A SEMINAR PAPER

On

Drought Stress Response in Different Growth Stage and Yield of Rice (*Oryza sativa* L.)

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ABSTRACT

Scarcity of water for irrigation is an alarming issue that limiting crop production worldwide and is becoming increasingly severe with the passage of time in Bangladesh. Drought is a major challenge limiting rice production. It affects rice at morphology like plant height, plant biomass, number of tillers, various root and leaf traits couple with physiological attributes like reduced photosynthesis, transpiration, stomatal conductance, water use efficiency, relative water content, chlorophyll content moreover biochemical properties like accumulation of proline, sugars level are also altered and thereby affects yield. Severe drought stress applied at the vegetative stage and mild drought stress at the flowering stage in rice results in 20% and 28% yield loss, respectively. Furthermore drought stress in different growth stages, increased proline content and thus cultivars with higher proline content had higher grain yield in drought stress. Drought stress decreased chlorophyll content and relative water content (RWC) in different cultivars. However panicle initiation stage was the most sensitive to drought stage exerting more adverse effects on all the physiological and agronomic parameters under study. To facilitate the selection or development of drought tolerant rice varieties, a thorough understanding of the various mechanisms that govern the yield of rice under water stress condition is a prerequisite. In plants, a better understanding of the morphological and physiological basis of changes in water stress resistance could be used to select or create new varieties of crops to obtain a better performance under water stress conditions. Finally parent line found as resistant based on the physiological/morphological and molecular mechanisms, a strategy is suggested to select a particular environment and adapt suitable germplasm to that environment.

Key words: Drought stress, morpho-physiological response, yield attributes, proline, germplasm.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the important primary cereal crop in the world. It is the staple food about for more than two- third of the world's population (Dowling *et al*, 1998).It is ranked second to wheat as the most extensively grown crop in the world, it is the most essential food crop and largest irrigated crop in the world (Roel *et al.*, 1999). About 75% of the world's rice supply carries from 79 million hectare of irrigated land in Asia. Thereby, the present and future food security of Asia depends largely on the irrigated rice production system. This system is a major user of fresh water (Tabal *et al.*, 2002). The available amount of water for irrigation, however, is increasingly getting scarce. Environmental factors that cause water-deficit stress, such as drought, salinity and temperature extremes, place major limits on plant productivity (Boyer, 1982). Moreover rice is a drought susceptible crop exhibiting serious detrimental effects when exposed to water stress at critical growth stages especially at reproductive stage (Suriyan *et al*., 2010). Shortage of water for irrigation is one of the most critical factors limiting growth and production of almost all the crops including rice worldwide and intensity of the issue is aggravating with the passage of time (Passioura, 1996**,** Passioura, 2007, Anonymous, 2010). Thus, the percentage of drought prone land has approximately doubled from the 1970s to the early 2000s, affecting crop yield,quality and quantity of various crops resulting in food shortages in the world (Isendahl and Schmidt, 2006). Global climate change and arithmetically multiplying world populace augmented with drought stress are making the situation more dangerous and to cope with the ever growing food, feed and shelter needs of human beings is becoming more problematic day by day (Hogbo *et al*., 2005, Akram, 2007). In compare with other crops, rice is generally more sensitive to water stress especially at critical growth stages such as panicle initiation, anthesis and grain filling (Tao et.al**,** 2006, Yang *et al.*, 2008). Thus, drought stress is affecting about 50% of rice yield in the world (Mostajean and Eichi, 2009).

Drought stress causes various physiological changes in plants such as reduction in PAR, photosynthetic rate, transpiration rate, stomatal conductance, pigment degradation and relative water content (RWC) resulting in decreased water use efficiency (WUE) and growth reduction prior to plant senescence (Chaves and Oliveira, 2004; Cattivelli *et al*., 2008; Tuna *et al*., 2010).

These physiological parameters in coupled with yield components can be used as criteria for improving drought stress in different crops (Ashraf, 2010). In rice water stress at vegetative growth especially booting stage (Pantuwan *et al*., 2002) , flowering and terminal period can interrupt floret initiation causing spikelet sterility and grain filling resulting in lower grain weight and ultimately poor paddy yield (Kamoshita *et al*., 2004; Botwright *et al*., 2008). Response of different plants to water stress is much complex and various mechanisms are adopted by plants when they encounter drought stress at various growth stages (Levitt, 1980; Jones, 2004). Even behavior of genotypes within a species is also different so, one of the strategies to abate drought stress is selection of a genotype expressing comparatively better drought tolerance (Suriyan *et al*., 2010). It is, therefore, imperative to understand the mechanism of plant responses to water deficit conditions and to study the performance of new genotypes under water stress with the objective of improving crop performance in the drought prone areas of the world. In previous research has indicated that Proline accumulation in plant cells exposed to salt or water stress is a widespread phenomenon (Lin and Kao, 1996). Therefore this study was designed to determine, aside from growth phenology, the effect of drought stress on some physiological responses such as proline content, relative water content and chlorophyll florescence parameters in some commonly traditional and modern rice varieties exhibiting differences in drought tolerance. The present study was conducted to study the responses of drought stress at various growth stages on some physiological and yield traits of rice cultivars.

Objectives:

- A thorough understanding of the various responses that govern the yield and grain quality of rice under water stress condition.
- To explore the selection strategies for screening as well as development of drought tolerant rice varieties.

CHAPTER II

MATERIALS AND METHODS

This paper is exclusively a review paper so that all of the information has been collected from the secondary sources. During the preparation of the review paper, various relevant books, journals publications etc. were studied. The related topics have been reviewed with the help of library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Research Institute (BARI)), internet browsing. Valuable suggestion and information were taken from honorable major professor. After collecting all the available information, it has been compiled and arranged chronologically for better understanding and clarification and it has been presented as per the objectives of this paper.

CHAPTER III

Review of Findings

3.1. Physiological Responses:

Plant experiences drought stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high. It severely impairs growth, development and ultimately the production of rice. When water stress occurs, plants react by slowing down or stopping their growth. This is a normal plant reaction to lack of water, and it acts as a survival technique (Zhu, 2002). Plant growth and development reduces as a consequence of poor root development, with reduced leaf-surface traits (form, shape, composition of cuticular wax, leaf pubescence and leaf color), which affect the radiation load on the leaf canopy, delay in or reduced rate of normal plant senescence as it approaches maturity, and inhibition of stem reserves (Blum, 2011).

