Approaches for Enhancing Nitrogen Use Efficiency in some Upland rice *(Oryza sativa L.)* Genotypes under Water Stress Conditions

Larbeen Teronpi[1], Bhagawan Bharali[2]

Department of Crop Physiology, Assam Agricultural University, Jorhat-13

Abstract— *Water stress causes serious yield loss of upland rice under water stress condition due to reduction in various physiological parameters, more particularly nitrogen use efficiency (NUE). Therefore, a pot experiment was conducted to evaluate six indigenous upland rice genotypes (viz., Mairen Ake-er, Soksu Ajoha, Soksu Abara, Chubok Abara, Bijor Soksu, and Inglongkiri) from North Hill zones (i.e. Karbi Anglong) for higher NUE and yield potential under different water regimes (Full irrigation & No water + 5000ppm of 6000PEG spray at tillering and heading stages). Real Time Nutrient Management (RTNM) approaches were used to determine the optimum rate of nitrogen for maximum yield and higher NUE under physiological drought condition. As such, amount of nitrogen fertilizer received by each of the varieties during growing period was 130 kgN/ha (1300ppm=1.3%) irrespective of water regimes. The genotypes showed differences in grain yield, plant height, chlorophyll content, proline, nitrate reductase, N-content and N-uptake. The variety Inglongkiri with the highest score corresponding to total N-uptake (88.85%), NUE (25.78%) and HI (43.51%), and the lowest reduction in grain yield (1.6%) has emerged as suitable genotype under water stress condition as compared to the irrigated one. Inglongkiri, a developed variety of Assam (RARS, Diphu), was found physiologically efficient among the varieties tested. This variety possesses the adaptive traits, especially higher N use efficiency, higher yield and attributes under physiological drought condition. Therefore, Inglongkiri may be taken as a donor in breeding programme for direct seeded upland limited moisture condition, and can be grown suitably under agro climatic conditions of elsewhere in Assam during Ahu season.*

Keywords— Chlorophyll, grain yield, leaf area, plant height, proline, rice, water productivity.

I. INTRODUCTION

Rice is a semi-aquatic (mesophyte) plant which is commonly grown under submerged conditions. Submersed rice occupies about half of the cultivating areas (79 million hectares) in the world. Alternatively, rice is also grown in upland conditions. The yield of upland rice is reduced to some extent by scarcity of water, so called drought. Drought is defined as a period of no rainfall or no irrigation that affects crop growth (Hanson *et al*., 1990). Rice is the principal food crop for North Eastern region of India accounting for more than 80 per cent of the food grain production. The crop is extensively cultivated (72 per cent of the total cultivated area) in upland, lowland and deep water conditions. On an average 3,869 km^2 areas are put under shifting cultivation every year. The productivity of upland rice in N.E. India is very poor (0.9 tonnes per hectare) as compared to the national average (i.e. about 1.9 tonnes per hectare) (Singh 2002)

Water stress or drought is one of the most important abiotic constraints in rice. The effect of varying soil water regimes during different growth phases on rice yield. They reported that the soil water stress applied at any of the growth phases reduced rice grain yield, compared to the continuous flooding irrigation. The ripening phase appeared to be most sensitive as compared to the other phases. Soil water stress during the earlier growth phases (vegetative) reduces the production of effective tillers which lessens grain yield ultimately. Water stress during the later growth phases (reproductive) appeared to affect the reproductive physiology by interfering with pollination, fertilization and grain filling. As a result, there is reduction of grain yield in rice crop (Jana *et al.* 1971).

Nutrient availability might be further reduced by the often alternating soil water regimes and soil chemistry. Low soil fertility and the limited use of fertilizers contribute considerably to the low productivity of rain fed rice based systems (Haefels and Hijmans, 2007; Wade *et al.*, 1999; Pandey, 1998). Increased yield from fertilizer application even under water limited conditions were reported repeatedly, but it is often assumed that the economic return to applied fertilizer decreases with increasing drought stress (O'Toole and Baldia, 1982).

Indigenous rice genotypes grown in different water regimes may vary in nutrient use efficiency. Genotypic differences in nutrient use efficiency have been reported when they were mostly grown in well water intensive lowlands (Broadbent *et al.*, 1987; De Datta and Broadbent, 1990). It is, therefore, one of the major considerations to identify the critical steps controlling plant N use efficiency (NUE). Moll *et al*. (1982) defined NUE as being the yield of grain per unit of available N in the soil (including the residual N present in the soil and the fertilizer). According to Ladha *et al.* (1998), desirable cultivars with high nitrogen use efficiency (NUE) should produce large yields at low N supply. This seems even more important in upland environment where no nitrogen rates are applied. Several studies have addressed the optimization of fertilization and the improvement of NUE of crops to achieve high yields with reduced N fertilization rates, and limited environmental side effects related to N leaching (Agostini *et al.,* 2010; Burns, 2006; Neeteson and Carton, 2001; Rahn, 2002). Species and cultivars are expected to play a primary role: the genotype affects both the N uptake and the use of absorbed N, because every genotype has its own morphological and functional characteristics for roots, leaves, etc. (Schenk, 2006; Thorup-Kristense and Sørensen, 1999; Thorup-Kristensen and Vander Boogard, 1999). However, the same genotype can show different NUEs when subjected to different levels of N availability. New technologies in nutrient management in rice have been developed to increase nutrient use efficiency in recent years. Site-specific nutrient management (SSNM) such as Real-Time Nitrogen Management (RTNM) and Fixed-Time adjustable-dose Nitrogen Management (FTNM) were developed to increase the N use efficiency of irrigated rice (Peng *et al*., 1996 and Dobermann *et al*., 2002). In RTNM, N is applied only when the leaf N content is below a critical level. In this approach, the timing and number of N applications vary across seasons and locations, while the rate of each N application is fixed. The leaf N content is estimated non-destructively with a chlorophyll meter (SPAD: Soil Plant Analytical Development value) or Leaf Color Chart, commonly known as LCC (Tao *et al*., 1990, Peng *et al.*, 1996, Balasubramanian *et al*., 1999 and Yang *et al.*, 2003). In FTNM, the timing and number of N applications are fixed, while the rate of each N application varies across season and location. There is paucity of information on the responses of upland indigenous rice genotypes from North Hill zones (i.e. Karbi Anglong) to varying levels of water stress conditions. Moreover, management of Nitrogen in upland rice crop based on SPAD values under water stress conditions is lacking. The experiment was conducted to evaluate upland rice genotype(s) for higher nitrogen use efficiency (NUE) and yield potential using the Real Time Nutrient Management (RTNM) approaches, nitrogen use efficiency and productivity under water regimes and nitrogen levels.

