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# Management of nitrogen for enhancing physiological efficiency in upland rice (*Oryza sativa* L.) under water stress condition

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**Abstract**

Upland rice productivity is adversely affected by abiotic factors, particularly water stress condition. Rice genotypes may vary in nitrogen uptake and its use efficiency (NUE) for grain yield under drought stress. Real Time Nitrogen Management (RTNM) is one of the important techniques used for augmenting NUE in rice. In the RTNM approach, certain amount of fertilizer is applied only when leaf nitrogen content is below a critical level judged by SPAD values using a chlorophyll meter. In the study, nitrogen was applied in splits up to 130 kg $ha^{-1}$ in total based on the SPAD values of rice leaves under simulated water stress condition (No water+ 5000ppm of 6000PEG spray at tillering and heading stages against normal irrigation. Five indigenous upland rice genotypes *viz. Mairen ke-er, Soksu joha, Soksu bara, Chubok bara, Bijor soksu* and *one developed variety i.e. Inglongkiri* were collected from RARS, Diphu (Assam) to evaluate for their yield potential using RTNM approach under water stress condition. In the study, *Inglongkiri,* was found to be physiologically efficient as compared to the other varieties. The variety is characterized by higher total N uptake in leaf tissues (71.8%), NUE (25.8%), Harvest index (43.5%), and the lowest reduction in grain yield (1.6%) under water stress condition.

**Keywords:** Upland rice, water stress, RTNM, NUE, RLWC, HI, economic yield

## Introduction

Rice is the principal food crop for India as well as for North Eastern region of India accounting for more than 80% of the food grain production, and is extensively cultivated (72% of the total cultivated area) in upland, lowland and deep water conditions. The productivity of upland rice is very poor (about 0.90 $tha^{-1}$) as compared to the national average (1.9 $tha^{-1}$). Water stress causes serious yield loss of upland rice due to reduction in various physiological parameters, more particularly nitrogen use efficiency (NUE). Therefore, the site-specific nutrient management (Wang *et al.*, 2001) [17] such as Real-Time N management (RTNM) had been used for increasing physiological efficiency and yield potential of some upland rice genotypes under simulated water stress condition.

## Materials and Methods

A pot experiment was carried out with six upland rice varieties in polyhouse (kept only during water stress 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 development. A constant water supply (2-3cm) was ensured from transplanting till seven days before harvesting. A mixture of sandy loamy soil with FYM @4:1 was filled in all the pot. The pot mixture also contained the NPK fertilizers @40:20:20 per hectare as basal. Six rice varieties *viz.*, Mairen Ake-er, Soksu Ajoha, Soksu Abara, Chubok Abara, Bijor (Soksu) and Inglongkiri were considered as test materials to evaluate their nitrogen use efficiency (NUE) and productivity under two different water regimes (No water+ 5000ppm of 6000PEG spray at tillering and heading stages and irrigation) facilitated by Real Time Nitrogen Management (RTNM) approach (Peng *et al.*, 1996) [14]. Temperature (30.4$^0$ C), relative humidity (91.8%), total Bright sunshine (607.5h), and total rainfall (1314.6 mm) were recorded during the crop period. The soil of the experimental pots was sandy loam with acid in reaction (pH= 5.6), available N, P and K was 257.2 $kgha^{-1}$, 24.6$kgh^{-1}a$ and 106.3 $kgha^{-1}$ respectively.

The various physiological and yield attributing parameters were recorded at tillering (45 days after sowing) and heading stages (90 days after sowing). For RTNM, a certain rate of N-fertilizer was applied when leaf N content was below a critical level (Peng *et al.*, 1996) [14]. Relative leaf water content (RLWC) was determined by the method of Barrs (1968) [2].