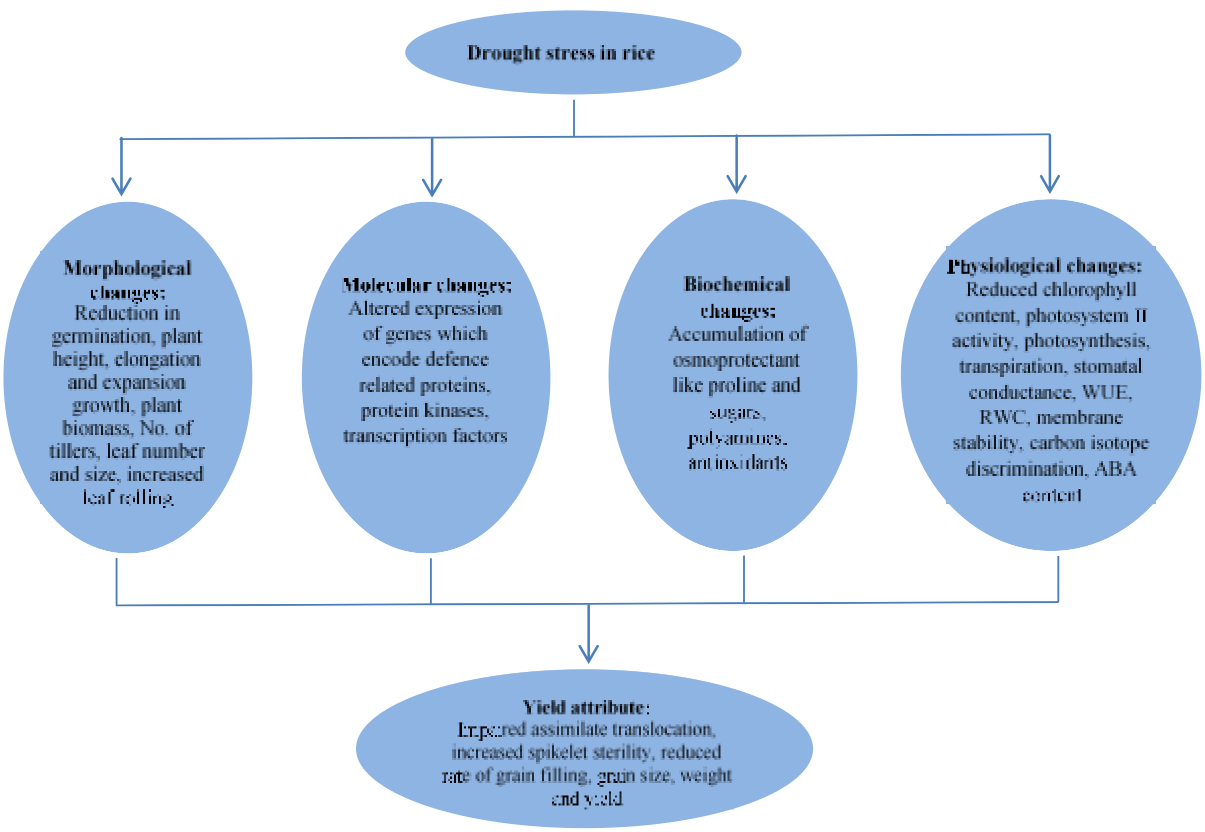

Figure 1: Drought induced various responses in rice which ultimately affect yield,WUE, Water use efficiency; RWC, Relative water content; ABA, Abscisic acid.

Source: Punday and Shukla,2015

3.1.2. Drought stress responses in photosynthesis and transpiration of rice

Differential response of upland rice varieties was also observed by Botwright *et al.*, (2008), Kamoshita *et al.*, (2004) and Basu *et al* (2008). Panicle initiation was found to be the most crucial one for affecting various physiological attributes. Water stress at panicle initiation due to disturbed biochemical, physiological processes and adverse effect on enzymatic activities drastically reduced stomatal conductance and degraded chlorophyll pigments leading to severe decrease in PAR, photosynthetic rate, transpiration rate and relative water content. Eventually, Table 1 shows that it diminished the maximum quantum yield of PSII (F_v/F_m) in flag leaves of all the three rice cultivars viz; Basmati-Super, ShaheenBasmati and Basmati-385 irrespective of stages at which water stress was imposed. Rice cultivar, ShaheenBasmati exhibited less decrease in the above said physiological parameters under drought stress conditions while; the maximum reduction in various parameters under the study was noted in Super-Basmati. (Akram *et al.*, 2013)

Table 1: PAR, photosynthesis, transpiration, conductance and water use efficiency of three rice cultivars under drought stress

	Factors	PAR μ mol m $^{-2}$ s^{-1}	% Decrease	Photosynthesis μ mol m $^{-2}$ s^{-1}	% Decrease	Transpiration (m mol m $^{-2}$ s^{-1})	% Decrease	Conductance m molH $_2$Om $^{-2}$ s^{-1}	% Decrease	WUE	% Increase
	Basmati- Super	518.89	24.57	30.94	21.92		36.00	35.25	22.21	9.42	22.66
	Shaheen-Basmati	355.70	12.50	46.69	14.96	.95	30.33	32.50	26.66	13.48	31.00
Variety						4.06					
	Basmati-385	557.63	23.40	36.68	18.07	4.11	34.66	35.50	24.63	10.34	26.33
	Control	628.05	-	46.32	-	5.05	-	46.33	-	9.17	-
Stress	**Stress at Panicle**	473.30	24.63	32.10	30.69	2.62	48.11	38.67	16.53	11.56	26.06
Stages	**Stress at Anthesis**	482.78	23.13	33.35	28.00	3.61	28.11	28.67	38.11	11.36	23.88
	Stress at Grain Filling	530.25	15.57	40.46	12.26	4.77	5.54	24.00	48.19	12.21	33.15
LSD at 5 % prob.	**Cultivars**	38.09	-	5.97	-	0.13	-	2.33	-	1.09	-
	Stress St.	47.07	-	5.62	-	0.96	-	3.19	-	2.08	-
	Interaction CxS	117.17	-	2.78	-	1.07	-	8.72	-	2.35	-