II. MATERIALS AND METHODS

The investigation was carried out in 2015 at the vicinity of stress physiology laboratory under the Department of Crop physiology during Ahu season as a part of the M.Sc (Agri) degree program in Assam Agricultural University, Jorhat. A pot experiment was carried out with six upland (Ahu) rice varieties of same medium duration. The study was carried out by keeping the pots inside a poly house only during drought treatment periods in vegetative and reproductive stages, and then in the open field conditions for exposure to more sunlight so that crop does not suffer from low light situations during its developmental periods. A mixture of sandy loamy soil with FYM was used to fill in one pot (capacity: 6.5 Kg soil). FYM @5t/ha (≈.50g/pot) was applied initially to each pot. The whole amount of P&K @ 20:20 in the form of SSP (Single Super Phosphate) and MoP (Muriet of Potash) were applied as basal. N was applied based on RTNM method (Section 3.7). In here, N @ 20-150 Kg Nha^{-1} was applied according to the demand of the crop based on the SPAD (Soil Plant Analytical Development) values measured at different growth stages of the crop. In RTNM, a certain rate of N- fertilizer was applied when leaf N content was below a critical level (Peng *et al.*, 1996) as follows: First dose: 30 KgN/ha was applied at 10 days after sowing, Second dose: 40 kgN/ha was applied at tillering (SPAD value <33), Third dose: 40 kgN/ha was applied at panicle initiation (SPAD value <33), Fourth dose: 20 kgN/ha at heading (SPAD value <33). A constant water supply (2-3cm) was ensured from transplanting till seven days before harvesting except the periods of drought in treated pots. The soil of the experimental field was sandy loam with acid in reaction (pH= 5.6), available N, P and K was 257.2 kg/ha, 24.6kg/ha and 106.3 kg/ha respectively. The total rainfall received during the crop growth period was 1314.6 mm in the open field conditions. The temperature (31-25 ºc and 33-27 ºc) relative humidity (69-66 % and 72-69 %) and light intensity (2050 and 1685 lux) was also maintained inside the polyhouse in the vegetative and reproductive stage. Grain yield and straw yield was calculated.

TABLE 1 (A)
METEOROLOGICAL DATA DURING THE CROP SEASON (2015)

Months	Temperature (ºC) (Monthly mean)		Relative Humidity (%) (Monthly mean)		Monthly total Bright Sunshine (Hours)	Monthly total Rainfall (mm)
	Max.	Min.	Morn.	Even.		
March	29.8	16.1	90	55	154.6	42.7
April	27.4	19.0	93	73	115.7	293.3
May	30.1	22.5	92	77	97.4	298.0
June	31.6	24.4	94	80	78.7	335.8
July	34.0	25.3	90	72	161.1	344.8
Total						1314.6

Source: Meteorological observatory, Agricultural Meteorological Department, Assam Agricultural University, Jorhat

TABLE 1(B)
METEOROLOGICAL DATA DURING DROUGHT TREATMENTS INSIDE THE POLY HOUSE

Duration of withholding water and Polyethylene Glycol (PEG) treatments	Temp. (ºC) (Mean of 7days)		Relative Humidity (%) (Mean of 7days)		Light intensity (Reading x10) Lux (Mean of 7days)
	Max.	Mini.	Morn.	Eve.	
7 Days (11st – 20th April) + apply PEG 6000 (5000ppm)	31	25	69	66	2050
7 Days (13th May – 22nd May) + apply PEG 6000 (5000ppm)	33	27	72	69	1685

III. RESULTS AND DISCUSSION

The crop was subjected to water stress by withholding irrigation for seven days plus spraying with PEG-6000 (5000ppm) both at maximum tillering and heading stages. The crop was deprived of natural precipitation during these periods inside a poly house except supply of live saving water while soil tensiometer auto-fixed its readings at 80 centibars, and crop wilted visually. All the plants received a range of temperature (25-33°C), Relative humidity (66-72%) and light intensity (1685-2050 Lux) during the drought treatments in the months of April and May. The crop experienced same weather conditions outside the poly house during the rest of the growth periods. As the soil was strongly acidic in nature (pH 5.64), and N, P, K were in the lower ranges, fertilizer SSP and MoP were applied at recommended doses (20:20) as basal, but N was supplied based on SPAD values at different growth stages to get rid of crop starvation and to contribute in crop growth. Interestingly, all the plants, irrespective of drought and irrigation treatments, demanded equal amount of N (i.e. 130 kg/ha) throughout the growth periods (10days after sowing to tillering, panicle initiation and heading). As such, soil moisture remained as the only variable factor during the period of treatments, and its impacts on physiological changes were recognised subsequently.

