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DROUGHT TOLERANCE MECHANISM AND GRAIN QUALITY OF RICE

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DROUGHT TOLERANCR MECHANISM AND GRAIN QUALITY OF RICE [1]

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Abstract

Rice (*Oryza sativa* L.) is staple food crop and requires huge amount of water throughout its life cycle as compared to other crops. Drought is a one of the major challenge limiting in case of rice production. It hampers rice at different morphological such as reduced germination, plant height, plant biomass, number of tillers, various root and leaf traits. Physiological traits as 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 osmoprotectant like proline, sugars, polyamines and antioxidants) and molecular (altered expression of genes which encode transcription factors and defence related proteins) levels also affect by drought and thereby affects its yield and grain quality. For improving grain quality of rice selection of suitable cultivar is prerequisite .Grain quality also be increased by creating drought tolerant cultivar through plant breeding program . Drought stress greatly reduced the rice growth and grain quality while Glycinebetaine (GB) application improved it both under well-watered and drought conditions. Foliar treatments were more effective than the seed treatments, while among the GB treatment, foliar application with 100 ppm was the most effective. Moreover, both selenium and silicon pretreatments also mitigated the adverse effects of drought and improved grain quality via the increments in the levels of amylose, phenolic compounds as well as flavonoid and oil contents and by reduction in grain water uptake during cooking.

Key words: Drought stress; yield attribute; morphological characteristic; physiological characteristic; biochemical characteristic; molecular level, Glycinebetaine, selenium, silicon.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Water is an important factor in agricultural and food production though it is a highly limited resource (Wang *et al.*, 2012). Water deficit stress causes extensive loss to agricultural production worldwide. So it is being a severe threat to sustainable agriculture. Feeding continuously increasing population with depleting water supply requires crop varieties which are highly adapted to dry environments (Foley *et al.*, 2011).

Rice plays a major role as a staple food. It is supporting more than three billion people and comprising 50% to 80% of their daily calorie intake (Khush, 2005). Drought stress severely impairs its yield and ultimately production. Worldwide, drought affects approximately 23 million hectares of rainfed rice (Serraj *et al.*, 2011). Climate variability badly influences the water resources, and the frequencies of droughts and floods are likely to increase in future. Crop yield depends on specific climate conditions. Thus it is highly affected by climatic variations. The overall rice yield variability as a result for climate variability over the last three decades was estimated by Ray *et al* .,(2015), and it was concluded that approximately 53% of rice harvesting regions experiences the influence of climate variability on yield at the rate of about 0.1 t/hm^2 per year and approximately 32% of rice yield variability is explained by year-to-year global climate variability .

With diminishing water supplies for agriculture in the whole world, the needs to improve drought adaptation of rice and to screen resistant varieties are becoming increasingly more important. The unpredictability of drought occurrence patterns and the complexity of the response mechanism involved have made it difficult to characterize component traits required for improved performance, thus limiting crop improvement to enhance drought resistance (Serraj *et al.*, 2009). Drought tolerance is a complex trait, because it is a combined function of various morphological, biochemical and molecular characters.

The mechanisms associated with water-stress tolerance and adaptation and the systems that regulate plant adaptation to water stress through a sophisticated regulatory network in rice have been extensively studied. In order to achieve a full understanding of drought-response mechanism in rice and to produce rice with improved drought tolerance, there are needs to combine the data derived from different studies and to put a figure on how various traits which affect the rice productivity respond to water deficit condition for improving yield and grain quality.The occurrence of soil moisture stress also hampers lot of the physiological processes such as photosynthesis and transpiration resulting in poor grain filling and poor quality grain, (Samonte *et.al*.,2001).

Incorporation of preferred grain quality features has become very important objective in rice improvement programs next to enhancement in yield attributes. Therefore, it is very crucial to identify how quality of rice is affected when rice crop is under drought stress condition. Though rice is consumed worldwide, therefore is no universal rice quality attribute (Veronic *el al*.,2007). But mostly rice appearance and cooked rice texture are the characters considered as main quality attributes by most of the consumers (Rousset *et al*.,1999). Grain size is also an important quality trait in rice trade with different preferences among consumers throughout the world (Fan *et al*., 2006). For example, consumers who are living in the USA and most Asian countries prefer long slender grains (Juliano *et al*.,1993). Genetic correlation provides the information about type of relationship of traits among themselves as well as with yield parameters(Known *et al*.,1964).So it is necessary to concentrate on the yield as well as grain quality while selection a variety or at the time of breeding. Although general effects of drought on rice growth are fairly well known but the exogenous Glycinebetaine (GB) application and seed treatments may alleviate the oxidative damage with the enhanced activities of enzyme antioxidants and promote seedling growth and grain quality. Quality of grain and nutritional value can also be improved which are affected by drought through seed treatment with selenium and silicon.

In view of above information, the present study was undertaken to achieving the following objectives:

1. To facilitate the selection or development of drought tolerant rice varieties,
2. A thorough understanding of the various mechanisms that govern the yield and grain quality of rice under water stress condition.

CHAPTER II

MATERIALS AND METHODS

This is as a whole, a review paper. All data and information are adopted as a secondary data. This review paper has compiled through an exclusive going through different books, booklets, articles, proceedings, thesis, Journals. For collecting recent information I visited different websites through internet. After collecting necessary information, it has been compiled and arranged chronologically for better understanding and clarification.