Source: (Akram *et al.*, 2013)

3.1.3. Biochemical responses of drought stress in rice

Proline plays a highly beneficial role in plants exposed to various stress conditions (Verbruggen and Hermans, 2008). The very first report, regarding the free proline accumulation due to water stress, is proposed by Kemble and Mac-Pherson (1954) in rye grasses. Proline acts as osmolyte and its accumulation contributes to better performance and drought tolerance (Vajrabhaya *et al.*, 2001). Changes in the concentration of proline have been observed in rice exposed to drought stress (Sheela and Alexallder, 1995; Mostajeran and Rahimi-Eichi, 2009; Bunnag and Pongthai, 2013; Kumar S *et al.*, 2014; Lum et al, 2014; Maisura *et al.*, 2014). Besides acting as an excellent osmolyte, proline plays three major roles during stress, i.e., as a metal chelator, an antioxidative defence molecule and a signaling molecule (Hayat *et al.*, 2012). Proline accumulation might promote plant damage repair ability by increasing antioxidant activity during drought stress. In plants under water stress, proline content increases more than other amino acids, and this effect has been used as a biochemical marker to select varieties aiming to resist to such conditions (Fahramand *et al.*, 2014). Thus, proline content can be used as criterion for screening drought tolerant rice varieties.(Punday and Shukla,2015)

Table 2: Proline content (μmol lit ^{1}) of blade under submerged and non-submerged conditions

	Young Leaves			Old Leaves		
Rice cultivars	Submerged	Non-submerged	Change (%)	Submerged	Non-submerged	Change (%)
Zayande-Rood	116	129	0.112	58	60	0.034
829	82	85	0.036	45	45	0.00
216	100	104	0.04	51	53	0.039
Average	99.3	106	0.067	51.3	52.7	0.026

Source: *(*Mostajeran and Eichi,2009*)*

The amount of proline in both young and old leaves substantially increased in plants under drought effect (Table 2). There was a significant variation in proline content among all rice cultivars and between different ages (P<0.001) and different parts of the leaves (P<0.01) with maximum accumulation in young leaf sheath (sheath) of Zayande-Rood cultivar and minimum in old leaf blades (blades) of 829 cultivar. 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. *(*Mostajeran and Eichi,2009*)*

Table 3: Total soluble sugar content (mg g 1 DW) of sheath under submerged and non-submerged conditions

	Young Leaves			Old Leaves		
Rice cultivars	Submerged	Non-submerged	Change (%)	Submerged	Non-submerged	Change (%)
Zayande-Rood	239	310	0.297	180	205	0.138
829	225	276	0.226	181	203	0.121
216	208	237	0.139	173	193	0.115
Average	224	274	0.223	178	200.3	0.123

(Mostajeran and Eichi,2009)

The data showed that the highest content of these osmotic adjustments was found in sheath under non-submerged treatment (P<0.01) (Table 3). Moreover, soluble sugar content in young leaves was more than old ones (P<0.01). The average amount of total soluble sugar in sheath and blade was found as 219 and 212 (mg g^{-1}), respectively. However, these amounts were increased under non-submerged treatment, especially in young leaves. Under non-submerged treatment, sheath of respectively. However, these amounts were increased under non-submerged treatment, especially in young leaves. Under non-submerged treatment, sheath of young leaves had the highest soluble carbohydrate level (274 mg g^{-1}DW) and the lowest value was found of old leaves (181 mg g^{-1}DW). Soluble sugars may also function as a typical osmo-protectant, stabilizing cellular membranes and maintaining turgor pressure. *(*Mostajeran and Eichi,2009*)*

Table 4: Changes of SOD activity in rice flag leaf under water stress after anthesis (µg/g·Fw)

Cultivar	Treatments	Days after anthesis					
		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 4 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.(Wu Na *et al*.,2007)

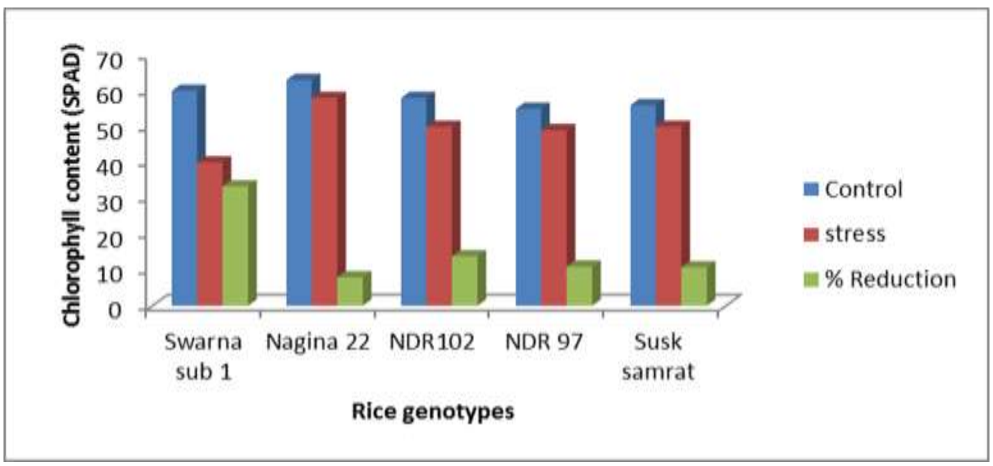

Figure 2: Effect of drought stress on total chlorophyll content (SPAD) of rice genotypes

Sources: Sing *et al.*,(2018)

The total chlorophyll content varied in rice genotypes (Fig.2). Drought stress reduced the total chlorophyll content. Highest reduction in chlorophyll content was recorded in Swarna Sub-1 (33.33%) and lowest in Nagina 22 (7.93%). Energetic status of the chloroplast increases as a consequence of the water stress which has a direct relationship to that of increased amount of total chlorophyll and Chla and Chlb among the stressed induced verities (Ranjbar-fordoei *et al*. 2000).