3.1 Growth characteristics

Water and nitrogen significantly influenced average plant height and leaf area. Plant height and leaf area increased with nitrogen application in the well-watered treatment, but excessive nitrogen inhibited their growth. The variety Inglongkiri has the highest percent reduction and Soksu ajoha has the lowest percent reduction in plant height among the varieties at harvest. The reduction in plant height was either as a result of water stress imposed at tillering stage or might be due to its genetic behaviour x environment interaction, which inclined it towards high yielder at harvest. Bhattacharjee *et. al.*, (1973) and De Datta (1973) found significant reductions in tillers and panicles numbers as well as plant height and grain yield when water stress was imposed at tillering stage. Water stress resulted to decrease in plant height, number of tillers per plant, total biomass and grain yield (Tantawi and Ghanem, 2001; Tuong *et. al.*, 2005). 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).

Specific leaf weight (SLW), characteristic features of plants which could be used as a selection criterion for abiotic stress factor (Bharali and Chandra 1996). The variety Inglongkiri had the highest per cent reduction (19.7 %) of SLW at heading stage as compared to tillering stage among all the other varieties, illustrated in (Fig. 3) Stress leaves had a lower SLW, suggesting that these leaves were thicker or had more densely packed mesophyll cells with less intracellular air space.

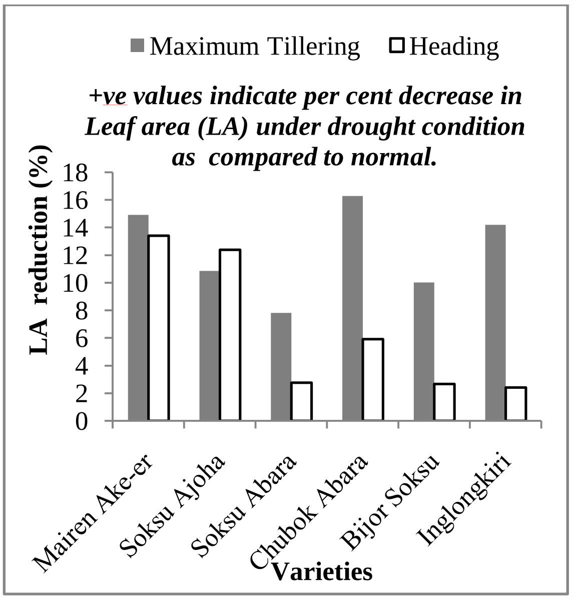


FIG. 1. CHANGES OF LEAF AREA (LA) UNDER DROUGHT AS COMPARED TO IRRIGATION

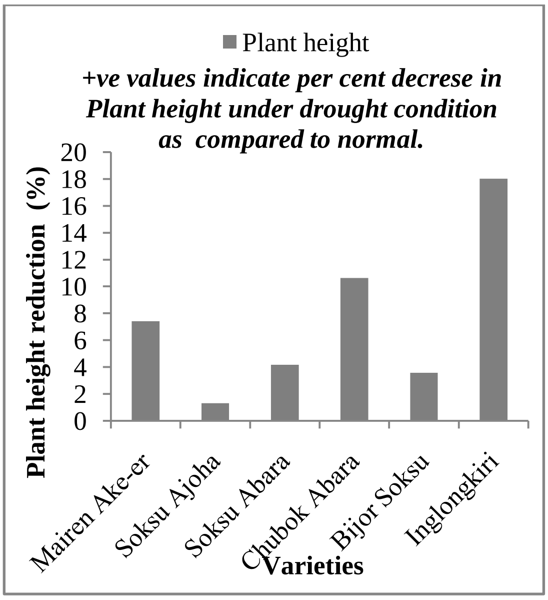


FIG. 2. CHANGES OF PLANT HEIGHT UNDER DROUGHT AS COMPARED TO IRRIGATION

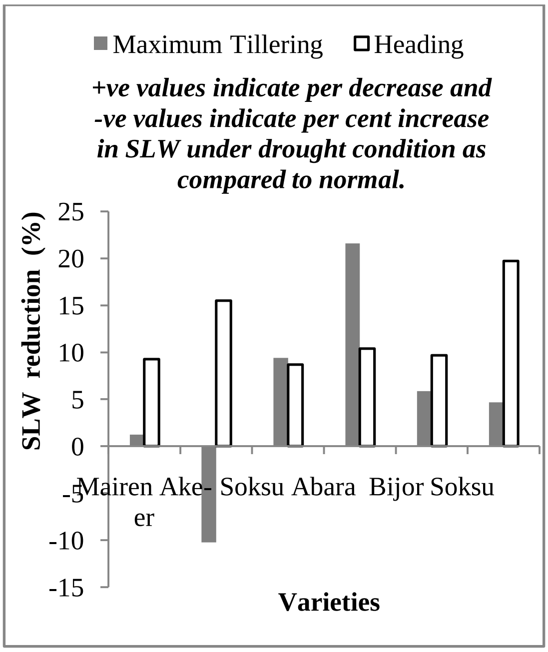


FIG. 3. CHANGES OF SPECIFIC LEAF WEIGHT (SLW) UNDER DROUGHT AS COMPARED TO IRRIGATION

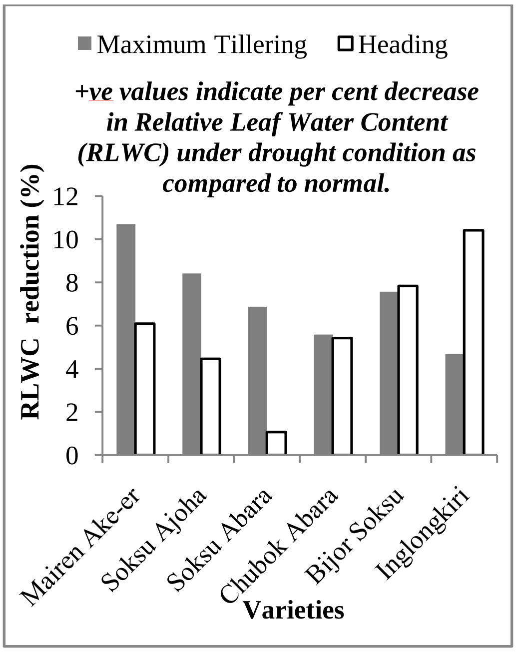


FIG. 4. CHANGES OF RLWC UNDER DROUGHT AS COMPARED TO IRRIGATION

Relative leaf water content (RLWC) of all the genotypes decreased significantly under drought condition (Fig. 4). There was more reduction in RLWC at tillering stage of all the varieties except Inglongkiri. Although at heading stage, Inglongkiri had the highest RLWC reduction (10.4%) among the varieties. Khan *et. al.,* (2007) concluded that water deficit stress results in a considerable decline in RLWC (18-68%). The variety Soksu abara with 1 % reduction contained the highest relative leaf water at heading stage: it might possess a drought tolerant tendency. Schonfeld *et. al.,* (1988) suggested that cultivars with high RLWC are likely to be drought resistant.

