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Bikha Timung
Department of Crop Physiology, Assam Agricultural University, Jorhat, Assam, India

B Bharali
Department of Crop Physiology, Assam Agricultural University, Jorhat, Assam, India

Milon Jyoti Konwar
Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Correspondence
Bikha Timung
Department of Crop Physiology, Assam Agricultural University, Jorhat, Assam, India

Physiological parameters of some upland rice (*Oryza sativa* L.) genotypes under moisture stress condition

Bikha Timung, B Bharali and Milon Jyoti Konwar

Abstract
Rice (*Oryza sativa* L) is the staple food for more than 70 % of India population. In upland rice, water stress causes serious yield loss of upland rice due to reduction in various physiological parameters. A pot experiment was carried out during February, 2014 using the Polyhouse to maintain physiological drought, and thereafter the nearby experimental field of the Department of Crop Physiology, AAU, Jorhat. Results revealed from the investigation that leaf area (0 to 10.7 %), RLWC (2.32 to 8.94 %) and total chlorophyll (1.24 to 6.86 %) were reduced significantly in the varieties under physiological drought condition as compared to irrigated one. It has been observed that varieties Inglongkiri, Sok langlu and Sovak performed well under moisture stress condition and have well adaptive physiological traits which can be used in growing different areas of Assam.

Keywords: Chlorophyll content, RLWC, root biomass, Inglongkiri, leaf area

Introduction
Rice is the staple food for more than 70% of Indian, which is grown in 44 million hectares with a production of of about 90 million tons (Viraktamanth, 2007) [28]. It is estimated that rice demand in 2025 will be 140 million tons in India (Chandrasekaran *et al,* 2007) [6] the demand for food grain is expected to rise only as a function of population growth but also as more and more people cross poverty line (30% of more than one billion population). The increase in production has necessary productivity under depleting and diminishing resources, scare and costly labour decreasing total factor. Productivity has to meet the demand of sustainability and production of environment and preservation of environment quality. Water is one of the most important factors limiting crop yield. Crop water deficiet influence the growth and development and limits crop yield. An understanding of adaptive mechanism of plants to water stress environment holds much theoretical and practical value. Plant adaptation to such environment can be expressed at for levels phenological or developmental, morphological, physiological and metabolic (Hansen, 1980) [11].

The main rice of Assam, in terms of production and consumption, is the *Sali* rice. But the crop faces severe intermittent floods during tillering to panicles initiation stage due to which crop of some pockets get damaged extensively. It results in poor grain and straw production in the lean period (during/ after- flood). Farmers have to depend on the other types of rice cultivation to meet requirement. The *Ahu* rice is the second major group of rice, which is used as buffer stock for food grain and fodder during lean period. So, *Ahu* rice can play a pivotal role in agricultural economy of the state. But, the major constraint with *Ahu* rice is the lowered productivity. The cultivation of most of the areas of Assam depends upon the residual moisture and nutrient, which is scarely left for succeeding. The traditional rice cultivars of North East India have may valuable genes possessing resistance to various biotic and abiotic stresses and unique quality and plant architecture. North east India is rich with hundreds of photoinsensitive traditional varieties of rice that may be adapted to the rainfed upland condition although their productivity is low. Moisture stress influences crop growth differentially based on the magnitude of stress, its duration and genotype. In Assam, information on the interaction of water stress at different growth phases under upland condition is lacking. The modern rice cultivars recommended for upland situation elsewhere in the country aren't well performing under Assam condition, which may be due to some environmental factors. Therefore, it appears very essential to evaluate certain local lines/cultivars/varieties along with some other which are performing better all over India.

Technically sound cultural management is felt necessary for this region and hence attempts were made to take care of these aspects and objectives were formulated accordingly with the approaches to identify the different physiological parameters of the different upland rice genotypes.

2. Materials and Methods

The experiments was laid out in Factorial RBD in pots replicated thrice in both irrigated an drought treatments. Five rice varieties, viz, Mipholong, Balam, Sok Langlu, Sovak and Inglongkiri were considered as test materials to evaluate their different physiological parameters of upland rice under two different water regimes (physiological drought and irrigation) facilitated by Fixed Time Nitrogen Management (FTNM) approach (Basal, Maximum tillering, Panicle initiations and Heading stages).