3.2. Agronomical Responses:

The grain yield of rice severely decreases under drought stress. Drought stress at the booting and flowering stages disrupts floret initiation, leading to slow grain filling and spikelet sterility and resulting in reduced grain weight and poor paddy yield. The most common characteristics of rice under drought stress include decreases grain weight and size , the 1000grain weight, and seed-setting rate and increases in spikelet sterility . Water deficits restrict the grain filling period, resulting in in reduced grain yields . Drought stress disrupts leaf gas exchange, limits the sizes of source and sink tissues, and impairs assimilate translocation and phloem loading . Drops in yield may be due to reductions in CO_2 assimilation rates induced by drought or decreases in photosynthetic pigments, stomatal conductance, stem extension, water use efficiency, the activities of starch and sucrose biosynthetic enzymes, and assimilate partitioning, resulting in reduced growth and productivity of the plant.(Sahebi *et al.*,2018)

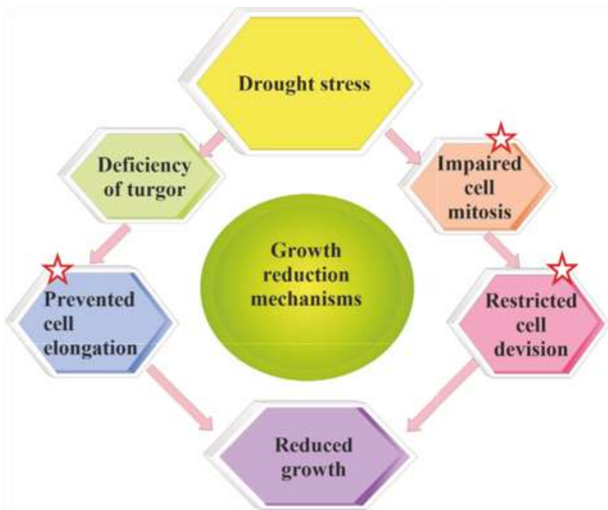

Figure 3: Annotation mechanisms of growth decline under drought stress condition

Source: Sahebi *et al.*,2018

Drought duration and crop growth stage are two determinants of grain yield loss, as is the harshness of the drought stress. Genetic, physiological, morphological, and ecological events and their multifaceted interactions are involved in cell division, enlargement, and differentiation and affect plant growth. Drought stress strongly affects the quantity and quality of plant growth through three main steps (Figure 3).

Cell growth is limited significantly due to reductions in turgor pressure under drought stress. Cell elongation in higher plants under severe drought stress may be limited by disrupted water flow between the xylem and the surrounding elongating cells . Reductions in mitosis, cell elongation, and cell expansion cause decreases in plant leaf area, height, and crop growth under water deficit. (Sahebi *et al.*,2018)

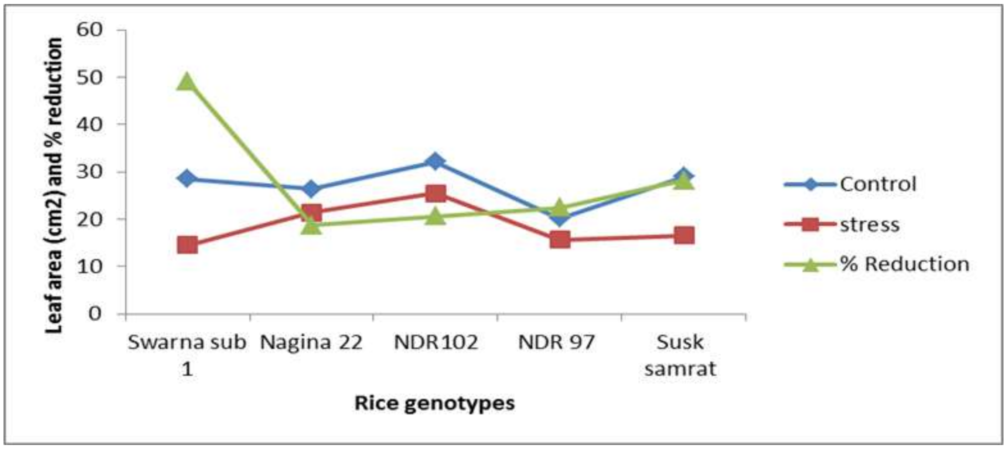

Figure 4: Effect of drought stress on leaf area (cm^2) of rice genotypes

Sources: Sing *et al.*, (2018)

Leaf area of rice genotypes significantly reduced irrespective of genotypes (Fig.6). The high reduction in leaf area was recorded in Swarna Sub 1 (49.08%) while low in Nagina 22(18.70%) Susk Samrat (28.22%), NDR 97 (22.40%) and NDR 102 (20.60%).

Negative effects of water deficit on mineral nutrition and metabolism decrease the leaf area and alter assimilate partitioning among the plant organs (Zain *et al*., 2014).

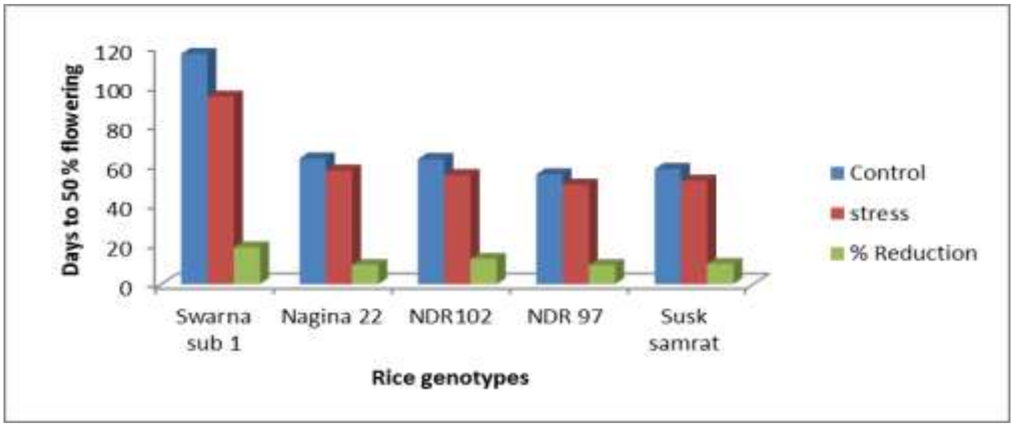

Figure 5: Effect of drought stress on days to 50% flowering of rice genotypes.