In the present investigation there was a fluctuate per cent reduction of chlorophyll content at tillering and heading stage under drought as compared to irrigation. The variety Bijor (40.4 %) had the highest and Soksu Ajoha (6.06%) had the lowest per cent reduction at heading stage (Fig. 5). Mohan *et. al.,* (2000) stated that the chlorophyll content is an indication of stress tolerance capacity of plants, and its high value means that the stress did not have much effect on chlorophyll content of tolerant plants. It is apparent from the (Fig. 6) that there were significant increase in proline contents both in tillering (upto 47.35 % in Soksu Ajoha) and heading stages (17.38%) of the varieties under water stress condition. Under water stress, accumulated proline might act as a compatible solute regulating and reducing water loss from the plant cell during water deficit (Yokota *et. al.,* 2006). Proline accumulates under stress also supplies energy for survivor and growth, and thereby helps the plants to tolerate stress condition (Kumar *et al*., 2011). Chubok Abara had the highest nitrate reductase activity reduction (37.46%) at tillering whereas Bijor soksu (40.6%) had the highest nitrate reductase activity at heading stage. There was a significant decline of NR at maximum tillering (1-37%) and heading (12-41%) stages in the varieties. Polyethylene glycol induces stress resulting in free amino acids as well as reduction in nitrate reductase activity in pearl millet (Hanson *et al.,* 1981; Hanson *et al*., 1982). Water stress induced decline in nitrate reductase activity has also been reported by Sarkar *et al*. (1991). In the study, changes of (0-0.71%) and (0-0.43%) were found at the two subsequent growth stages of rice varieties respectively. As such, the highest per cent changes were observed in Soksu ajoha (0.71%) at tillering and Soksu abara (0.43%) at heading stage. This means, Soksu Abara contained the highest amount of leaf nitrogen at reproductive stage under drought as compared to irrigated, indicating better ability of this genotype in acquiring N either from soil or applied nitrogen, and in remobilizing N under favorable water regime (normal) conditions. The results of Ghanbari *et al.* (2013) were also in confirmatory with the present finding. According to Janadhan and Murty (1980) nitrogen present in all plant parts decreases at harvest when compared with that of flowering stage. There was higher changes in carbohydrate contents in Mairen ake-er (1.32%) at maximum tillering stage followed by Soksu Ajoha (1.0%) under drought as compared to irrigated one. Whereas, at heading stage Chubok Abara (1.17%), Mairen ake-er (1.15%) and Bijor soksu (0.98%) had experienced some changes in carbohydrate content. Inglongkiri (1.03%) followed by Soksu abara (0.98%) and Soksu ajoha (0.70%) had higher changes in carbohydrate contents at this stage. It indicates that these varieties could carry out the process of photosynthesis well, particularly at maximum tillering stage under physiological drought stress. Dubey and Singh (1999) also reported that the sugar contents increases more in the sensitive than in the tolerant rice cultivars. Nakayama (1974) suggested that reduce transport of carbohydrate from the source to the developing grain might be a casual factor for impaired grain filling in rice.