The treatments detailed were given accordingly:

(V_1) Mipholong T_1= Irrigated
(V_2) Balam T_2 = Physiological drought Stress
(V_3) Sok Langlu N_0 = N,P,K@0,20,20Kg/ha
(V_4) Sovak and N_1= N, P, K @40,20,20Kg/ha+ FTNM
(V_5) Inglongkiri

3. Results and Discussion

3.1. Effect of water stress on leaf area at maximum tillering and heading stages of rice

Data portrayed in the Table 1 revealed that water stress reduced leaf area significantly (F=4.812 P<0.05) at maximum tillering stage. Under irrigated condition, the highest leaf area was recorded in the rice varieties Sok Langlu (64.5 $cm^2/plant^2$) followed by (>) Mipholong (59.133 $cm^2/plant^2$), and the lowest was in Sovak (46.233 $cm^2/plant^2$) < Inglongkiri (52.267 $cm^2/plant^2$). Under drought condition, leaf area was the highest in the rice varieties Sok Langlu (62.133 $cm^2/plant^2$) > Mipholong (57.767 $cm^2/plant^2$), whereas leaf area was the lowest in Sovak (46.233 $cm^2/plant^2$) < Inglongkiri (50.167 $cm^2/plant^2$) under the same condition.

Table 1: Effects of water stress on Leaf area (LA) at different stages of rice crop.

Leaf area at Maximum tillering stage (cm^2/plant)				Leaf area at Heading stage (cm^2/plant)		
Varieties of rice	**Irrigated**	**Drought**	**Mean**	**Irrigated**	**Drought**	**Mean**
Mipholong	59.10	57.80	58.50	61.00	59.30	60.20
Bbalam	56.30	54.50	55.40	58.70	55.70	57.20
Sok langlu	64.50	62.10	63.30	66.70	63.00	64.80
Sovak	46.20	46.20	46.20	53.00	47.30	50.20
Inglongkiri	52.30	50.20	51.20	53.30	52.70	52.70
Mean	55.70	54.20		58.50	55.60	
	S.E. (d) (±)	C.D. (0.05)		S.E. (d) (±)	C.D. (0.05)	
Treatment (T)	0.20	0.40		0.40	0.80	
Varieties (V)	0.30	0.60		0.60	1.30	
T X V	0.40	0.90		0.90	1.80	

At heading stage under irrigated condition the highest leaf area was recorded in Sok Langlu (66.667 cm^2/plant) >Mipholong (61.00 cm^2/plant), and the lowest was found in Sovak (53.00 cm^2/plant) < Inglongkiri (53.333 cm^2/plant).

In the present study, there was variation of leaf area among the varieties due to water stress. The varieties Inglongkiri (4.02%) had the highest reduction of leaf area at maximum tillering stage. There was no reduction of leaf area at all in Sovak. At heading stage, the cultivar Sovak (10.7%) had the highest reduction, while Inlongkiri (1.25 %) had the lowest leaf area reduction. The finding is close confirmation with the finding of Specht and Rundel (1990) [25] and Gupta *et al*. (2011) [10]. Leaf area is the indicative of vegetative growth. Leaf area of crop is primarily affected by water stress. In general, 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) [12]. The water deficit in rice caused a larger reduction in leaf area demonstrating the greater sensitivity of leaf enlargement to water stress (Gloria *et al*, 2002). A reduction in leaf area due to water scarcity may represent an increase in xeromorphy (Stocker, 1960) [26].

3.2 Effect of water stress on specific leaf weight at maximum tillering and heading stages of rice crop

It is apparent from the Table 2 that there were significant reduction of specific leaf weight (SLW) by water stress (F=165.943 P<0.05), and the varieties (F=822.514 P<0.05) varied significantly, too, in respect of SLW at maximum tillering stage. The varieties Inglongkiri (56.667 mg cm^{-2}) recorded the highest SLW followed by (>) Sovak (55.667 mg cm^2). The lowest SLW was recorded in varieties Balam (40.667mg cm^{-2}) < Sok langlu (43.667 mg cm^{-2}) under irrigated condition. At heading stage under drought condition, the varieties Inglonkiri (53.667 mg cm^2) maintained the highest SLW > Sovak (52.667 mg $cm^{2)}$, and lowest SLW was recorded in Balam (36.333 mg cm^{-2}) < Sok langlu (41.333 mg cm^{-2}).

