such as booting, flowering, and panicle initiation. According to research yield decreases of up to 70% were recorded when drought stress occurred for 15 days at panicle initiation, 88 percent at flowering, and 52 percent at grain filling. Water stress affects pollination, especially during the meiotic phase, resulting in flower abortion and grain abscission, as well as an increase in the number of unfilled spikelets and poorer grain yield. Drought stress affects female fertility negatively (Nguyen and Sutton 2009). Exsertion of panicles is altered by water stress, resulting in sterility in panicles that have not been exserted. This happens when the panicle achieves its maximum length and the peduncle grows longer. Drought stress causes reversible peduncle extension inhibition. Drought stress causes blooming days to be postponed, and early developing genotypes evolve a drought escape mechanism to prevent terminal chevalier. These early maturing genotypes might reduce yield loss owing to drought stress due to their short growth period.

Drought stress reduces the number of nodes and the space between internodes, lowering stem height (Jatoi *et al.*, 2012). Stem height and diameter decrease as a result of water stress.

Rice crops produce less biomass as a result of fewer tillers and slower leaf growth (Jatoi *et al.*, 2012). Rice varieties that produce a large amount of biomass can absorb moisture from the soil and transport it to the leaves for photosynthesis (Singh *et al*., 2012). When water is restored after a drought, morphological characteristics such as the number of productive tillers per hill, flag leaf length, grain size, and biomass, as well as yield components such as 1000 grain weight and panicle length, are unchanged (Momo *et al.*, 2013). Nematodes, brown spot, and blast were detected during the drought stress screening. Drought and disease resistance lines must be established to combat the incidence of these diseases and pests. These issues have been solved by keeping the field aerobic for two-thirds of the crop's growth, changing drought screening fields every three years, cultivating pulses in the off-season, and using nematicides in areas where soil alterations are not possible (Barnwal *et al.,* 2013).

Physiology and measurement of drought tolerance in rice. Water scarcity has resulted in catastrophic losses in agricultural production, jeopardising global agriculture sustainability. Understanding the physiology of drought tolerance is critical when producing crops that are both high yielding and drought tolerant when coping with water stress (Yong'an *et al.,* 2010). Plant emergence characteristics, phenology of development, nutrient uptake efficiency, photosynthesis, water use efficiency, carbon isotope discrimination, hormonal regulation, stay green, osmotic adjustment, grain number maintenance, grain fill duration and rate, and yield and its components are all used to assess drought tolerance in rice.

Rapid leaf development characterises the vegetative phase, and the amount of water used is proportional to the rate of transpiration. The initial stages of the development of a rice plant, Stem elongation and leaf growth are both affected by water stress (very sensitive stages to plant water status). Rice's gas exchange is disrupted when soil moisture is at 70%, unlike other crops, which are affected when soil moisture is at 30%. (Fischer, 2003). Rice plants are significantly affected by drought stress from approximately 12 days to 50 percent flowering and from about seven days to 100 percent flowering. As a result, the drought tolerance of the crops is determined by recording the date when 50% of the plants in the plot have bloomed. Crops that have flowered early or late can be identified by keeping track of their flowering dates. Even if the crops are re-watered in the advanced stages, late flowering rice crops provide modest yields (Fischer, 2003).

When it comes to determining drought tolerance, grain yield is an important factor to consider. Most grain breeders have utilised direct selection based on yield to select for high yields in drought-stressed environments. Drought stress has an effect on the several growth phases of rice, which has an effect on the various components of grain output (Davatgar *et al.,* 2009). The following are the main criteria for determining drought tolerance: The important parameters for measuring drought tolerance are yield and its components, which include plant height, number of productive tillers, 1000 grain weight, number of spikelets (full and unfilled), percentage panicle sterility, and panicle length. Random samples from a seed batch are chosen, 1,000 whole grains are counted, and the sample is then weighed to obtain a grain weight of 1000 grains. The number of spikelets is a critical statistic used to compute % spikelet fertility when screening for drought tolerance. When compared to yield, percentage spikelet fertility reveals genetic responses to drought stress. The unfilled spikelets are separated from the filled spikelets by pressing the harvested rice samples (Fischer, 2003). The spikelets are weighed or numbered, and the filled and unfilled spikelets are separated by pressing (Fischer, 2003). The spikelets are weighed or counted, both filled and unfilled. The following formula is used to calculate percentage spikelet fertility:

$$\text{Percentage of spikelet fertility } = \frac{\text{Number of fi le grains in the sample}}{\text{Total number of fi and u spiklets}} \times 100$$