Chlorophyll content in leaves was recorded by colorimetric method suggested by Arnon (1949) [1]. Proline content was estimated in leaves using formula described by Bates *et al.* (1973) [3]. Nitrogen uptake was calculated by the following formula as described by Hauck and Bremner, (1976) [6]. NUE of the rice crop was calculated as suggested by Goodroad, and Jellum (1988) [4]. Harvest index (HI) was measured dividing the economic yield by biological yield, and expressed in per cent as suggested by Nichiporovich (1967) [11]. Data for each character was analyzed by Fisher's method of analysis of variance (Panse and Sukhatme, 1978) [13]. Least significance difference (LSD) between a pair of treatment means at P<0.05 was used for determination of the significance difference between two treatment effects.

## Results and Discussion

The effects of water stress on RLWC, total chlorophyll content and proline contents are presented in Table 1.

**Table 1:** Variations of Relative Leaf Water Content (RLWC), Total chlorophyll and Proline content at tillering and heading stages of rice crop under different water regimes

| **Treatments→** | **Irri-gated** | **Water stress** | **Irri-gated** | **Water stress** | **Irri-gated** | **Water stress** | **Irri gated** | **Water stress** | **Irri gated** | **Water stress** | **Irri gated** | **Water stress** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters → Varieties ↓** | **RLWC (%) at Tillering stages (45 DAS)** | | **RLWC (%) at Heading stages (90 DAS)** | | **Total Chlorophyll (mg/g FW) at Tillering stages (45DAS)** | | **Total Chlorophyll (mgg$^{-1}$ FW) at Heading stages (90DAS)** | | **Proline (µgmol$^{-1}$/g f.w.) at Tillering stages (45 DAS)** | | **Proline (µgmol$^{-1}$/g f.w.) at Heading stages (90 DAS)** | |
| Mairen Ake-er | 89.3 | 79.8 | 80.5 | 75.6 | 2.9 | 2.1 | 2.8 | 2.1 | 212.8 | 309.9 | 298.0 | 348.7 |
| Soksu Ajoha | 85.8 | 78.6 | 83.1 | 74.6 | 2.1 | 1.7 | 3.8 | 3.5 | 208.2 | 306.8 | 297.5 | 346.0 |
| Soksu Abara | 84.7 | 78.9 | 75.9 | 75.1 | 2.7 | 1.9 | 3.6 | 2.2 | 213.4 | 293.6 | 297.9 | 341.8 |
| Chubok Abara | 87.5 | 82.6 | 76.2 | 72.1 | 2.3 | 0.9 | 2.5 | 2.0 | 212.8 | 299.0 | 298.0 | 338.0 |
| Bijor Soksu | 88.0 | 81.3 | 75.6 | 69.6 | 1.8 | 0.8 | 2.1 | 1.3 | 212.1 | 281.8 | 296.0 | 333.2 |
| Inglongkiri | 93.0 | 88.6 | 77.3 | 73.8 | 2.4 | 1.1 | 2.7 | 2.6 | 212.1 | 299.5 | 295.4 | 346.8 |
| Mean | 88.0 | 81.6 | 78.1 | 73.5 | 2.4 | 1.4 | 2.9 | 2.3 | 211.9 | 298.4 | 297.1 | 342.4 |
| | SED (±) | CD (0.05) | SED (±) | CD (0.05) | SED (±) | CD (0.05) | SED (±) | CD (0.05) | SED (±) | CD (0.05) | SED (±) | CD (0.05) |
| Treatment (T) | 1.6 | 20.5 | 2.1 | 26.8 | 0.1 | 0.6 | 0.1 | 0.7 | 3.3 | 42.2 | 4.6 | 58.1 |
| Variety (V) | 2.8 | 7.2 | 3.6 | n.s. | 0.1 | 0.2 | 0.1 | 0.3 | 5.8 | n.s. | 7.9 | n.s. |
| T × V Interactions | 4.0 | n.s. | 5.2 | n.s. | 0.1 | 0.3 | 0.1 | 0.4 | 8.1 | n.s. | 11.2 | n.s. |

In the study, all the varieties had significantly lesser RLWC at water stress conditions as compared to irrigated one at both the maximum tillering and heading stages of crop growth. At maximum tillering stage, the highest reduction in RLWC was in Mairen ake-er (10.7%), and the lowest was in Inglongkiri (4.7%). On the other hand, at heading stage, Soksu ajoha had the highest RLWC reduction (10.4%) among the varieties (Fig.1). The lowest (1.1%) was in Soksu abara followed by Inglongkiri (4.5%). Schonfeld *et.al*. (1988) [15] suggested that cultivars with high RLWC are likely to be drought resistant.