Sources: Sing *et al.*, (2018)

Days to 50% flowering significantly affected in rice genotypes due to drought stress (Fig 7). Maximum reduction in days to 50% flowering was recorded in Swarna Sub 1 (18.56%) which minimum in Nagina 22 (9.67%). Drought stress enhances the phasic change from vegetative to reproductive stage. Susceptible plant flowering early while resistant plants maintains it more or less about normal condition upto same extent (Fukaai *et al.*,1999).

Moisture stress at panicle initiation was more destructive regarding panicle numbers per hill, panicle length, panicle dry weight, shoot dry weight and total grains per panicle, irrespective of the cultivars resulting in drastic decrease in per hectare paddy yield. This may be due to the significant reduction in photo synthetic rate resulting in reduced production of assimilates for growth of panicles and filling of rice grains; ultimately paddy yield was drastically decreased. Mostajean and Eichi (2009) have reported the similar findings with the observations that water shortage adversely affected growth and paddy yield of rice in addition to accumulation of proline and soluble sugars in sheaths and blades of rice leaves.

Table 5. Relative water content (WUE), panicle length, number of Panicles & tillers per hill and shoot & panicle dry weight per hill of three rice cultivars under drought stress.

	Factors	**RWC**	**% Decrease**	**Tiller/ hill**	**% Decrease**	**Panicle length, cm**	**% Decrease**	**Panicles/h ill**	**% Decrease**	**F_v/F_m**	**% Decrease**
Variety	**Basmati-Super**	82.41	23.10	18.98	4.25	25.95	8.86	6.93	16.46	0.83	2.13
	Shaheen-Basmati	78.13	26.17	18.28	5.08	25.30	9.76	7.03	16.66	0.81	1.82
	Basmati- 385	75.87	28.56	18.28	4.40	25.58	9.67	6.80	18.56	0.78	5.15
Stress Stages	**Control**	98.02	-	19.17	-	27.53	-	8.07	-	0.82	-
	Stress at Panicle	63.55	35.16	18.20	5.05	23.87	13.29	5.97	26.02	0.79	3.65
	Stress at Anthesis	72.31	26.22	18.20	5.05	25.13	8.71	6.60	18.21	0.80	2.43
	Stress at Grain Filling	81.32	17.03	18.47	3.65	25.90	5.92	7.37	8.67	0.81	1.21
LSD at 5 % prob.	**Cultivars**	2.91	-	0.15	-	0.09	-	0.14	-	0.07	-
	Stress St.	8.99	-	0.18	-	2.37	-	1.39	-	0.03	-
	Interaction CxS	4.54	-	0.07	-	1.67	-	1.06	-	0.04	-

Source: (Akram ***et al.,***2013)

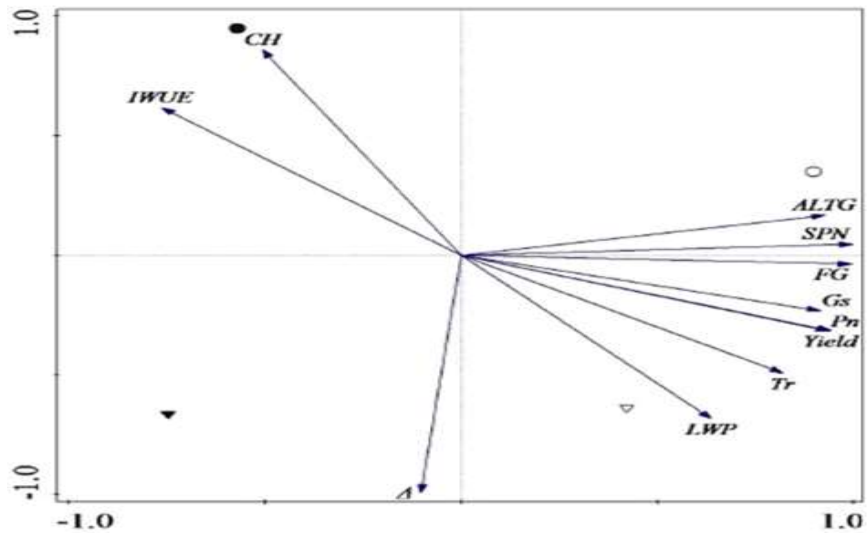

Figure 6. Principal component analysis of target traits. Grain yield, GY; Spikelets per panicle, SPN; Filled grains, FG; Chalkiness, CH; Leaf water potential, LWP; Air-leave temperature gap, ALTG; Net photosynthetic, P_n,; Stomatal conductance, G_s; Instantaneous water use efficiency, IWUE; Carbon isotope discrimination, Δ; HY113-drought stress (●); HY113-traditional flooding (◯); YLY6-drought stress (▼);YLY6- traditional flooding (∇).

Sources: Xiaolong *et al.*, (2019)

As showed in the Fig. 4, the main ordination axis was significantly positively correlated with ALTG, SPN, FG, G_s, P_n, Yield, T_r and LWP at the flowering stage, while ALTG, SPN, FG had great contributions to ordination axis. HY113-DS and YLY6-DS were negative closely related to the main ordination axis, which indicates that DS had significant effects on flag leaf photosynthetic capacity. Moreover, HY113-DS was significantly positively correlated IWUE and CH.