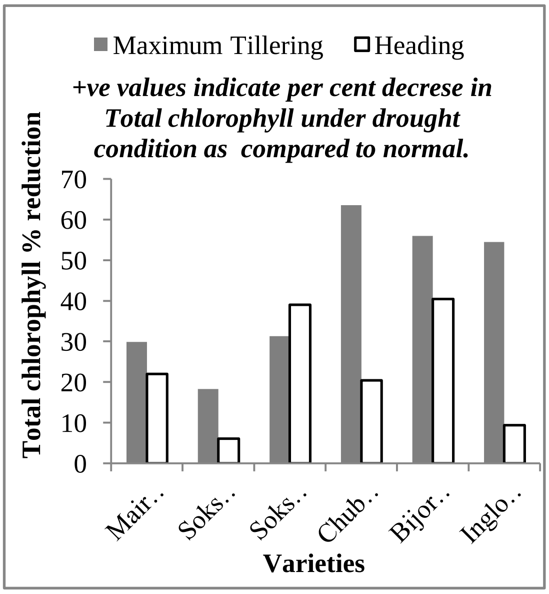


FIG. 5. CHANGE OF TOTAL CHLOROPHYLL UNDER DROUGHT AS COMPARED TO IRRIGATION

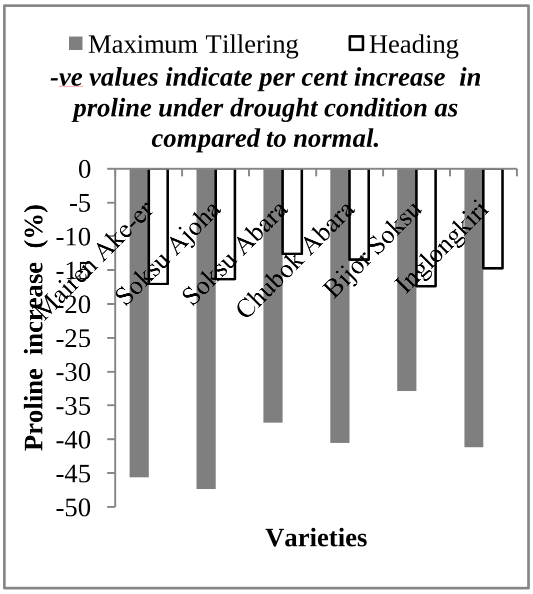


FIG. 6. CHANGES OF PROLINE UNDER DROUGHT AS COMPARED TO IRRIGATION

Photosynthesis is the main metabolic process determining crop production, and is affected by drought stress. Drought reduces photosynthetic rate of rice crop (Ji *et al.,* 2012; Lauteri *et al.,* 2014; Yang *et al.,* 2014). The lowest per cent reduction was seen in Chubok abara (14.14%) at tillering, and in Mairen ake-er (26.95%) at heading under drought as compared to normal (Fig. 10). The lowest per cent reduction under drought as compared to normal indicates the increase in photosynthetic rate in rice leaves. The increase in leaf photosynthetic rate is important to increase the yield potential of rice (Hirasawa *et al.,* 2010), because the photosynthetic rate of individual leaf which form the canopy, affects dry matter production via photosynthesis within the canopy. There were insignificant differences in Root: shoot among the varieties (Fig. 11a), and increase in root biomass (Fig. 11b) under drought as compared to normal. The highest changes in root: shoot was observed in Chubok Abara (0.072%) followed by Soksu Abara (0.065%) under drought as compared to irrigated. The highest increment in root biomass was found in Chubok Abara (41.2%) under drought. O'Toole and Chang (1979) suggested that upland variety should have a relatively high root-shoot ratio in order to yield efficiently under soil moisture stress conditions. Root dry mass and length are good predictor of rice yield under drought (Fageria and Moreira, 2011; Feng *et al*., 2012).