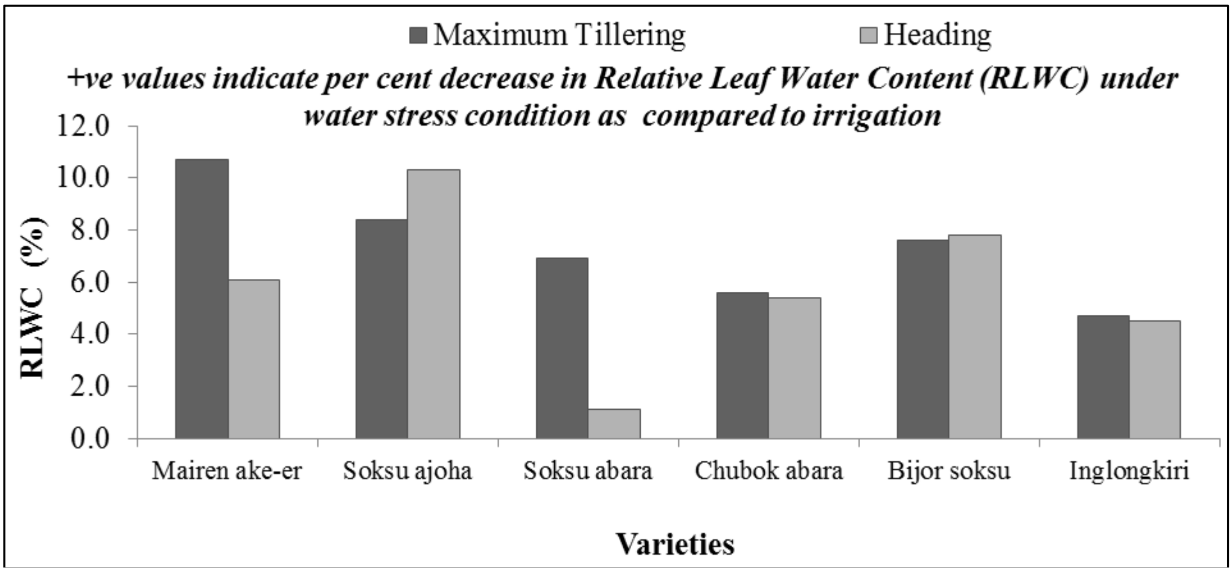


**Fig 1:** Changes of RLWC under water stress as compared to irrigation

The total chlorophyll content was significantly higher in irrigated conditions as compared to drought condition at both maximum tillering and heading stages. The variety Chubok bara had the highest percent reduction (63.5%) as compared to all the other varieties, and the least was in Soksu ajoha (18.3%) under water stress (Fig.2). At heading stage, the variety Bijor soksu (40.4%) had the highest per cent reduction, and the least reduction of total chlorophyll content was found in Inglongkiri (6.1%). Mohan *et al.* (2000) [9] 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.