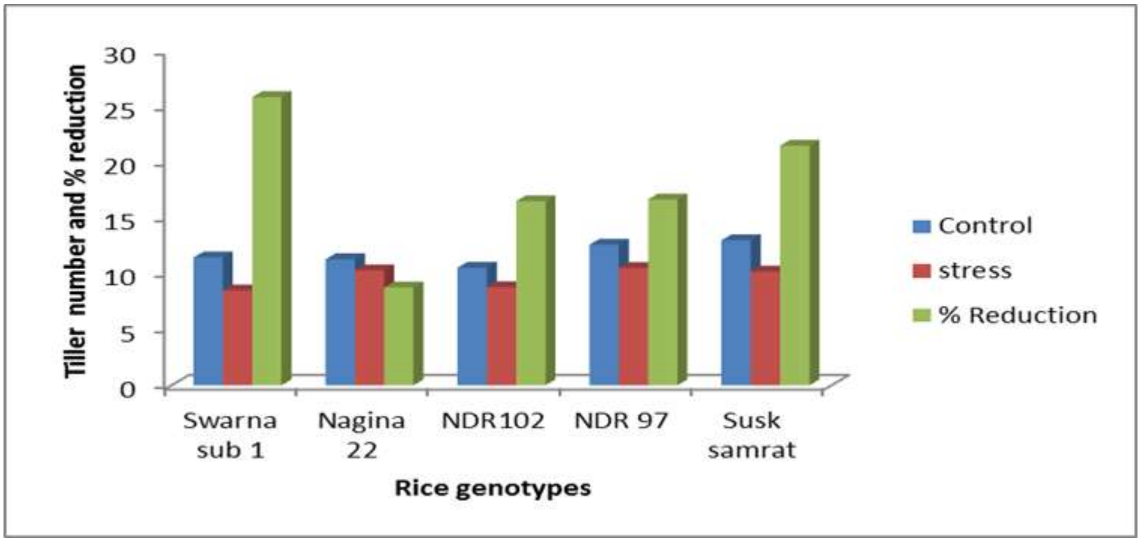

Figure 7: Effect of drought stress on tiller number of rice genotypes

Sources: (Quampah *et al., 2011*)

Drought stress reduces the tiller number per plant in all rice genotypes (Fig.5). Maximum reduction in tiller number is recorded in Swarna Sub 1 (25.82%) while minimum in Nagina 22(8.76%).The number of tillers reduces due to reduced growth and photosynthesis processes of plant (Quampah *et al., 2011*).

An increasing number of studies witnesses early morphological changes in rice upon exposure to drought. Drought stress induces reduction in plant growth and development of rice (Tripathy *et al.,* 2000; Manikavelu et al, 2006). Due to the reduction in turgor pressure under stress, cell growth is severely impaired (Taiz and Zeiger, 2006). Drought affects both elongation as well as expansion growth (Shao *et al.,* 2008), and inhibits cell enlargement more than cell division (Jaleel *et al.,* 2009). It impairs the germination of rice seedlings (Jiang and Lafitte, 2007; Swain *et al.,* 2014) and reduces number of tillers (Mostajeran and Rahimi-Eichi, 2009; Ashfaq et al, 2012; Bunnag and Pongthai, 2013) and plant height (Sarvestani *et al.,* 2008; Ashfaq et al, 2012; Bunnag and Pongthai, 2013; Sokoto and Muhammad, 2014).

A common adverse effect is the reduction in biomass production (Farooq *et al.,* 2009a, 2010). Many studies indicate significant decrease in fresh and dry weights of shoots (Centritto et al, 2009; Mostajeran and Rahimi- Eichi, 2009) and roots (Ji *et al.,* 2012) under drought. Reduced fresh shoot and root weights as well as their lengths ultimately reduce the photosynthetic rate of physiology and biochemical processes of rice (Usman *et al.,*2013).

3.3. Drought stress responses in yield of rice

Drought stress significantly influenced the number of filled grains panicle^{-1} of rice. Results revealed that, among the different level of drought stress, severe drought stress (water withheld from Panicle initiation stage to season end) demonstrate the lowest number of filled grains panicle^{-1} (Table 6). Decreased filled grain per panicle under lower soil moisture levels might be due to inhibition of translocation of assimilates to the grain due to moisture stress. These results agree with Hossain (2001) who observed that the number of filled grain panicle^{-1} was decreased due to moisture stress. Farooq *et al*., (2009) found that a reduction in grain filling occurs due to a reduction in the assimilate partitioning and activities of sucrose and starch synthesis enzymes.

Table 6: Effect of different level of drought stress on yield and yield contributing character of rice.

Drought stress	Panicle hill^{-1} (N0.)	Filled grain panicle^{-1} (No.)	Unfilled grain panicle^{-1} (No.)	1000 grains weight (g)	Grain yield (g)
Control	16.42 a	44.40 a	11.84 c	19.515 a	11.21 a
Severe drought stress	9.48 c	27.70 c	16.74 a	17.537 c	8.89 c
Moderate drought stress	13.38 b	36.35 b	14.34 b	18.499 b	9.78 b
$LSD_{(0.05)}$	1.12	2.68	0.71	0.39	0.47
CV (%)	11.13	9.69	6.49	2.73	6.20

Sources: Hosain *et al.,* (2020)

Drought stress signifies the number of unfilled grains panicle^{-1} of rice. Results demonstrate that, among the different levels of drought stress, severe drought stress (water withheld from Panicle initiation stage to season end) showed the maximum number of unfilled grains panicle^{-1} (Table 6). Increased unfilled grains per panicle under lower soil moisture levels might be due to inactive pollen grains for dryness, incomplete development of pollen tube, insufficient assimilate production and its distribution to grains due to soil moisture stress.

Drought stress considerably influenced the number of 1000 grains weight of rice. Results declare that, among the different level of drought stress, severe drought stress (water withheld from Panicle initiation stage to season end) exhibit the lowest 1000 grains weight (Table 6). Lower soil moisture might decrease the translocation of assimilates tothe grain which lowered grain size and increased empty grain. The results are in agreement with the findings of Rahman *et al*. (2002) and Zubaer *et al*., (2007) who observed that water stress reduced grain weight in different varieties of rice.

Drought stress significantly influenced the grain yield of rice. Results revealed that, among the different level of drought stress, severe drought stress (water withheld from Panicle initiation stage to season end) demonstrate the minimal grains yield (Table 6). So, it was observed that grain yield hill^{-1} decreased in decreasing moisture levels.