At heading stage, SLW was significantly reduced by water stress (F=54.675 P<5), and the SLW due to varieties (F=605.550 P<5) also differed significantly. The highest SLW was found in varieties Inglongkiri (58.0 mg cm^{-2})> Sovak (56.0 mg cm^{-2}), and the lowest was recorded in Balam (42.333 mg cm^{-2}) < Sok langlu (46.0 mg cm^2) under irrigated condition. The varieties Sovak (55.333 mg cm^{-2}) showed the highest SLW > Inglongkiri (54.667 mg cm^{-2}), whereas the lowest SLW was recorded in Balam (40.667 mg cm^{-2}) < Sok langlu (44.0 mg cm^{-2}) under drought condition. Overall, there was higher SLW in varieties under drought condition as compared to the irrigated one.

Table 2: Effects of water stress on Specific leaf weight at different stages of rice crop.

Specific leaf weight at maximum tillerin stage (mg/cm²)				Specific leaf weight at heading stage (mg/cm²)		
Varieties of rice	**Irrigated**	**Drought**	**Mean**	**Irrigated**	**Drought**	**Mean**
Mipholong	46.333	44.333	45.333	48.333	45.333	46.833
Balam	40.667	36.333	38.5	42.333	40.667	41.5
Sok langlu	43.667	41.333	42.5	46	44	45
Sovak	55.667	52.667	54.167	56	55.333	55.667
Inglongkiri	56.667	53.667	55.167	58	54.667	56.333
Mean	48.6	45.667	-	50.133	48	-
	S.E.(d) (±)	C.D. (0.05)		S.E.(d) (±)	C.D. (0.05)	
Treatment (T)	0.228	0.482		0.202	0.429	
Varieties (V)	0.36	0.762		0.32	0.678	
T X V	0.509	1.078		0.453	0.958	

Specific leaf weight (SLW) is a selection criterion for abiotic stress factors like low light in rice (Bharali and Chandra 1996) [5]. The changes in SLW as a result of water stress. There were reductions in SLW at maximum tillering and heading stages of all the varieties. The variety Balam (10.65 %) had the highest per cent reduction in SLW, and Balam was the most sensitive genotype to drought stress. Similarly, at heading stage, the variety Sovak had the highest per cent reduction (8.33 %) of SLW, and Balam had the lowest per cent reduction (3.7 %) of it under drought as compared to irrigated condition. SLW and Specific leaf area (SLA) decrease with stress, especially when water stress is applied at booting stage (Munamava and Riddoch, 2001) [16]. Varieties having high SLW and higher epicuticular waxes were found to be drought tolerant (Balasimha 1987; Balasimha *et.al*. 1985) [3, 4]. Instead, according to O'Neill (1983), stressed leaves had a lower SLW, suggesting that these leaves are thicker or had more densely packed mesophyll cells with less intracellular air space. The increase in SLW could be due to carbohydrates and variation in mesophyll tissue density or leaf thickness, as suggested by Araus *et al*. (1986) [2].

3.3 Effect of water stress on root biomass at harvest of rice crop

The data presented in the Table.3 reveal that root biomass at harvest showed significant variation among the varieties (P<0.05) of rice as well as among the treatments (F=154.559 P<0.05), and the interaction (P<0.05) among the varieties of rice and treatments**.** The highest root biomass was recorded in Inglongkiri (530 mg/plant) followed by (>) Sovak (480 mg/plant), and the lowest was recorded in Balam (438.333 mg/plant) < Sok langlu (458.33 mg/plant) under irrigated condition. Under drought condition, Inglongkiri (546.667 mg/plant) maintained the highest root biomass > Sovak (503.333 mg/plant), whereas the lowest root biomass was recorded in Balam (453.333 mg/plant) < Sok langlu (473.333 mg/plant).

Table 3: Effects of water regimes on Root biomass (mg/plant)at harvest of rice crop.