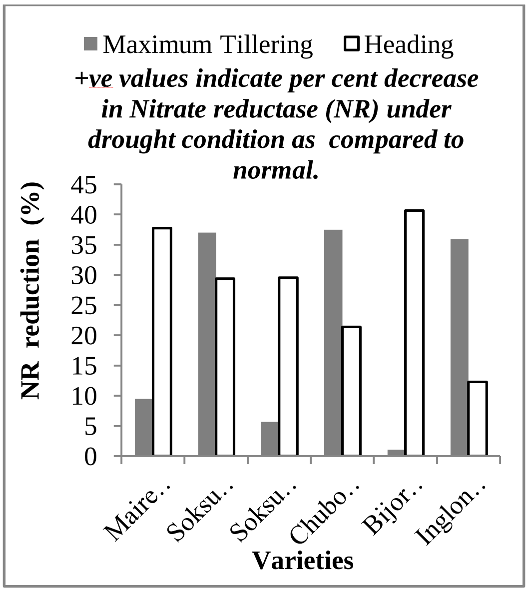


FIG. 7. CHANGES OF NITRATE REDUCTASE (NR) UNDER DROUGHT AS COMPARED TO IRRIGATION

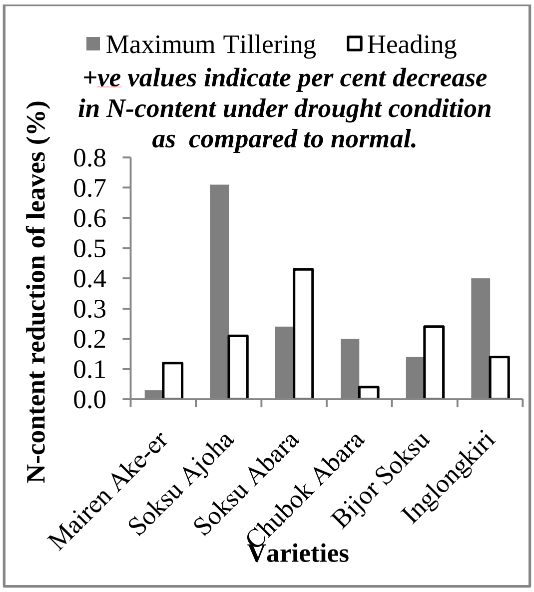


FIG. 8. CHANGES OF N-CONTENT OF LEAF TISSUES UNDER DROUGHT AS COMPARED TO IRRIGATION

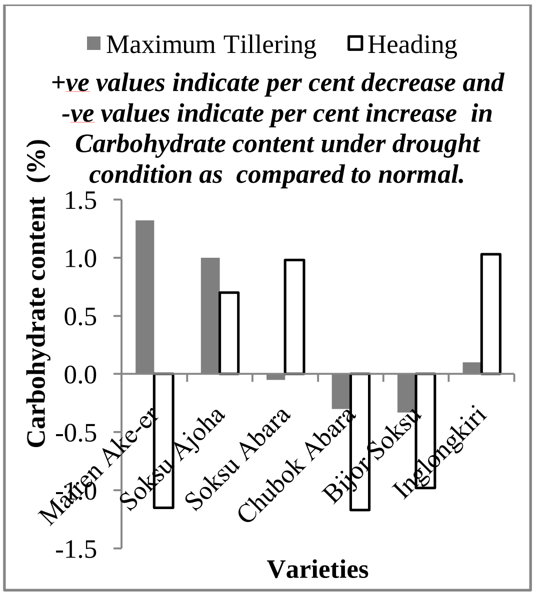


FIG. 9. CHANGES OF CARBOHYDRATE CONTENT OF LEAF TISSUES UNDER DROUGHT AS COMPARED TO IRRIGATION

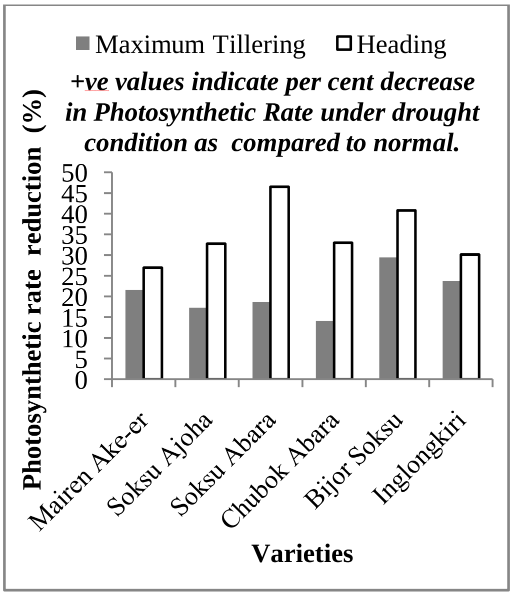
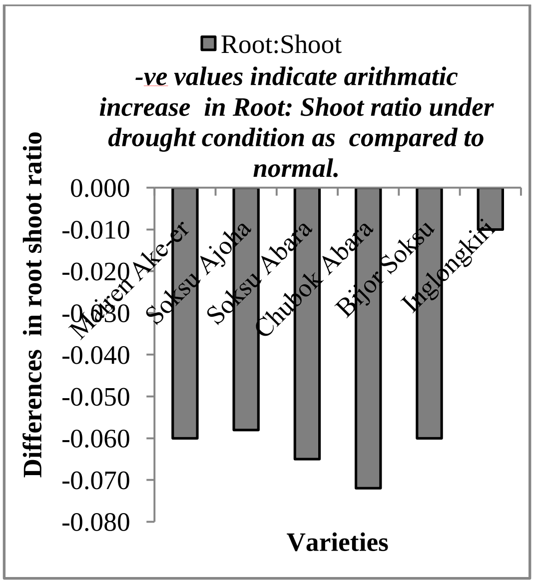


FIG. 10. CHANGES OF PHOTOSYNTHETIC RATE UNDER DROUGHT AS COMPARED TO IRRIGATION



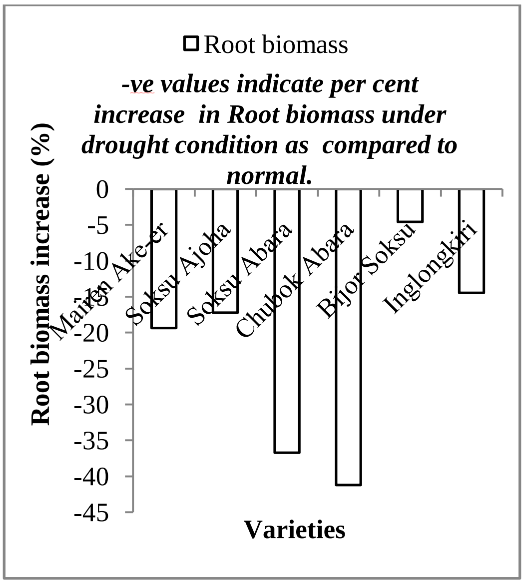


FIG. 11(A). CHANGES OF ROOT: SHOOT UNDER DROUGHT AS COMPARED TO IRRIGATION

FIG. 11(B). CHANGES OF ROOT BIOMASS UNDER DROUGHT AS COMPARED TO IRRIGATION

3.2 Yield and yield attributing characters

There were significant variations among the varieties and between the treatments with respect of grains per panicle, which is illustrated in (Fig. 12). The highest per cent reduction of number of grains per panicle was observed in Soksu abara (8.37%) under drought as compared to irrigated one, and the lowest reduction was in Bijor soksu (1.10%). The lowest per cent reduction indicates increase in number of seeds per panicle under drought. However, grains per panicle are genetically controlled yielding component. This finding supports the result of Chaunhan *et al.* (1989). They reported that grains per panicle was a varietal character, and varied according to cultivars. Thousand grain weights (Test weight) differed significantly among the varieties, but the water regimes had no significant effects on it. The highest per cent reduction (Fig. 12) of test weight was found in Chubok Abara (1.4%), and the lowest was in Bijor soksu (0.61%). This is in support of the findings of Schonfeld *et al.* (1988) who were also in the opinion that kernel weight of wheat cultivars decreased under stress.