Table 7: Yield and yield attributes of six rice genotypes influenced by drought (40% FC) at three growth stages; maximum tillering, panicle initiation and grain filling in 2014

Treatments	Effective tiller hill^{-1}	Total spikelets panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	1000-grain weight (g)	Sterility %	Grain yield hill^{-1} (g)
Drought imposing stage						
Control	23.78 a	149.6 a	109.7 a	13.43 a	26.32 b	40.31 a
Maximum tillering	24.00 a	137.3 ab	100.5 ab	13.24 a	26.94 b	38.12 a
Panicle initiation	23.50 a	142.1 ab	90.59 bc	13.08 a	34.34 a	34.01 b
Grain filling	22.56 a	134.3 b	85.92 c	12.96 a	33.77 b	33.28 b
Lsd $_{0.05}$	2.20	12.96	10.07	0.51	5.43	2.64
Genotype						
BINA dhan-13	21.50 c	97.33 c	81.50 d	12.89 b	17.60 c	43.21 a
Kalizira	22.42 c	135.8 b	85.64 cd	11.04 c	37.06 a	35.48 bc
RM-100-16	27.33 a	165.2 a	111.4 a	10.56 c	32.41 a	30.22 d
Ukunimodhu	20.67 c	150.4 ab	109.7 ab	10.81 c	25.50 b	33.90 c
BRRI dhan-34	23.08 bc	146.9 b	93.92 cd	9.91 d	34.04 a	38.16 b
NERICA mutant	25.75 ab	149.3 ab	97.88 bc	23.84 a	35.44 a	37.60 b
Lsd$_{0.05}$	2.67	15.87	12.33	0.62	6.65	3.24

Sources:Moonmoon and Islam,2017

In the present research all the yield parameters were adversely affected at all the stress stages and in all the rice genotypes over control under study. Grain yield was reduced under drought in both of the year (Tables 7). Under drought, plant development is reduced as a consequence of (a) poor root development; (b) reduced leaf-surface traits (form, shape, composition of cuticular and epicuticular wax, leaf pubescence, and leaf color), which affect the radiation load on the leaf canopy; (c) delay in or reduced rate of normal plant senescence as it approaches maturity; and (d) inhibition of stem reserves (Blum 2002). The results showed that the number effective tillers hill^{-1} was decreased with drought (40% FC) (Tables 7). The reduction of effective tillers production under low soil moisture might be due to limited supply of assimilate under water stress condition. It might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue (Zubayer *et al.,*2007).

Drought stress at grain filling (anthesis to maturity) was more destructive followed by panicle initiation stage regarding effective tillers hill^{-1}, total spikelets panicle^{-1}, filled grains panicle^{-1} , 1000-grain weight and grain yield hill^{-1}, irrespective of the genotypes (Tables 7). This may be due to the significant reduction in photosynthetic rate resulting in reduced production of assimilates for growth of panicles and filling of rice grains; ultimately rice yield was drastically decreased. According to the result, under drought stress condition, NERICA mutant and BINA dhan-13 genotypes showed lesser reduction in above said parameters over control in different growth stages (Tables 7). Drought stress during different growth stages might decrease translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. Pantuwan et al. (2002) and Cattivelli *et al.* (2008) have reported reduced rice yield because of drought stress at critical growth stages. Thus, yield traits such as effective tillers hill^{-1}, total spikelets panicle^{-1}, filled grains panicle^{-1}, 1000-grain weight, % sterility and grain yield hill^{-1} are the most popular parameters used to identify drought tolerance in rice breeding programs.

Table 8: GY of two rice cultivars of YLY6 and HY113 under DS at flowering stage in 2013 and 2014

Year	Varieties	Treatment	SPN	EP ($\times 10^3$ m^{-2})	FG (%)	TGW (g)	GY ($t.ha^{-1}$)
	YLY6	CK	164 a	43.5 a	75.5 a	26.2 a	10.45 a
2013		DS	139 b	34.5 b	61.2 b	25.7 a	8.03 b
	HY113	CK	180 a	43.3 a	85.3 a	27.1 a	10.65 a
		DS	144 b	35.1 b	67.4 b	26.8 a	8.09 b
	Mean		156	39.1	72.4	26.5	9.31
	YLY6	CK	166 a	40.9 a	77.8 a	26.3 a	10.35 a
2014		DS	131 b	29.4 b	63.4 b	25.8 a	9.12 b
	HY113	CK	178 a	43.4 a	74.8 a	27.1 a	10.06 a
		DS	139 b	32.9 b	61.7 b	27.2 a	8.39 b
	Mean		153	36.7	69.4	26.6	9.48

Source: Yang *et al.*,2019

Yield components of the number of spikelets per panicle (SPN) and filled grains (FG) were significantly reduced by 18%, and 19% for YLY6 and 21%, and 19% for HY113, respectively, when compared with the traditional flooding irrigation system on average across two seasons, which contribute to the significantly decreased in GY in YLY6 and HY113 and reduced by 23.2%, 24.0% respectively under DS. (Yang *et al.*,2019)

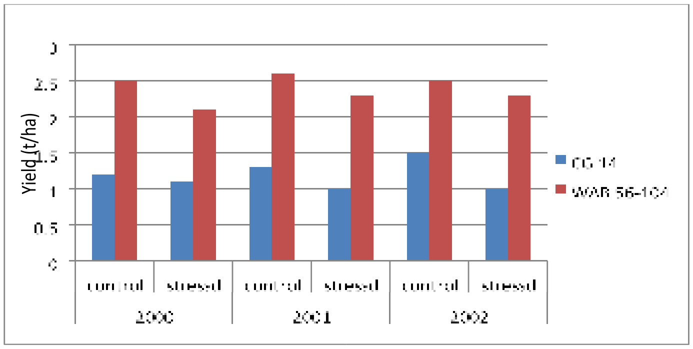

Figure 8: Effect of water stress on Yield (t/ha) on two varieties of rice during the three year trial

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

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.8) are observed largely due to the reduction of spikelet fertility and panicle exsertion(Ji *et al*.,2005).