Varieties of rice	Irrigated	Drought	Mean
Mipholong	474.00	493.33	483.67
Balam	438.33	453.33	445.83
Sok Langlu	458.33	473.33	465.83
Sovak	480.00	511.67	511.67
Inglongkiri	530.00	546.67	538.33
Mean	474.67	494.00	-
	S.E. (d) (±)	C.D. (0.05)	-
Treatment (T)	1.57	3.33	-
Varieties (V)	2.48	5.26	-
T X V	3.51	7.44	-

Plants use various mechanisms to cope with drought stress *viz*, drought, escape, drought avoidance and drought tolerance (Turner *et al*, 2001) [27]. The changes in root biomass as a result of water stress. Root biomass increased under drought stress than that of irrigated growth condition. The highest increase in root biomass was obtained in the variety in Sovak (6.6%) whereas the lowest increase in root biomass was obtained in the variety Inglongkiri (3.14%). The increase in root biomass in water stressed varieties may be due to their abilities to divert assimilates in enhancing the growth of the roots so as to exploit water from the deeper parts of the soil (Matsui and Singh, 2003) [15]. In the current work, the second mechanism, i.e. drought avoidance might be involved to maintain high plant water status during period of stress, either by efficient water absorption from roots or by reducing evapotranspiration from aerial parts. The present study is deficient in examining these sorts of aspects.

3.4 Effects of water stress on relative leaf water content at maximum tillering and heading stages of rice crop.

Data presented in Table 4 reveal that Relative leaf water content (RLWC) was reduced significantly due the water regimes (F=327.180 P<0.05), varieties (F=253.947 P<0.05) and the interaction between the treatments and the varieties (F=6.973 P<5). At maximum tillering stage, the highest RLWC was recorded in Inglogkiri (29.8%) followed by (>) Sok langlu (29.067 %), and the lowest was found in Balam (24.967%) < Sovak (26.933%) under irrigated growth condition. The varieties Inglongkiri (28.367%) maintained the highest RLWC > Mipholong (26.833 %), whereas the lowest RLWC was recorded in Balam (23.6%) < Sovak (25.767 %) under drought condition.

At heading stage, Inglogkiri (30.30%) also possessed the highest RLWC followed by Sok langlu (29.867%), and the lowest was found in Balam (26.80%) under irrigated growth condition. Under drought condition, Inglongkiri (29.10%) recorded the highest relative water content also, and the lowest was recorded in Balam (25.30%).

Table 4: Effects of water stress on Relative Water Content (RLWC) at different stages

RLWC (%) at maximum tillering stage				RLWC (%) at heading stage		
Varieties of rice	**Irrigated**	**Drought**	**Mean**	**Irrigated**	**Drought**	**Mean**
Mipholong	28.033	26.833	27.433	29.667	28.267	28.967
Balam	24.967	23.6	24.283	26.8	25.3	26.05
Sok Langlu	29.067	26.467	27.767	29.867	28.9	29.383
Sovak	26.933	25.767	26.35	28.633	27.967	28.417
Inglongkiri	29.8	28.367	29.083	30.3	29.1	29.7
Mean	27.76	26.207		29.053	27.907	
	S.E.(d) (±)	C.D. (0.05)		S.E.(d) (±)	C.D. (0.05)	
Treatment (T)	0.101	0.214		0.05	0.105	
Varieties (V)	0.159	0.338		0.079	0.167	
T X V	0.226	0.477		0.111	0.236	

Relative leaf water content (RLWC**)** has been reported as an important indicator of water stress in leaves which is directly related to soil water content. This indicated grater resistance to water flow at the soil-root interface or decreased hydraulic conductivity of soil at low soil moisture. In addition, Ranney *et al*, (1991) [21] proved that with osmotic adjustment mechanism, there is lowering osmotic potential of the cells, and hence participates in maintaining of full turger of tissue under water stress conductions. Osmotic adjustment is an active accumulation of solutes within the plant in response to decrease in soil water potential, thus reducing the harmful effects of water deficit. In the present study, RLWC of all the genotypes was reduced significantly by physiological drought condition. In general, moisture stress at maximum tillering stage reduced RLWC more than at the heading stage of all the varieties. Over all, the highest reduction in RLWC was obtained in Sok langlu (8.94 %), and the lowest was obtained in Mipholong (4.3%) at maximum tillering. At heading stage, Balam had the highest RLWC reduction (5.6 %) among the varieties. The lowest was obtained in Sovak with (2.32 %) only. Khan *et al*. (2007) concluded that water deficit stress results in a considerable decline in RLWC (18-68%). A 50% reduction of RLWC on exposure to moisture stress was reported by Das *et.al*. (2000) [7]. The RLWC had been considered as a better indicator for water stress, because RLWC through its relation to cell volume reflects the balance between water supply to the leaf and transpiration rate (Sinclair and Ludlow 1985) [24]. Since, the variety Balam contained the highest relative leaf water at heading stage; it might possess a drought tolerant tendency. Schonfeld *et.al*. (1988) [23] suggested that varieties with high RLWC are likely to be drought resistant. Jones (1978) [13] observed a decrease in RLWC with age in response to gradually induced water stress in four temperate herbage species. The present investigation was close confirmation with the finding of Lobato *et al*, (2011) [14] and Aguyoh *et al*, (2013) [1].