It is apparent from the (Fig. 13) that there was significant difference in economical yield among the varieties under drought as compared to irrigation. The highest per cent reduction in economical yield under drought was observed in Soksu ajoha (21.06%), whereas the lowest per cent reduction in grain yield was maintained in Inglongkiri (2.27%). This indicates that Inglongkiri behaves as one of the drought tolerant varieties. This finding is in support with Pandey *et al*., (2014). They reported that rice crop under water stress markedly reduces the grain-filling percentage and grain weight, resulting in a significant decrease of grain yield. Biological (straw) yield of rice showed significant difference among the varieties under stress condition. There is much reduction of straw yield in rice under moisture stress condition in some varieties which have higher grain yield (Fig. 13). The highest reduction per cent in straw yield was in Bijor soksu (29.78%) > Soksu abara (24.64%) > Chubok abara (23.7%) and Inglongkiri (21.19%). These varieties have higher grain yield and lower straw yield. The lowest per cent reduction was observed in Soksu ajoha (2.21%), which indicates the highest straw yield in the variety under drought as compared to irrigated condition. These results are in accordance with the findings of Radford (1986), Kalamian *et al.* (2006), Jasso *et al.* (2002), who also showed decreasing biological yield because of drought stress. It is evident from the (Fig. 13) that there were significant varietal variations in HI in rice crop in the study. Among the varieties, Soksu ajoha (14.67%) had the highest per cent reduction of HI under drought as compared to normal. The physiological drought condition did not affect HI in Soksu Abara, Chubak Abara, Bijor Soksu and Inglongkiri at all; rather there were increases (8-20%) in HI in these varieties under drought condition. Water stress at flowering and grain filling resulted in lower HI than water stress at tillering stage. Sharma *et al.*, (2003) observed higher HI in well irrigated genotypes compared to that of the genotypes which were grown under water stress condition. They reported that water stress at flowering and grain filling caused lower HI than water stress at tillering stage.

It is seen from the (Fig. 14) that the moisture stress exerted significant effect on nitrogen uptake by grain, straw and total N uptake among the varieties under different water regimes. The nitrogen uptake into grain, straw and total uptake decreased significantly with water stress. The highest per cent reduction of grain N uptake was seen in Soksu ajoha (31.05%), and the lowest was in Inglongkiri (1.93%). The highest per cent reduction in N uptake into straw was in Bijor soksu (47.75%), and the lowest was seen in Mairen ake-er (13.92%). In case of total N uptake, the highest per cent reduction was recorded in Bijor soksu (32.6%), and the lowest was obtained in Mairen ake-er (9.3%) under drought as compared to irrigated. The increase in uptake of nitrogen at higher moisture regimes due to cumulative effect of increase in grain and straw yield as well as increased nitrogen content in grain and straw. Increase in uptake of nitrogen at higher moisture regimes have also been reported by Murthy and Reddy (2013) and Sandhu and Mahal (2014).

3.3 Nitrogen Use Efficiency

The (Fig. 15) clearly indicates that there was significant variation among the varieties in respect of nitrogen use efficiency (NUE). However, it was observed that Soksu Ajoha (31.06%) had the highest NUE per cent reduction, while Inglongkiri (1.9%) exhibited the lowest per cent reduction of NUE under drought as compared to irrigated one. Haefele *et al.* (2008) observed that water stress lowered the NUE in rice plants. This parameter remained high in tolerant cultivars that presented greater production. In the current study, as equal amount of fertilizer was demanded by all the varieties at different stages based on the RTNM method of N application. There was an exception with the variety Inglongkiri, which showed the lowest per cent reduction of NUE, and produced more yield. This might be due to varietal character or the variety has an adaptive mechanism under the stress condition as evidenced from its higher yield. Campbell and Davison (1979) suggested that, inefficient use of N is associated with excessive vegetative growth. Part of the decrease in NUE can be attributed to decrease in light Intensity or increase in evapotranspiration that could result from excessive vegetation (Pearman *et al*., 1977).

3.4 RTNM Technique

In use of the Real Time Nitrogen Management (RTNM), a certain amount of N- fertilizer is applied only when leaf N content is below a critical level (Peng *et al.*, 1996). Therefore, N status in leaf (Tao *et al.*, 1990) determines the timing, number of Nitrogen applications and doses of N in crop conditions. Feeding with N nutrition at different successive growth stages of rice crop following the N management technique for higher NUE of the genotype under physiological drought condition is in the heart of the present investigation. So, the RTNM approaches were followed for application of N-fertilizer in splits to increase NUE and corresponding yield of the varieties under different water regimes (physiological drought and full irrigation). Although each of the varieties equally received an amount 130 kg N during their period of growth, a few of them could maintain higher N uptake in grains, boost NUE, and exhibit higher yield in response to the whole dose of applied N. Therefore, such varieties(s) viz., Inglongkiri might have some special molecular features (i.e. QTL) for higher NUE and yield potential under physiological drought condition. This possibility has not been explored in the current study, and needs serious attention in future frontier research goal.