CHAPTER III

REVIEW OF FINDINGS

3.1 Understanding drought by plants

Plant roots can sign (warning) to send the air to show that they are under water stress condition and tension before the leaves, stomata are being closed. Due to the sign (warning), ABA hormone is produced as a result of stress in the root tip (Pur Najaf, 2005). In this respect, the most important plant hormone abscisic acid has a major role in the life cycle of plants and many important physiological processes, morphological and plant adaptation to the environment, and reactions to adjust the tension (Kafi and Mahdavi Damghani 1999).In case of scarcity of water in the root zone region and reduce the pressure in the cells of this region though ABA synthesis in roots and aerial parts of the plant quickly spread (Ghodsi et al, 1998). Due to the very fast reaction of stomatal guard cells during stress stomatal closure at noon the weather is warm and low water absorption and transpiration rate increases. In situations where moderate or severe stress, there increases the concentration of proline, as it is a nitrogen storage tank but soluble cytoplasmic osmotic potential decrease in acts of plant stress tolerance assists (Ghodsi et al, 1998). The decrease in chlorophyll content under drought stress has been considered a typical symptom due to pigment photo oxidation and chlorophyll degradation (Anjum *et al.*, 2011). Decreased of chlorophyll content during drought stress depend upon the duration and severity of drought level (Zhang and Kirkham, 1996).

3.2 Water loss from plant may cause the following changes in plant

Shrinkage of the protoplast and increase the concentration of the cellular solutions. Due to decrease of loss of turgor changes in the water potential gradient across membranes. In the worst cases, disintegration of biomembranes (changes in states, such as crystalline state and become leaked) and denaturing of proteins (Anjum *et al.*, 2011),decrease in nucleic acids and proteins. Changes in plant hormones, Growth promoters decreases, inhibitors (esp. ABA) increases as well as poisonous agents accumulation, NH3 and amines increases.

3.3 A primary response to water deficit reduced leaf area

At the onset of water stress, inhibition of cell growth and that leads to a reduction in leaf development because lower leaf surface causes less water uptake from the soil and transpiration is reduced. Restrictions on the leaf surface area could be the first line of defense against drought stress (Kafi and Mahdavi Damghani, 1999).

3.4 Water deficiency stimulates leaf abscission

If the plants, leaf water after the completion of the encounter, the old leaves are falling. This regulation of leaves, long term change is important to improve the adaptability of the environment which is facing a water shortage (Maleki et al. 2013). The process of shedding leaves during water stress, largely the result of increased synthesis and sensitivity of some hormone in plants (Kabiri, 2010).

3.5 Stomata are closed during water stress in response to abscicic acid

Abscisic acid to form a continuous and at low levels in leaf mesophyll cells produced and starts accumulates in the chloroplasts. When mesophyll with a mild wilting, two things happen: first, the amount of abscisic acid stored in mesophyll cells that may be released to Pvplast transpiration stream and some of it to pass the guard cells. Second, the net production rates increased abscisic acid amount. Abscisic acid biosynthesis after stomatal closure started and it seems to prolong the effect of primary block is stored by abscisic acid (Matysik *et al*.,2002).

3.6 Mechanisms of resistance to drought

Drought Resistance in fact that is the ability of species or cultivars for growth and production in drought conditions. By a long dry period on the physiological and morphological effects on yield and yield depended many factors. To prevent water losses, crop should close the stomata, also reducing in absorption or decreased sweating, or a combination of all three levels will reduce the amount of transpiration (Shekari, 2000). With increasing water shortages, *Oryza* species can clog pores. This reduces transpiration when the stomata are completely blocked and cuticular resistance is much more true. Active and inactive motion and increased leaf wax cracking effective in the reduction the absorption of radiation. Drought stress may also causes to mentose or waxy leaves of some plants are both of these characteristics are reflected by the increasing amount of leaves to reduce water loss (Leila, 2007). One of drought tolerance in crop plants through water conservation and sustaining water absorption system. The important feature is that this requires have deep roots and branches and a low resistance to flow of water inside the plant (Zareian, 2004).

The shortage of water, causing discoloration and leaf trichomes and stomata on the leaf surface is increased. In conditions of severe water shortage, the roots will shrink and in the leaves induced deposition (Bagheri, 2009).Different types of antioxidant activity and Poisonous agents accumulation also increased such as proline, ammonia.

3.6.1 Role of proline under drought

Proline plays a very beneficial role in plants exposed to various stress conditions (Verbruggen and Hermans, 2008). Proline acts as osmolyte ,its accumulation contributes to better performance as well as drought tolerance (Vajrabhaya *et al.*, 2001).Rather than acting as an excellent osmolyte,it plays three major roles during stress, i.e., act as a metal chelator, an antioxidative defence molecule and a signaling molecule (Hayat *et al.*, 2012). Proline accumulation might promote plant damage repair capability by increasing antioxidant activity during drought stress. In plants during water stress, proline content increases more than other amino acids. This effect has been used as a biochemical marker to select varieties aiming to resist to drought conditions (Fahramand *et al.*, 2014). Thus, proline content can be used as criterion for screening the drought tolerant rice varieties.