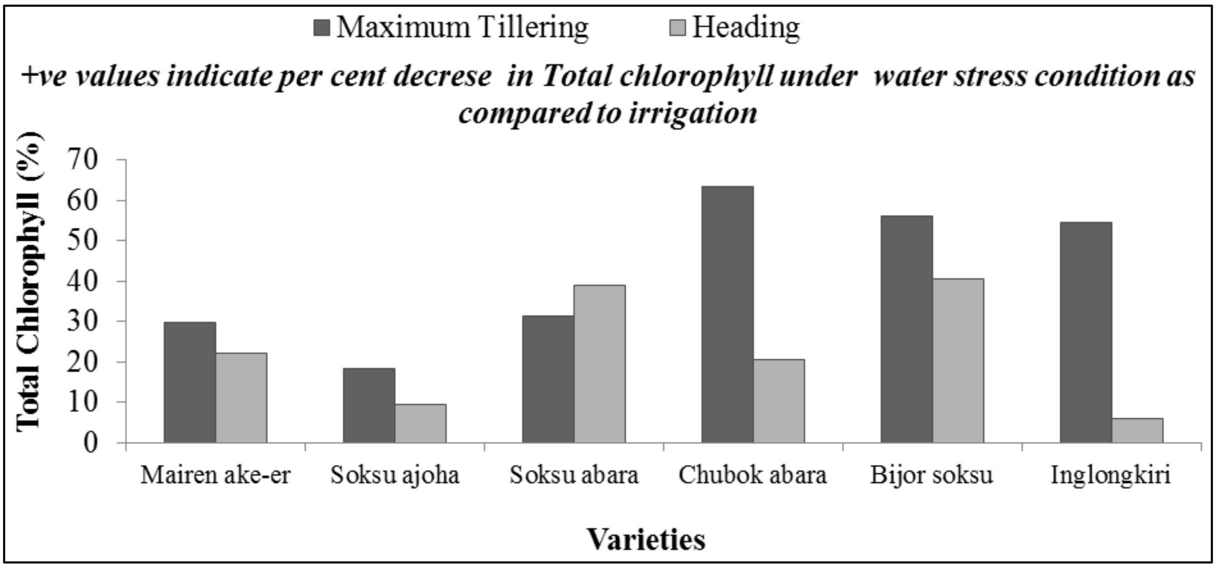


**Fig 2:** Changes of Total Chlorophyll under water stress as compared to irrigation

It was interesting to note that water stress increased proline accumulation significantly in leaf tissues as compared to irrigated condition. The proline content was significantly higher both at maximum tillering (upto 47.3% in Soksu Ajoha) and heading stages (17.4% in Inglongkiri) of the varieties under water stress condition. The highest per cent reduction of total N uptake was recorded in Bijor soksu (32.6%), and the lowest was obtained in Inglongkiri (9.3%) under water stress as compared to irrigated one (Fig.3). Proline accumulation under water stress also supplies energy for survivor and growth, and thereby helps the plants to tolerate stress condition (Kumar *et al*., 2011) [8]. Increase in uptake of nitrogen at higher moisture regimes have also been reported by Murthy and Reddy (2013) [10].