Root depth in centimetres, root number per hill, root volume in millilitres, root: shoot ratio, root xylem vessel numbers, and root thickness are all root characters. Drought avoidance is a trait that aids crops in obtaining water deeper in the soil, which is dependent on the depth, penetration ability, and thickness of the roots. Osmotic adjustment, increased hydraulic conductivity, and xylem thickness are some of the other secondary features shown by roots. These characteristics allow for better uptake of existing soil water content. Because of the large investment in green house facilities and field nurseries, most of these features are expensive to use in breeding projects. Root measurement is prone to problems of reproducibility due to changes in the environment and is time-consuming (Babu, 2010).

When plants are stressed by water, their chlorophyll content, or SPAD value, is assessed. Because chlorophyll is made up of nitrogen, there is a strong link between the colour of a leaf and the nitrogen status of a crop (Wang *et al.*, 2012). Nitrogen is essential for rice crop development, and a lack of it results in lower chlorophyll content, smaller leaves, and lower biomass, all of which lead to worse grain quality and production (Wang *et al.*, 2012). Water stress reduces photosynthetic pigments like carotenoids, chlorophyll a and b, as well as leaf and shoot weight (both fresh and fresh), affecting photosynthesis. There was a major reduction in fresh shoot mass in rice with increase in water stress.

A hand-held gadget known as a SPAD-502 metre is used to detect leaf chlorophyll concentrations. The SPAD-502 metre determines the amount of chlorophyll in a leaf by measuring its absorbance in two wavelength ranges. It is non-destructive, accurate, and quick.

Agro-physiological variables such as plant height in centimetres (cm), panicle length in cm, tiller number per hill, leaf angle measurement, leaf rolling, flag leaf area in cm^2 and flag leaf dry weight in grammes are also used to assess drought tolerance (Allah, 2009).

As a visual indicator of their misery, water-stressed plants roll their leaves. Plants roll their leaves when they can't keep up with the need for transpiration (Allah, 2009). This reaction is seen in several species, including sorghum, wheat, and rice (Kadioglu *et al.*, 2012). Leaf rolling assists in maintaining a proper water balance in plant tissues during drought stress. The ability of a leaf to recover from dehydration during drought stress is determined by its ability to retain a high relative water content. Radiation on the leaf is lowered during leaf rolling, stomates are closed, resulting in decreased transpiration, and gaseous exchange is inhibited, resulting in decreased photosynthesis. In rice, leaf rolling is scored in the middle of the day. When a rice crop exhibits delayed leaf rolling and a faster recovery rate after being removed from water stress, this is a positive trait (Singh *et al.*, 2012).

Understanding drought by plants. Plant roots can send out a signal (warning) to the air to indicate that they are experiencing water stress and tension before the leaves' stomata close. As a result of the notice (warning), ABA hormone is created in the root tip as a response of stress (Pour Najaf, 2005). In this regard, the most significant plant hormone, abscisic acid, plays an important part in the life cycle of plants as well as many important physiological processes, morphological and environmental adaptation, and tension-adjusting reactions (Kafi and Mahdavi Damghani 1999). In the event of a water shortage in the root zone, ABA synthesis in the roots and aerial parts of the plant swiftly spreads to relieve pressure in the cells of this region. The decrease in chlorophyll content under drought stress has been considered a typical symptom due to pigment photo oxidation and chlorophyll degradation. Decreased of chlorophyll content during drought stress depend upon the duration and severity of drought level (Zhang and Kirkham 1996).

Water loss from plant may cause the following changes in plant. The protoplast shrinks, and the concentration of cellular solutions rises. The water potential gradient across membranes changes when the loss of turgor decreases. In the worst-case scenario

Cases includebiomembrane breakdown (changes in states such as crystalline state and leakage) and protein denaturing, as well as a drop in nucleic acids and proteins. Changes in plant hormones, decreases in growth promoters, increases in inhibitors (especially ABA), and accumulation of toxic agents, NH_3 and amines.

A primary response to water deficit reduced leaf area. Water stress promotes cell growth inhibition, which leads to a reduction in leaf development since a smaller leaf surface means less water uptake from the soil and less transpiration. Drought stress could be mitigated in part by limiting the amount of leaf surface area (Kafi and Mahdavi Damghani 1999).