Table 1: Proline content (µmol/lit) of 1 sheath under submerged and non-submerged conditions

	Young leaves			**Old leaves**		
Rice cultivar	Submerged	Non-submerged	Change(%)	Submerged	Non-submerged	Change (%)
Zayande-Rood	112	155	0.38	58	73	0.25
829	84	102	0.21	48	52	0.83
216	97	120	0.23	54	61	0.12

Source: Verbruggen *et al.*,2008

Table 2: Proline content (μmol/lit) of blade under submerged and non-submerged conditions

	Young leaves			**Old leaves**		
Rice cultivar	Submerged	Non-submerged	Change(%)	Submerged	Non-submerged	Change (%)
Zayande-Rood	116	129	0.11	58	60	0.03
829	82	85	0.04	45	45	0.0
216	100	104	0.04	51	53	0.04

Source: Verbruggen *et al.*,2008

In all cultivars, higher proline content was observed in young leaves than the old ones. Under un-submerged treatment, proline content in sheath increased significantly more than blades, especially in young leaves. Moreover, Zayande-Rood cultivar shows more amounts of proline in both submerged and non submerged treatments(Table 1,2).

3.6.2 Role of polyamines under drought

Polyamines (PAs) are small and positively charged molecules (Fuell *et al*., 2010).These are involved in the response to drought (Calzadilla *et al*., 2014) and they stabilize membranes, regulate osmotic and ionic homeostasis, and act as antioxidants and interact with other signaling molecules. Under drought stress conditions, higher PAs contents in plants are related to increased photosynthetic capacity as well as reduced water loss, improved osmotic adjustment and detoxification. Exogenous PAs application can also alleviate drought stress because its application improved net photosynthesis, leaf water status, production of free proline, anthocyanins and soluble phenolics and alleviate oxidative damage on cellular membranes (Farooq *et al*., 2009b).

3.6.3 Role of antioxidants under drought

A regular effect of drought stress is the the generation and quenching of reactive oxygen species (ROS) (Faize *et al*, 2011). ROS includes the superoxide radical, hydroxyl free radical, hydrogen peroxide and singlet oxygen.It causes peroxidation of lipids, denaturation of proteins, mutation of DNA, disrupt cellular hemeostasis as well as various types of cellular oxidative damage. Plant cells become protected against the detrimental effects of ROS by a complex antioxidant system comprising of the non-enzymatic and enzymatic antioxidants. Ascorbate (AsA) and glutathione (GSH) are served aspotent non-enzymatic antioxidants within the plant cell. The enzymatic antioxidants are superoxide dismutase (SOD), catalase (CAT), guaiacol peroxidise (GPX), enzymes of ascorbate-glutathione cycle, ascorbate peroxidase (APX)(Noctor and Foyer, 1998) and these antioxidants are critical 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 dought (Hasanuzzaman *et al*., 2014).

Table 3.Change of *SOD* activity in rice flag leaf under water stress after anthesis (*µg/g·Fw*)

Cultivar	**Treatments**	**Days after anhesis**					
		0	7	14	21	28	35
C418	Water stress	422	399	359	309	233	122
	Control	415	390	311	229	141	90
Zaoxian14	Water stress	437	403	372	324	246	135
	Control	431	394	351	245	154	102
DLR37	Water stress	455	420	397	351	284	148
	Control	453	407	361	333	259	119

Source:Wu Na *et al.*,(2007)

SOD (superoxide dismutase) acted as one of the major key enzymes in plant to elimination active oxygen. As Table 3 indicated, in each cultvar, the SOD activity in flag leaves decreased along the flowering days increased and the SOD activity of control treatment was always lower than that of water stress treatment in flag leaves(Table 3). The rice drought resistance and leaf SOD activity assumed the inverse correlation relations; the SOD activity is higher in the variety with strong drought resistance.

3.7 Methods to increase the resistance against drought

Selection of cultivars with high resistance to drought along with high yield and grain quality. Drought hardening such as "Seedling drought", "seedling starvation", "double sprout" may also help to acclimatize plant under drought stress. Seed priming, suitable fertilizer application, chemical regents application such as ABA also can improve yield and grain quality under drought stress.