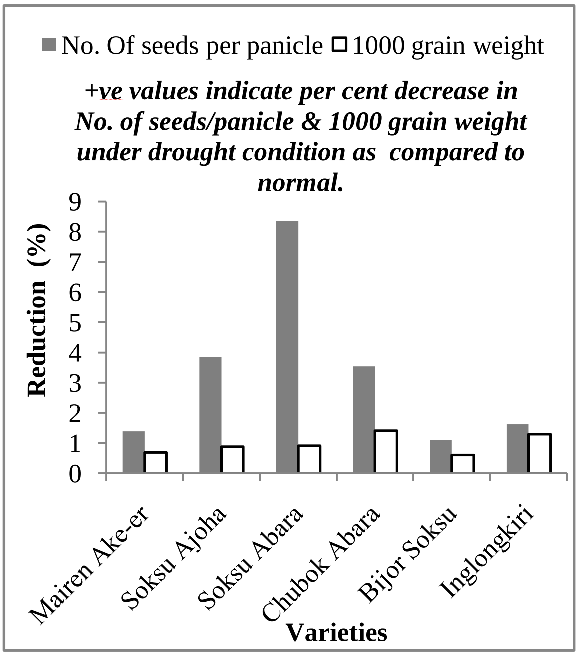


FIG. 12. CHANGES OF NO. OF SEEDS/PANICLE & 1000 GRAIN WEIGHT UNDER DROUGHT AS COMPARED TO IRRIGATION

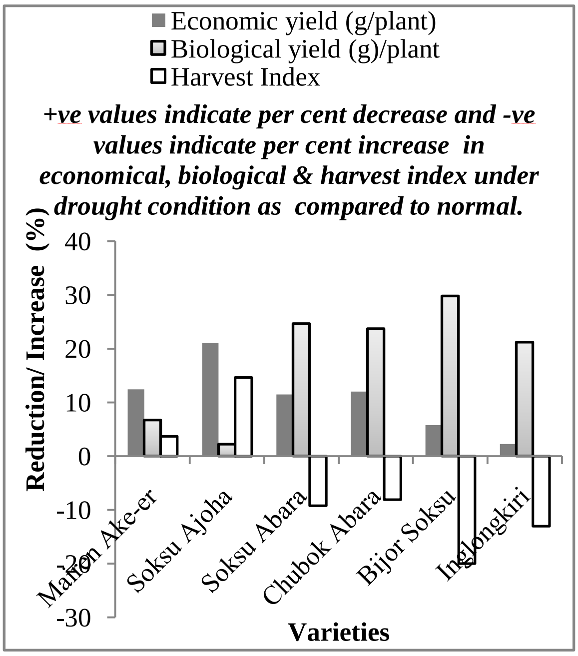


FIG. 13. CHANGES OF ECONOMICAL, BIOLOGICAL YIELD AND HARVEST INDEX UNDER DROUGHT AS COMPARED TO IRRIGATION

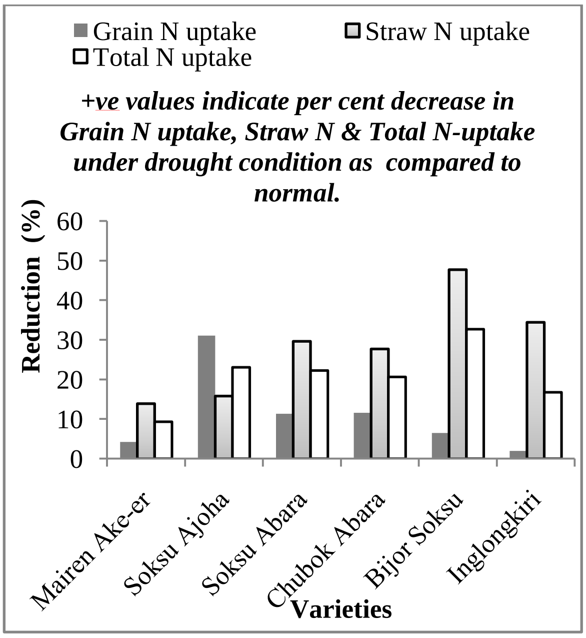


FIG. 14. CHANGES OF GRAIN, STRAW AND TOTAL N-UPTAKE UNDER DROUGHT AS COMPARED TO IRRIGATION

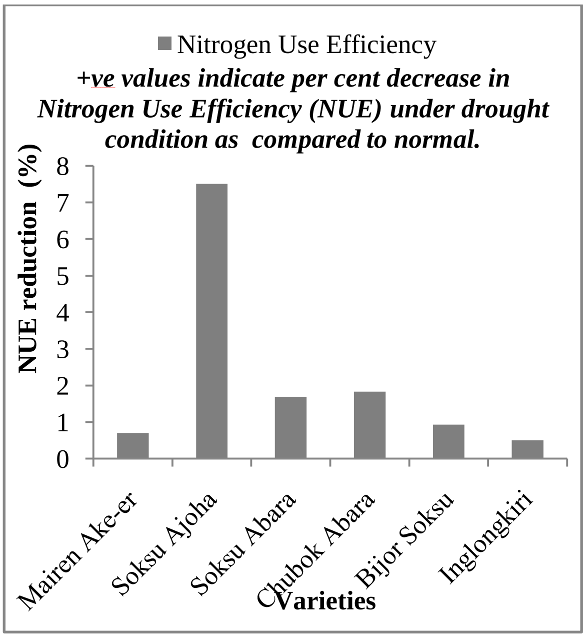


FIG. 15. CHANGES OF NITROGEN USE EFFICIENCY (NUE) UNDER DROUGHT AS COMPARED TO IRRIGATION

IV. CONCLUSION

In present study, the reduction in plant height was observed highest in Inglongkiri (18.03%) under drought as compared to irrigated. The highest per cent reduction in economical yield under drought was observed in Soksu ajoha (21.06%), whereas the lowest per cent reduction in grain yield was maintained in Inglongkiri (2.27%). This indicates that Inglongkiri behaves as one of the drought tolerant varieties. Inglongkiri (1.93%) processes the lowest per cent reduction of grain N uptake. The lowest per cent reduction of NUE under drought as compared to irrigated was exhibited in Inglongkiri (1.9%). Thus in this series of experiment, it could be concluded that Inglongkiri, a developed variety of Assam (RARS, Diphu), was found physiologically efficient among the varieties tested. This variety possesses the adaptive traits, especially higher N use efficiency, higher yield and attributes under physiological drought condition. Therefore, Inglongkiri may be taken as a donor in breeding programme for direct seeded upland limited moisture condition, and can be grown suitably under agro climatic conditions of elsewhere in Assam during *Ahu* season. Furthermore, to achieve an optimum yield, the cumulative dose of nitrogen as envisaged in the RTNM approaches, may be applied in splits up to 130 kg/ha based on the SPAD values of upland *Ahu* rice crop under physiological drought condition.

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