Water deficiency stimulates leaf abscission. If the plants receive leaf water after the meeting, the old leaves begin to fall. This long-term alteration in leaf regulation is critical for improving the environment's adaptation in the face of a water shortage (Maleki *et al.*, 2013). The process of plants dropping leaves as a result of enhanced synthesis and sensitivity of certain hormones in response to water stress (Kabiri, 2010).

Stomata are closed during water stress in response to abscicic acid. Abscisic acid is created in leaf mesophyll cells in a constant and low-level manner, and it begins to accumulate in the chloroplasts. When mesophyll wilts, two processes happen: first, the quantity of abscisic acid contained in mesophyll cells is released into the Pv plast transpiration stream, with part of it passing through the guard cells. Second, net production rates increased the amount of abscisic acid produced. After stomatal closure, abscisic acid biosynthesis began, and it appears to prolong the action of the initial block, which is stored by abscisic acid.

Mechanisms of resistance to drought. Drought resistance refers to a species' or cultivar's capacity to grow and produce in drought circumstances. The physiological and morphological impacts of a lengthy dry period on production and yield depend on a variety of parameters. To reduce transpiration, the crop should block the stomata, which will also reduce absorption and sweating, or a combination of all three levels will reduce transpiration (Shekari, 2000). *Oryza* species can clog pores when water scarcity grows. When the stomata are entirely blocked, this inhibits transpiration and cuticular resistance is substantially higher. Active and inactive motion, as well as increased leaf wax cracking, are useful in reducing radiation absorption. Drought stress can lead some plants' leaves to become mentose or waxy, and both of these qualities are mirrored in the increased number of leaves to prevent water loss. Drought resistance in crop plants can be achieved by conserving water and maintaining a water absorption system. The most significant aspect is that this necessitates deep roots and branches, as well as a low resistance to water movement within the plant. The lack of water causes discolouration and an increase in leaf trichomes and stomata on the leaf surface. In the event of a severe water scarcity, the roots will shrivel and induced deposition will occur in the leaves. Antioxidant activity and poisonous agent buildup, such as proline and ammonia, both increased.

Role of proline under drought. In plants that have been subjected to a variety of stresses, proline plays an important role (Verbruggen and Hermans 2008). Proline functions as an osmolyte, and its accumulation aids in improved performance and drought tolerance (Vajrabhaya *et al.*, 2001). Rather than serving as an effective osmolyte, it serves as a metal chelator, an antioxidativedefence molecule, and a signalling molecule during times of stress (Hayat *et al.*, 2012). During drought stress, proline buildup may help plants repair damage by enhancing antioxidant activity. Proline content increases more than other amino acids in plants when they are stressed by water. This effect has been employed as a biochemical marker in the selection of drought-resistant cultivars. As a result, proline content can be utilised in a variety of ways.

Role of polyamines under drought. Polyamines (PAs) are positively charged, tiny compounds (Fuell *et al.*, 2010). They maintain membranes, regulate osmotic and ionic homeostasis, act as antioxidants, and interact with other signalling molecules in the response to drought (Calzadilla *et al.*, 2014). Higher PAs levels in lants are linked to greater photosynthetic capacity, reduced water loss, improved osmotic adjustment, and detoxification during drought stress. Exogenous PAs can help relieve drought stress by improving net photosynthesis, leaf water status, the formation of free prolineanthocyanins and soluble phenolics, and reducing oxidative damage to cellular membranes (Farooq *et al.*, 2009).

Role of antioxidants under drought. The formation and quenching of reactive oxygen species (ROS) is a frequent outcome of drought stress (Faize *et al.*, 2011). The superoxide radical, hydroxyl free radical, hydrogen peroxide, and singlet oxygen are all examples of reactive oxygen species (ROS). It causes lipid peroxidation, protein denaturation, DNA mutation, cellular hemeostasis disruption, and many types of cellular oxidative damage. A sophisticated antioxidant system that includes both non-enzymatic and enzymatic antioxidants protects plant cells from the harmful effects of ROS. Within the plant cell, ascorbate (AsA) and glutathione (GSH) serve as strong non-enzymatic antioxidants. Superoxide dismutase (SOD), catalase (CAT), guaiacolperoxidise (GPX), enzymes of the ascorbate-glutathione cycle, and ascorbate peroxidase (APX) are enzymatic antioxidants (Noctor and Foyer 1998) that are important components of the ROS scavenging system in plant, also their expressions can improve drought tolerance in rice (Wang *et al.*, 2005). Enhancement of components that are naturally occurring antioxidant (enzymatic and non-enzymatic) may be one of the major strategy for reducing oxidative damage and improving the resistance of plants against drought (Hasanuzzaman *et al*., 2013). SOD (superoxide dismutase) acted as one of the major key enzymes in plant to elimination active oxygen.