3.8 Effect of drought on Grain quality

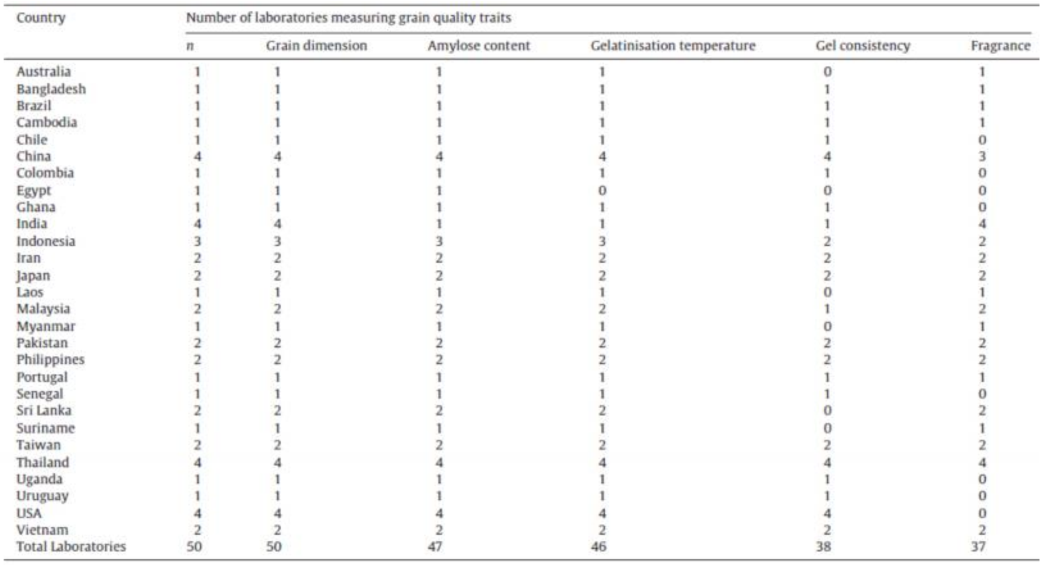
Drought stress at vegetative growth especially at booting stage (Pantuwan *et al.*, 2002), flowering and terminal periods can interrupt floret initiation, causing spikelet sterility as well as slow grain filling, resulting in lower grain weight and ultimately poor paddy yield (Kamoshita *et al.*, 2004). Drought reduces grain yield probably by shortening the grain filling period under drought (Shahryari *et al.*, 2008), disrupting leaf gas exchange properties, limiting the size of the source and sink tissues as well as impaired phloem loading and assimilate translocation (Farooq *et al.*, 2009b).As a result the plant produced half filled grain, partially developed grain and under developed grain which ultimately decrease the grain quality.

Quality grain is the first priority among most of the rice consumers but there is no proper definition or description of rice grain quality, because as definition of quality, depends on several factors such as cooking practice and region and usages for example rice miller, and head and broken rice kernels, grain size, aroma, appearance and cookability.

In general many countries quantify rice into four main categories (i) milling quality (ii) cooking, eating and processing quality, (iii) nutritional quality and (iv) specific standards for cleanliness, soundness and purity.

For supplying the quality grain among the consumers a number of laboratories are established throughout the world.

Table 4:The number of laboratories around the world that routinely measure rice grain quality traits (grain length and shape, fragrance, amylose content, gelatinisation temperature and gel consistency), where n = number of laboratories

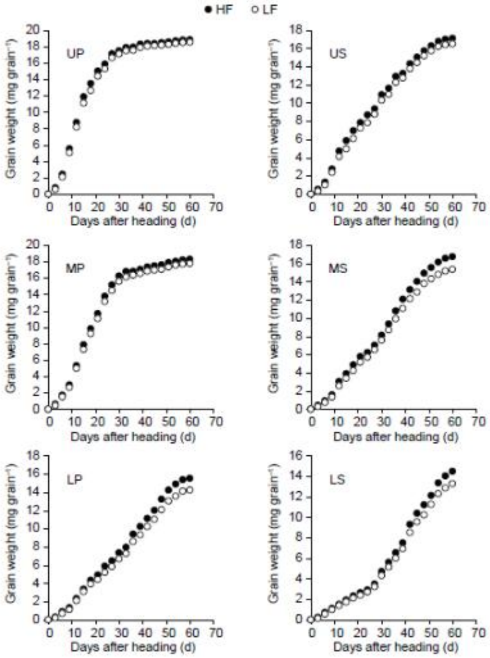


Country	Number of laboratories measuring grain quality traits					
	n	Grain dimension	Amylose content	Gelatinisation temperature	Gel consistency	Fragrance
Australia	1	1	1	1	0	1
Bangladesh	1	1	1	1	1	1
Brazil	1	1	1	1	1	1
Cambodia	1	1	1	1	1	1
Chile	1	1	1	1	1	0
China	4	4	4	4	4	3
Colombia	1	1	1	1	1	0
Egypt	1	1	1	0	0	0
Ghana	1	1	1	1	1	0
India	4	4	1	1	1	4
Indonesia	3	3	3	3	2	2
Iran	2	2	2	2	2	2
Japan	2	2	2	2	2	2
Laos	1	1	1	1	0	1
Malaysia	2	2	2	2	1	2
Myanmar	1	1	1	1	0	1
Pakistan	2	2	2	2	2	2
Philippines	2	2	2	2	2	2
Portugal	1	1	1	1	1	1
Senegal	1	1	1	1	1	0
Sri Lanka	2	2	2	2	0	2
Suriname	1	1	1	1	0	1
Taiwan	2	2	2	2	2	2
Thailand	4	4	4	4	4	4
Uganda	1	1	1	1	1	0
Uruguay	1	1	1	1	1	0
USA	4	4	4	4	4	0
Vietnam	2	2	2	2	2	2
Total Laboratories	50	50	47	46	38	37

Source: Calingacion *et al*., 2014

In Bangladesh now-a-days people are becoming more concern about choosing the quality grain for eating purpose. So different types of quality traits measuring laboratories are also established for routinely measure rice grain quality in Bangladesh (Table 4).