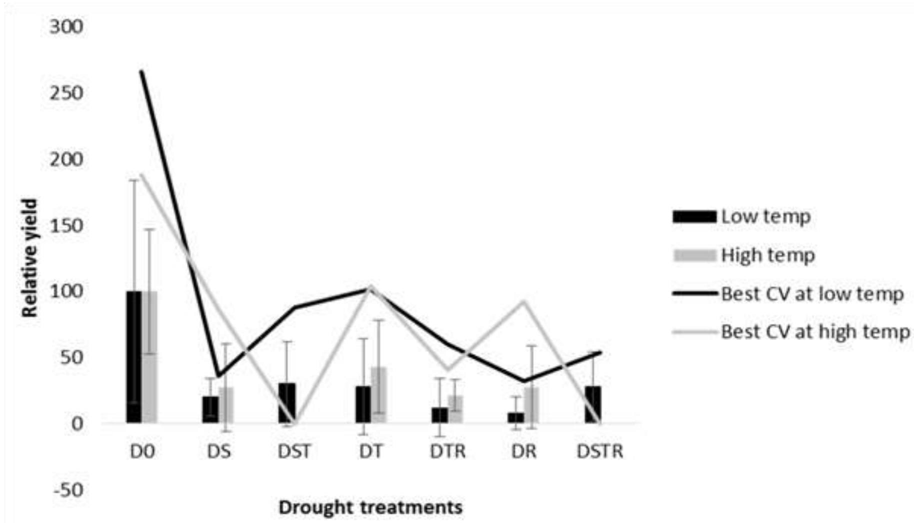

Figure 9: The relative yield of all cultivars at each of the drought treatments at each of the temperatures (bars) and of the cultivar with the highest at each treatment and temperature (line). well-watered throughout the growth cycle (D0), drought during the seedling stage only (DS), drought during the seedling and active tillering stages (DST), drought at the active tillering stage only (DT), drought at the active tillering and reproductive stages (DTR), drought at reproductive stage only (DR), and drought at every stage, i.e., the seedling, active tillering, and reproductive stages (DSTR).

Source: Mukamuhirwa *et al.*,2019

All drought treatments resulted in severe decreases in yield as compared to when the plants were subjected to no drought (Figure 9). In drought stressed pots, a negative correlation ($r = -0.28$; $p = 0.025$) was found between soil and water content at the end of the experiment and grain yield. (Mukamuhirwa *et al.*,2019)

Water deficit during vegetative growth tended to delay panicle initiation (Lilley and Fukai, 1994b). Water stress at flowering is most serious and devastating to yield because it has diverse effect of pollination and causes flower abortion, grain abscission and increasing of percentage of unfilled grain (Hsiao, *et al.*, 1976). Several workers *viz.,* Kumar, *et al.* 2006 and Davatgar, *et al.,* 2009 observed that the percentage of unfilled grains were significantly higher in sites that were affected by drought at reproductive stage. It indicated the high sensitivity of rice to water stress with any intensity (mild or sever) during the reproductive stage (booting, flowering and panicle initiation). This effect might be due to decrease in translocation of assimilates towards reproductive organs (Rahman, *et al.,* 2002). In a study of 20 early maturing rice cultivars, it is reported the severe drought stress prolonged the maturity period (Dikshit, *et al.,* 1987) and found significant correlation with yield reduction. 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 but cultivars which having high recovering ability after removing the water stress condition had relatively higher grain yield.

3.4. Strategies for development of drought tolerant rice variety

Water stress affected the morphology and physiology of the crop, resulting observed the reduction in grain yield. Thus we need to develop such type of varieties which survive and give better yield under water stress condition. The following mitigation strategies may be useful:

1. Development of early maturing rice varieties to escape the drought.

2. Development of drought tolerance varieties that perform better under drought stress condition Heterosis breeding is more effective breeding method for improvement of yield and its associated traits.

3. Improvement and incorporation of those characteristics which are essential for survivability of rice plants under water stress condition. (Singh *et al.*,2012)

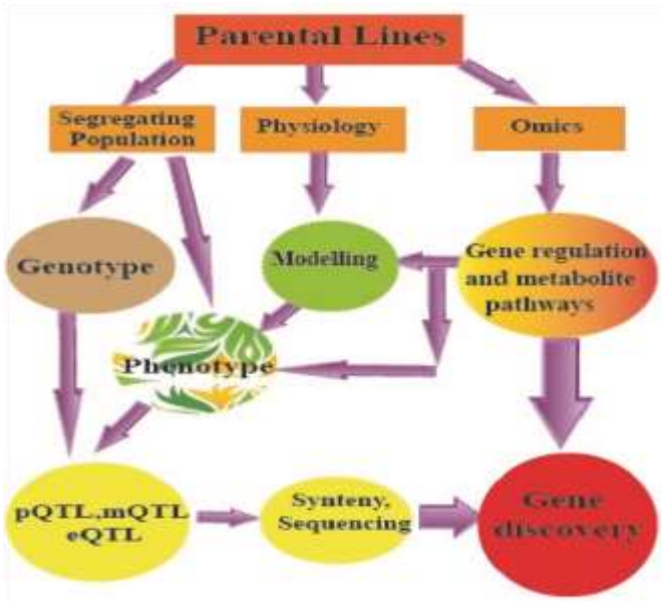

Figure 10: The schematic pathway from selection of parental lines to gene identified.

Source: Sahebi *et al.*,2018

A complete pathway towards improving drought tolerance in rice bydiscovering candidate genes is illustrated (Figure 10) and briefly described in this paper and includes (i) selecting a specific environment, (ii) creating controlled populations by selecting germplasm adapted tothetarget environment, (iii) describing the morphological, molecular, and physiological mechanisms involved in the tolerance of the parents, and (iv) integrating this information into models used for QTL analysis and positional cloning (Figure 10). Investigation of the drought regime type is the main and first step. Selection suitable germplasm based on target environment, which possibly leads to release majority of loci related to tolerance, is the next issue. The selected lines then will be used to improve segregating populations required for genetic analysis. Selection recombinant lines based on parental omics and physiological traits using different mathematical models offer functional data to choice candidate genes and work on QTLs.(Sahebi *et al.*,2018**)**

CHAPTAR IV

CONCLUSION

Drought is recognized as an environmental disaster that impairs rice production. Drought stress significantly reduced yield and yield components of rice genotypes. Drought stress affects the growth, dry mater, yield and its associated traits in rice plant. It was made out that water stress at panicle initiation was more crucial regarding plant growth as well as paddy yield and hence at this growth stage water stress may possibly be avoided.

To facilitate the development of tolerant varieties which can survive and give better yields under drought conditions, a thorough understanding of the various morphological, biochemical, physiological and molecular characters that govern the yield of rice under water stress condition. Morphological and biochemical characteristics may be a big consideration during the development of drought tolerance varieties. Nonetheless exploring the correlation between drought tolerance, seed set, yield, and its components couple with grain quality measures are the prerequisite for substantial improvement of grain yield. Also, it may be possible to prevent the irreversible effects of drought stress on the yield and grain quality by selecting suitable cultivar.

CHAPTAR V

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