Effect of drought on Grain quality. Drought stress during vegetative growth, particularly at the booting stage (Pantuwan *et al*., 2002), flowering, and terminal periods can disrupt floret initiation, resulting in spikelet sterility and slow grain filling, resulting in lower grain weight and, ultimately, poor paddy yield (Kamoshita *et al.*, 2004). Drought affects grain yield by shortening the grain filling time, changing leaf gas exchange characteristics, decreasing the size of the source and sink tissues, and impairing phloem loading and assimilate translocation (Shahryari *et al.*, 2008; Farooq *et al*., 2009). As a result, the plant generated half-filled, partially formed, and underdeveloped grain, all of which reduced grain quality.

Rice grain quality is affected by a multitude of elements including cooking technique, region, and usages such as rice miller, head and broken rice kernels, grain size, fragrance, appearance, and cookability. Rice is divided into four categories in many countries: I milling quality, II cooking, eating, and processing quality, III nutritional quality, and IV cleanliness, soundness, and purity criteria. A variety of laboratories have been established across the world to provide high-quality grain to customers.

The grains in the upper position of the panicle usually have a high grain-filling rate, and the grains on the US were comparatively slow (Fig. 1). The reason for this could be because grains grown on the UP have particularly strong apical dominance in terms of assimilate utilisation, which has slowed the filling activity of grains grown on the US (Mohapatra *et al.*, 2009). Because they were partially filled, the LP and LS display the least amount of grain in all circumstances, both HF and LF. So, under drought stress, the LP and LS yield low quality grain because homogeneity is lost, and they mill differently, retain moisture differently, and cook differently. Every year, due to drought stress, yields are reduced.

The Effect of Drought Stress on Yield. Drought stress reduces rice grain yield significantly (Maisura *et al*., 2014). Drought stress during booting (Pantuwan *et al.*, 2002) floret initiation, resulting in late grain filling and spikelet sterility, as well as reduced grain weight and poor paddy yield. Reduced grain weight and size, 1000-grain weight, and seed-setting rate, and spikelet sterility (Kumar *et al.*, 2014) are the most typical features of rice under drought stress. Water shortages shorten the grain filling time, lowering grain yields (Shahryari *et al.*, 2008). Drought stress inhibits assimilate transport by disrupting leaf gas exchange, limiting the diameters of source and sink tissues and impairs assimilate translocation and phloem loading (Farooq *et al.*, 2008).

Reduced growth and productivity of the plant may be caused by drought-induced reductions in CO_2 assimilation rates or decreases in photosynthetic pigments, stomatal conductance, stem extension, water use efficiency, the activities of starch and sucrose biosynthetic enzymes, and assimilate partitioning. Drought length and crop growth stage, as well as the severity of the drought stress (Kumar *et al.*, 2014), are two predictors of grain yield loss (Gana, 2011). Cell division, expansion, and differentiation are influenced by genetic, physiological, morphological, and ecological processes, as well as their complex relationships. Drought-induced decreases in turgor pressure inhibit cell development considerably (Saddique *et al*., 2018). Disrupted water transport between the xylem and the surrounding elongating cells may restrict cell elongation in higher plants under severe drought stress. Plant leaf area, height, and crop growth are reduced when mitosis, cell elongation, and cell expansion are reduced (Gana, 2011; Hussain *et al*., 2008).

Fig. 1. The Role of Photosynthesis and Photosynthetic Pigments in the Drought Response.