3.9 Grain filling characteristics during post anthesis period under drought stress



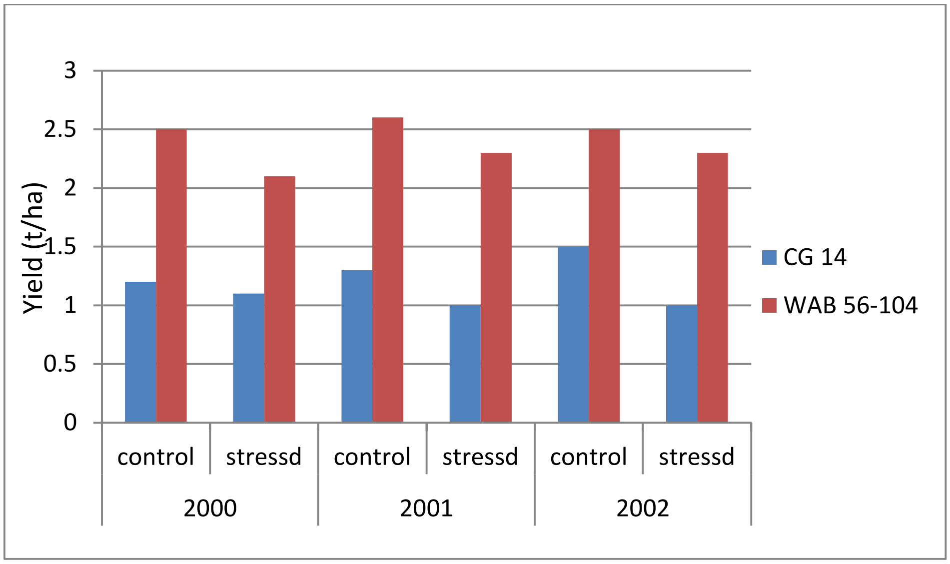
Source: Meng ,2016

Fig. 1: Changes in grain weight in six parts of panicle of large-panicle varieties with high grain filling (HF) and large-panicle varieties with low grain filling (LF) at 3-d intervals post anthesis. Data presented are means of the results in 2012 and 2013. **UP, upper primary branches; US, upper secondary branches; MP, middle primary branches; MS, middle secondary branches; LP, low primary branches; LS, low secondary branches.**

Generally, the grains located in the upper position of the panicle often exhibit a high grain-filling rate (Yang 2010). In this study, for HF and LF, the grain-filling rate of the grains on the UP was obviously higher among with the grains in the other parts of the panicle, but the grain-filling rate of the grains on the US was relatively slow (Fig. 1). The reason might be that grains located on the UP exhibited extremely shows strong apical dominance with respect to assimilate utilization, which depressed the filling activity of the grains on the US (Mohapatra *et al*. 2009).

In all cases both HF and LF the LP and LS shows minimum weight of grain because they were partially filled. So ultimately the LP and LS produces poor quality grain under drought stress condition because uniformity disappear and they will mill differently, retain moisture differently and cook differently.

3.10 Effect of drought on yield



Source: Fofana *et al*.,(2010)

Fig.2.Effect of water stress on Yield (t/ha) on two varieties of rice during the three year trial

In every year there is yield reduction due to drought stress in both of the cultivar. Sarkarung, *et al.*, 1995 reported the yield looses are more severe when drought occurs during the reproductive phase by slow growth during panicle development, which reduces grain number and grain size. The strong effects of drought on grain yield (Fig.2) are observed largely due to the reduction of spikelet fertility and panicle exsertion(Ji *etal*.,2005). Therefore, it is the key to enhance the drought stressed rice yield, that increase dry matter accumulation, panicle rate, grain number, seed setting rate, and 1000-grain weight.

3.11 Different techniques of improving grain quality of rice

3.11.1 Selection of suitable cultivar

Table 5. Grain quality and quality components of rice cultivars grown under draught stress and well irrigated paddy fields

Cultivar	**Head rice (%)**		**Chalkiness (%)**		**Amylose content (%)**	
	Drought stress	Control	Drought stress	Control	Drought stress	Control
Shanyou 64	53.2	31.3	2.8	19.2	28.4	29.9
Ewan 11	68.3	68.7	1.0	3.6	19.1	19.2
Caiapo	66.5	65.2	0.1	1.4	25.5	23.7
Carajas	61.2	61.0	7.3	8.1	26.3	25.0
Gvrani	60.4	61.0	3.9	4.6	28.4	25.9
Rio Paranaiba	65.0	64.7	1.8	4.9	20.0	18.3
Canastra	63.4	62.3	0.6	1.0	18.5	18

Source:Yang, *et al.*, 2002

Moderate drought stress during grain filling, may improve grain quality by the increase of head rice and the reduction of grain chalkiness (Table 5) **(**Yang, *et al.*, 2002) in all drought tolerant cultivar. Grain chalkiness has inverse relationship with grain quality.So,under drought stress the quality is increased. Except Shanyou 64 and Ewan 11 cultivar, in all cultivar the % amylose content increases which indicate that the firmness increases in those drought tolerant cultivar. Otherwise, in Shanyou 64 and Ewan 11the decrease in % amylose content is very low. So selection of suitable drought tolerant cultivar can minimize the drought stress effect on the quality of rice.