3.5 Effect of water stress on total chlorophyll content at different growth stages rice crop

Data mentioned in Table 5 indicate that there were significant differences of total chlorophyll contents between the water regimes ($P<0.05$), among the varieties ($P<0.05$), and due to interaction between the treatments and the varieties ($P<0.05$) at maximum tillering stage. It was interesting to note that total chlorophyll content increased from maximum tillering to heading stage. At maximum tillering stage, the highest total chlorophyll content was recorded in Inglongkiri in both irrigated (1.56 mg g^{-1} leaf f.w.) and drought (1.517 mg g^{-1} leaf f.w.) conditions. The lowest was recorded in Balam under both Irrigated (1.237 mg g^{-1} leaf f.w.) and drought (1.203 mg g^{1} leaf f.w.) conditions. The reduction of total chlorophyll content was 3.008% only as compared to irrigated condition.

At heading stage, Inglongkiri maintained the highest values in both irrigated (1.66 mg g^{-1} leaf f.w.) and drought (1.613 mg g^{-1} leaf f.w.), whereas the lowest was recorded in Balam, under both irrigated (1.343 mg g^{-1} leaf f.w.) and drought (1.29 mg g^{-1} leaf f.w.) conditions.

Table 5: Effects of water stress on Total Chlorophyll contents at different stages of rice crop.

At maximum tillering stage (mg g^{-1} leaf f.w.)				At Heading stage (mg g^{-1} leaf f.w.)		
Varieties of rice	**Irrigated**	**Drought**	**Mean**	**Irrigated**	**Drought**	**Mean**
Mipholong	1.527	1.503	1.515	1.607	1.587	1.597
Balam	1.237	1.203	1.22	1.343	1.29	1.317
Sok Langlu	1.537	1.513	1.525	1.623	1.583	1.517
Sovak	1.457	1.357	1.407	1.537	1.497	1.52
Inglongkiri	1.56	1.517	1.538	1.66	1.613	1.637
Mean	1.463	1.419		1.554	1.514	
	S.E.(d). (±)	C.D. (0.05)		S.E.(d) (±)	C.D. (0.05)	
Treatment (T)	0.003	0.006		0.003	0.006	
Varieties (V)	0.004	0.009		0.004	0.009	
T X V	0.006	0.013		0.006	0.013	

Total chlorophyll content in leaves of rice tissues declined at both maximum tillering (by 3.0%) and heading (by 2.57%) stages under drought condition in comparison with irrigated condition. Irrigated varieties of rice had more total chlorophyll contents than those under drought treated varieties. On an average, the cultivar Sovak had the highest per cent reduction (6.86 %) of total chlorophyll content as compared to all the other varieties. The least reduction was in Sok langlu (1.56 %) under moisture stress condition. At heading stage, the cultivar Balam (3.94%) had the highest per cent reduction, and the least total chlorophyll per cent reduction was in Mipholong (1.24%). The varieties having the lowest per cent reduction in chlorophyll contents might be tolerant under drought condition. These results are in close confirmation with the findings of Santos *et al,* (2009) [22], Zhang *et al,* (2012). It was also observed that increase in duration of water stress can reduce significantly the total chlorophyll content as well as chlorophyll a/b ratio (Nilsen & Orcutt, 1996). Guerfel *et al*. (2009a) reported, water stress posed significant effects on total cholorophyll in `Chemlali' and `Che toui'; olives, and the amount of reduction of total chlorophyll were 29% and 42% for in `Chemlali' and `Che toui'; olives respectively under water stress.

4. Conclusion

In the research paper, it could be concluded that the variety Inglongkiri was efficient among all the varieties of rice tested under drought condition. This variety possessing the suitable adaptive physiological traits among the varieties to drought stress condition. This variety may be taken as donor in crop improvement program for direct seeded upland condition. It can be grown in rabi season or under agro ecological situations of Karbi Anglong and in other districts of Assam.

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