During drought stress, photosynthesis is one of the most important metabolic processes. The CO_2 diffusional restriction caused by lower photosynthesis, early stomatal closure, and the decreased efficiency of PSII photochemical production and biochemical components connected to triose phosphate generation are the most important mechanisms that limit photosynthesis. The overall photosynthetic rate is affected by changes in any of these components. Drought stress reduces mesophyll conductance (gm) and stomatal conductance (gs) to CO_2 (Chakhchar *et al*., 2017). As a result, maintaining gm levels during drought stress demonstrates rice's resistance to water shortages. PSII activity is critical for ATP and power production. An extreme reduction in the electron transport chain occurs when PSII activity rises. If PSII activity rises, the electron transport chain in the photosynthetic apparatus may be overloaded, resulting in increased ROS generation. As a result, a balance between photoassimilate demand and photochemical activity is required. Drought stress reduces PSII activity in rice flag leaves considerably. Drought causes the breakdown of the D1 polypeptide, which in turn causes the PSII reaction centre to become inactive. Drought stress limits photosynthesis because the activity of Rubisco, a Calvin cycle enzyme, declines (Zhou *et al.*, 2007). Nonetheless, the amount of Rubiscoactivase promotes ATP-dependent conformational changes, rescues Rubisco sites from dead-end inhibition, and can rise as a drought-protective strategy. Currently,Rice has been given enzymes involved in C4 crop photosynthesis to change photosynthesis and plant productivity in response to stress. Transgenic rice plants that overexpress C4 photosynthesis enzymes including phosphoenolpyruvate carboxylase and pyruvate orthophosphate dikinase are drought resistant.

Drought causes a variety of metabolic changes, the most notable of which is the reduction or loss of photosynthetic pigment synthesis. This results in less light harvesting and less power, which serves as an energy source for photosynthesis's dark reactions. Changes in photosynthetic pigment concentrations are linked to biomass and yield (Jaleel *et al*., 2009). Chlorophyll, a photosynthetic pigment, absorbs light energy and delivers it to the photosystem reaction centre. Chlorophylls a and b, which are commonly present in higher plants, are particularly susceptible to soil dryness. Other pigments, like as carotenoids, play a role in light harvesting, chloroplast photosystem structure, and photoprotection, and can help crops resist drought to some extent. Chlorophyll levels are dropping. In various investigations on rice under drought stress, decreases in chlorophyll content and maximal quantum yield of PSII (Fv/Fm) have been found (Maisura *et al*., 2014). Under drought stress, decreases in Fv/Fm and chlorophyll content were found less frequently in autotetraploid lines than in diploid lines, implying that autotetraploid rice is more drought resistant. Stress may cause a decrease in chlorophyll content by impairing pigment degradation or pigment biosynthesis networks, as well as increasing lipid peroxidation and chloroplast membrane loss.

Different techniques of improving grain quality of rice

— **Selection of suitable cultivar.** Rice cultivars cultivated under draught stress and in well-irrigated paddy fields have different grain quality and quality components. In all drought tolerant cultivars, moderate drought stress during grain filling may improve grain quality by increasing head rice and reducing grain chalkiness (Yang *et al.*, 2002). Grain quality is inversely proportional to grain chalkiness. As a result, when there is a drought, the quality improves.

— ABA Application. Cultivars with excellent drought resilience, as well as good yield and grain quality, were chosen. Drought hardening techniques such as "Seedling drought," "seedling starvation," and "double sprout" can help plants adapt to drought stress. Under drought stress, seed priming, appropriate fertiliser treatment, and chemical reagents such as ABA application can all help to improve yield and grain quality.

CONCLUSION

Drought stress affects the growth, dry mater, yield and its associated traits in rice plant but the morphological traits *viz*., deep root system, cuticular wax, stomatal activity, leaf rolling character, high tissue water potential, membrane stability, rapid recovering ability after water stress has been implicated in the improvement of drought tolerance cultivar. In addition to these factors, changes in photosynthetic pigments, production of biochemical are also importance to drought tolerance. Thus, these morphological and biochemical characters may be considered during the development of drought tolerance varieties. The process of developing drought tolerance in rice is challenging and calls for careful consideration of the numerous morphological, biochemical, and molecular and physiological characteristics. Understanding the correlation between drought tolerance, seed set, yield, yield components and grain quality measures should have taken for substantial influence on grain improvement. Also, it may be possible to prevent the irreversible effects of drought stress on the yield and grain quality by selecting suitable cultivar or seed priming by Glycinebetaine. The simplified information from in this review will make it easier to do follow-up research to better understand the physiological and biochemical mechanisms of drought tolerance in rice and develop to new that are drought resistant and high-yielding.

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