3.11.2 Breeding high yielding drought tolerant rice

Table 6: Direct and indirect effects of drought related traits on yield per plant under simulated drought stress condition

Characters	RL	SL	RL/SL	TGW	LR	LD	G/P	SF	DRI
RL	-0.645	0.276	-0.534	-0.186	-0.311	0.125	-0.133	-0.080	-0.068
SL	-0.653	1.527	-1.164	0.010	-0.606	-0.745	0.131	0.242	0.479
RL/SL	2.436	-2.244	2.945	0.539	1.861	0.751	0.212	-0.118	-0.659
TGW	0.231	0.006	0.147	0.805	-0.105	-0.38	0.332	0.129	0.003
LR	-0.752	0.620	-0.988	0.203	-1.562	-0.503	0.293	0.311	-0.031
LD	-0.297	-0.744	0.389	-0.720	0.491	1.526	0.880	0.849	-1.095
G/P	-0.062	-0.060	-0.022	-0.125	0.057	0.174	-0.302	-0.253	-0.172
SF	0.047	-0.060	0.0151	-0.061	0.071	0.209	-0.316	-0.378	-0.263
DRI	0.257	0.769	-0.548	0.009	0.049	-1.759	1.396	1.705	2.449

RL=root length, SL=shoot length, RL/SL=root shoot length ratio, TGW=1000 grain weight, Y/p=yield per plant, LR=Leaf area, LD=Leaf drying, G/p=grains per panicle, DRI=Drought response index

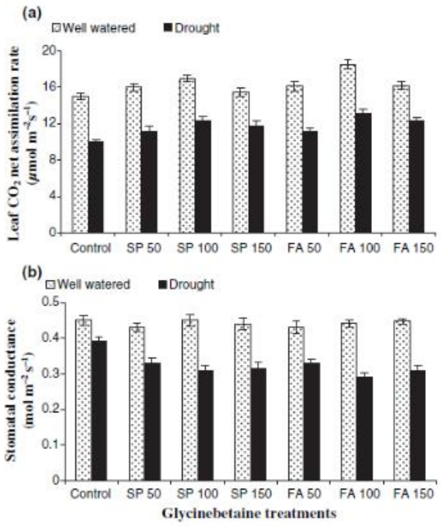
Source:Haider *et.al.,2012*

Under drought stress, direct effect of root length was negative and high. Indirect effect via root shoot ratio was positive and high (2.436). It emphasizes that selection of root length alone in drought stress would not be reliable criteria for improving yield per plant through breeding (Table 6) .Shoot length had positive and high direct effect (1.527) on yield per plant but indirect effect via root shoot ratio and leaf drying was highly negative (-2.244 and -0.744 respectively) and it indicates that shoot length did not contribute in yield because of it negative indirect effect via root shoot ratio and leaf drying (Table 6). Direct effect of root shoot length ratio was positive and high (2.945) so it indicates that root to shoot length ratio may be used as reliable criteria for screening high yielding genotypes in drought stress environments.

Grains per panicle had negative but negligible direct effect (-0.302) on yield per plant and had indirect effect via DRI was high and positive (1.705) which indicates that grains per panicle would not be reliable criteria for improving yield per plant (Table 6). Direct effect of thousand grain weight was positive and high (0.805) and its indirect effects via root length was negative and high, via root shoot ratio (0.539) was positive but pronounced and via leaf drying (-0.720) negative but high indicating that thousand grain weight may be used as be reliable criteria for improving yield per plant (Table 6).

Direct effect of drought response index on yield per plant was positive and high (2.449) and indirect effects via shoot length (0.479) was positive but negligible while indirect effect via root shoot ratio (-0.659) and leaf drying (-1.095) was negative and high which indicate that DRI may be used as direct criteria for improving drought resistance in rice.

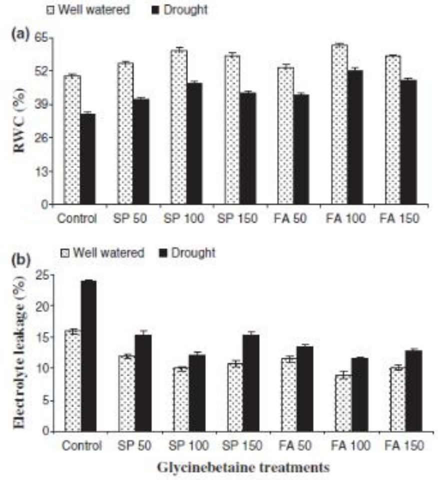
3.11.3 Seed priming by Glycinebetaine(GB)



Source :Farooq *et.al.*,2008

Fig. 3: Influence of glycinebetaine treatments on the (a) leaf CO2 net assimilation rate (b) stomatal conductance in rice under well-watered and drought conditions ±S.E. SP 50, seed priming with 50 ppm GB; SP 100, seed priming with 100 ppm GB; SP 150, seed priming with 150 ppm GB; FA 50, foliar application of 50 ppm GB; FA 100, foliar application of 100 ppm GB; FA 150, foliar application of 150 ppm GB.

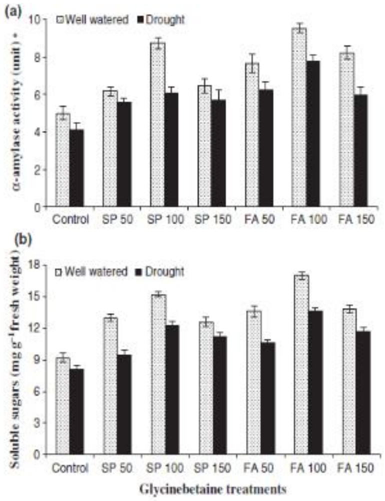
Drought considerably reduced the dry matter production in rice mainly due to impaired photosynthesis (Fig. 3a), which seemed to be affected by stomatal conductance (Fig. 3b) and ROS production (Ma *et al*., 2006). However, GB application can help plants to maintain a higher Pn (Fig. 3a, Ma *et al*., 2006) because it soothes the structures and activities of enzymes and protein complexes, and sustains the integrity of membranes under stress conditions (Sakamoto and Murata ,2002). GB stabilizes the structures and activities of enzymes and protein complexes and maintains the integrity of membranes against the damaging effects of stresses (Fig. 3b) .



Source :Farooq *et.al.*,2008

Fig. 4:Influence of glycinebetaine treatments on the (a) relative water content (RWC) and (b) electrolyte leakage in rice under well-watered and drought stress conditions ±S.E. ±S.E. SP 50, seed priming with 50 ppm GB; SP 100, seed priming with 100 ppm GB; SP 150, seed priming with 150 ppm GB; FA 50, foliar application of 50 ppm GB; FA 100, foliar application of100 ppm GB; FA 150, foliar application of 150 ppm GB.

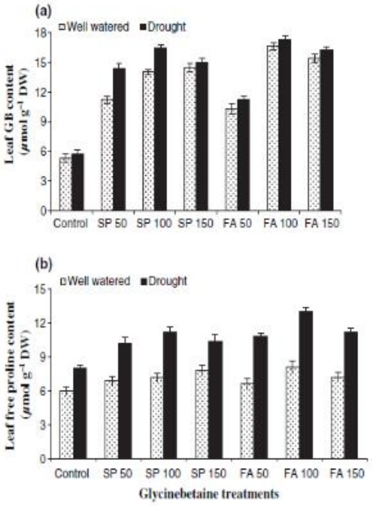
Plant water relations in rice were hampered under drought stress (Fig 4a); however, GB application improved these parameters. Strong correlations between plant water relation components and the accumulation of compatible solutes indicated the involvement of compatible solutes with improved leaf water status under drought. Lv *et al.,* (2007) opined that GB may not only protect the integrity of the cell membrane from drought stress damage, but also involved in osmotic adjustment. High levels of compatible solutes enabled the plant to maintain low water potentials. By lowering water potentials, the accumulation of compatible osmolytes involved in osmoregulation appeared to allow additional water to be taken up from the environment, thus offsetting the immediate effect of water shortages on the tissues (Kumar *et al*., 2003). Membrane stability was significantly reduced as indicated by increased level of electrolyte leakage under drought stress (Fig. 4b). However, GB application alleviated drought effects, which were evident in terms of substantially improved membrane stability as evident from reduced electrolyte leakage (Fig. 4b).



Source :Farooq *et.al.*,2008

Fig. 5: Influence of glycinebetaine treatments on the (a) a-amylase activity and (b) soluble sugars in rice under well-watered and drought conditions ±S.E. *One unit of the enzyme's activity is the amount of enzyme that released 1 lmol of maltose by 1 ml original enzyme solution in 1 min. ±S.E. SP 50, seed priming with 50 ppm GB; SP 100, seed priming with 100 ppm GB; SP 150, seed priming with 150 ppm GB; FA 50, foliar application of 50 ppm GB; FA 100, foliar application of 100 ppm GB; FA 150, foliar application of 150 ppm GB.

It improves amylose activity in all cases especially FA 100 (Fig. 5a) which is very good character for maintaining quality seeds. Higher amylose content tends to cook more firm and dry rice. Soluble sugars may function as a typical osmo protectant, stabilizing cellular membranes and maintaining turgor pressure.GA application improves soluble sugar amount in stress condition but FA 100 respond more notably (Fig. 5b).



Source :Farooq *et.al.*,2008

Fig. 6: Influence of glycinebetaine (GB) treatments on the (a) leaf GB content and (b) leaf proline content in rice under well-watered and drought conditions ±S.E. SP 50, seed priming with 50 ppm GB; SP 100, seed priming with 100 ppm GB; SP 150, seed priming with 150 ppm GB;FA 50, foliar application of 50 ppm GB; FA 100, foliar application of 100 ppm GB; FA 150, foliar application of 150 ppm GB.

Proline effect also increases due to FA 100 (Fig. 6b).Its accumulation might promote plant damage repair ability by increasing antioxidant activity during drought stress. If plant repairing activity is higher, there is possibility to get more quality grain. Amount of GB found higher in drought stress condition (Fig. 6a) which stabilizes the structures and activities of enzymes and protein complexes and maintains the integrity of membranes against the damaging effects of several abiotic stresses (Sakamoto and Murata 2002).

3.11.4 Seed treatment by sodium selenate, and potassium silicate

In this pretreatment process, the grains were surface sterilized by immersing the rice seeds in 1% sodium hypochlorite solution for 5 minutes, then rinsed thoroughly with distilled water and then the sterilized grains divided into three equal lots, which were soaked in water, sodium selenate, and potassium silicate at concentration 0.03 mM and 1.5 mM respectively.

Table 7: Effects of selenium (Se) and silicon (Si) on the cooking and eating quality (grain length, breadth, L/B ratio, water uptake and amylose content) of the two rice cultivars; Giza 177 and IET 1444 grown under drought condition

Cultivar	Treatments	Grain length(mm)	Grain breath(mm)	L/B	Water uptake(%)	Amylose(%)
Giza 177	Well-watered	5.27	2.94	1.79	430	12.9
	Drought	5.16	2.91	1.77	450	15.4
	Drought+Se	5.24	2.80	1.87	415	18.4
	Drought+Si	5.44	2.88	1.88	425	19.5
IET 1444	Well-watered	5.64	2.22	2.54	395	18.0
	Drought	5.52	2.19	2.52	410	19.1
	Drought+Se	5.59	2.18	2.56	400	20.4
	Drought+Si	5.60	2.13	2.63	390	21.8

Source: Emam *et al.,2014*

Uniformity in shape is considered the first quality characteristics of rice. The requirements to improve quality of rice cannot be over emphasized. The length of the stressed yielded grains cv.

Giza 177 and cv. IET 1444 reduced compared to well- watered grains but due to application of SE and Si the length is increased (Table 7)and L/B ratio of rice in Giza 177 and IET 1444 grains was greater compared to stress and control condition. However, grains of IET 1444 drought +Si treatment showed high increments in length compared with Giza 177. The increase in grain length without increase in grain breadth is desirable characteristics in high quality rice cultivar (Hossain, *et al*., 2009; Danbaba, *et al*., 2011)and it is found due to application of Si in drought stress condition. IET 1444 grains has highest L/B ratio due to application of Si which possesses good cooking qualities. During cooking, rice grains absorb water and increase in volume in terms of length and breadth. The percentage of water absorbed (WU) by rice during cooking is considered an economic quality and in Table 7 showed that, the percentage of water uptake (WU) during cooking was higher in grains of Giza 177 than that in grains of IET 1444. Imposition of drought stress increased the percentage of water uptake in both cultivars under investigation but application of Se and Si reduces the water uptake capacity especially by Si application.A higher WU of rice showed pasty appearance (Hossain *et al*., 2009) which is not favorable at all for cooking and eating quality. Either Se or Si treatment improved grain quality of both cultivars by reducing the percentage of WU. In both of the cultivar amylose content increases more than stress condition due to the application of Se and Si rice which tends to cook fluffy, with separate grains (Table 7). Besides, these amylose also hardens and forms crystals during cooking .

Table 8: Effects of selenium and silicon on the grain nutritional value of the two rice cultivars Giza 177 and IET 1444 grown under drought condition

Cultivar	Treatments	Soluble carbohydrate	Starch	Soluble protein	Insoluble peotein	Oil content	Total phenols	Flavonoids
Giza 177	Well-watered	4.36	15.2	2.45	1.25	4.24	0.258	0.57
	Drought	3.04	10.4	2.10	0.64	2.88	0.165	0.54
	Drought+Se	4.32	19.8	1.87	1.52	4.39	0.173	0.71
	Drought+Si	3.39	13.5	1.75	1.89	4.61	0.230	0.66
IET 1444	Well-watered	3.42	16.2	4.80	1.14	6.08	0.339	0.67
	Drought	1.89	11.6	2.57	0.89	5.13	0.173	0.60
	Drought+Se	4.33	15.8	2.02	1.60	10.5	0.258	0.66
	Drought+Si	2.19	16.6	2.40	1.28	7.65	0.303	0.79

Source: Emam *et al.,2014*

Carbohydrate that represented one of the main component of the dry matter composition is affected by drought stress. The present results indicated that, drought stress manifested marked reduction in total soluble carbohydrates and starch contents of the grains of both rice cultivars (Table 8) and such effect might be attributed to the decrease in photosynthetic rate which hamper the carbohydrate metabolism in leaves and might lead to the reduction in assimilate transported to the sink organs, thereby increasing the reproductive abortion (Westgate, 1994). The increments in the accumulation of total soluble carbohydrate and starch contents of Se pretreated stressed rice grains photosynthetic pigments dramatically increased (Yao *et al.,* 2009) which results in enhancement of carbohydrate synthesis (Table 8),in addition the antioxidative effect of Se particularly on the chloroplasts can retard senescence (Hartikainen *et al.,* 2000). On the other hand, Si pretreated seed enhance the effect was attributed to its effect in stimulation of chlorophyll formation also in protection of photosynthetic apparatus and consequently decreased the damage caused by water stress (Avila *et al.,* 2010),so soluble carbohydrate and starch content also enhance in Si treated seeds.Variations in protein content has great effect on modifying grain quality (Futakuchi *et al.,* 2008), in fact, the increase in grain protein content improves the nutritional value. Distelfeld *et al.*, (2007) suggested that the possible role of proteins as potential chelators for some micronutrients. It is well known that drought stress induces the production of reactive oxygen species (ROS), which in excess could be harmful to plant cells. On the other hand phenols and flavonoids act as reducing agents, hydrogen donators, chelators of metal catalyst and singlet oxygen quenchers (Shahidi and Wanasundra, 1992). However, drought stress caused decrease in antioxidant capacity of both cultivars parallel with reduction in phenolic and flavonoid content (Table 8). Selenium or silicon application enhances the production of both phenols and flavonoids parallel with further promotion in grain-antioxidant capacity of drought-stressed rice plant and Se and Si can alter antioxidant levels in plants and detoxify superoxide radicals, thus preventing oxidative damage and protecting the membranes and enzymes (Habibi, 2013; Karmollachaab *et al*., 2013).

CHAPTER IV

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 biochemichals are also importance to drought tolerance. Thus, these morphological and biochemical characters may be considered during the development of drought tolerance varieties.

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. Seed treatment by sodium selenate, or potassium silicate are also be capable of improving the grain quality of rice.

CHAPTER V

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