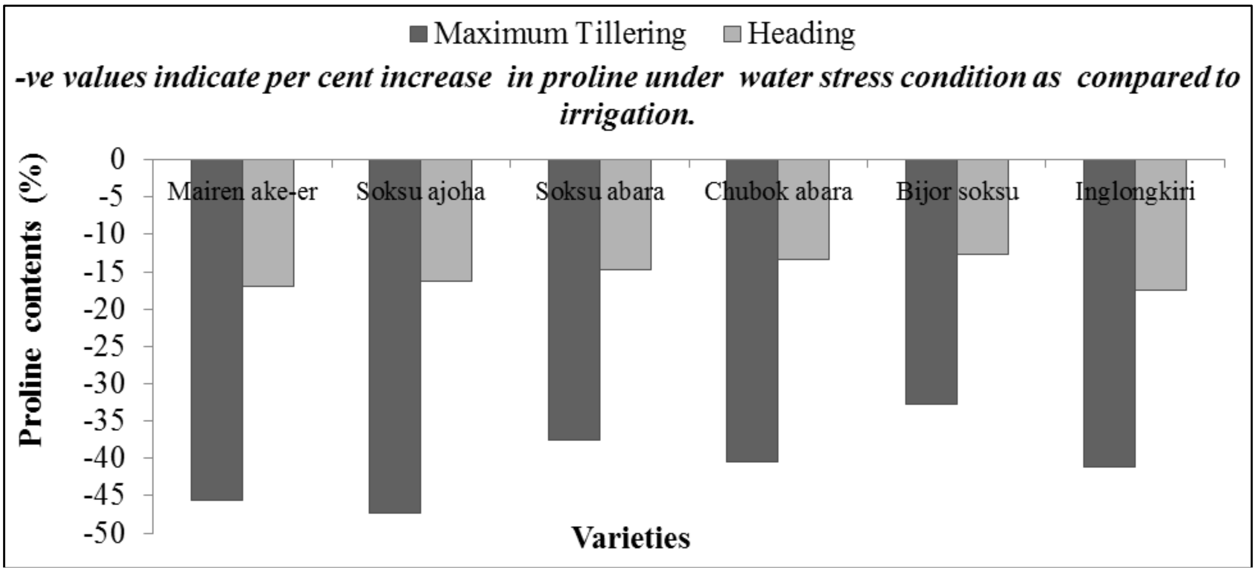


**Fig 3:** Changes of proline contents under water stress as compared to irrigation

The Variations of Total Nitrogen uptake, Nitrogen Use Efficiency (NUE), Grain yield, Straw yield and Harvest Index (HI) of rice crop under water stress against normal irrigation have been portrayed on Table 2. There were significant variations among the varieties in respect of nitrogen use efficiency (NUE). The highest reduction in NUE was found in the variety Soksu Ajoha (31.1%), while Inglongkiri (1.9%) exhibited the lowest reduction in NUE under water stress condition as compared to irrigated one (Fig.4.). Haefele *et al.* (2008) [5] opined that water stress lowered the NUE in rice plants. In tolerant cultivars, NUE remained higher corresponding to greater production of economic yield. In the current study, an equal amount of fertilizer was demanded by all the varieties at different stages applied based on the RTNM method, but Inglongkiri showed exceptionally the lowest reduction of NUE, and produced more yield as compared to the other varieties.

The reductions of grain yield, biological yield and Harvest Index (HI) of rice crop under different water regimes as compared to control have been depicted in Fig.5. There were significant differences in economical yield among the varieties under physiological drought as compared to irrigation. Pandey *et.al.* (2014) [12] reported that rice crop under water stress markedly reduces the grain-filling percentage and grain weight, resulting in a significant decrease of grain yield. The highest reduction was observed in Soksu ajoha (21.1%), whereas the lowest reduction in grain yield was maintained by Inglongkiri (2.3%). This indicates that Inglongkiri showes tolerance to water stress situation. Straw yield of rice crop showed significant differences among the varieties under water stress condition. The highest reduction in straw yield was found in Bijor soksu (29.8%). The lowest reduction was observed in Soksu ajoha (2.2%), which indicates the production of higher biological yield in the variety under water stress as compared to irrigated condition. These results are in accordance with the findings of Kalamian *et al.* (2006) [7], who also showed decreases in biological yield due to water stress.

Among the varieties, Soksu ajoha (14.7%) had the highest reduction of HI under water stress as compared to normally irrigated condition. 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 water stress condition. Sharma *et.al.* (2003) [13] observed higher HI in well irrigated genotypes compared to that of the genotypes which were grown under water stress condition.

**Table 2:** Variation of Total Nitrogen uptake, Nitrogen Use Efficiency (NUE), Grain yield, Biological yield and Harvest Index (HI) of rice crop under different water regimes

| **Treatments→** | **Irrigated** | **Water stress** | **Irrigated** | **Water stress** | **Irrigated** | **Water stress** | **Irrigated** | **Water stress** | **Irrigated** | **Water stress** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters → Varieteis ↓** | **Total N uptake ($kgha^{-1}$ )** | | **NUE (%)** | | **Economic yield (g $plant^{-1}$)** | | **Biological yield ($gplant^{-1}$)** | | **Harvest Index (%)** | |
| Mairen Ake-er | 106.7 | 88.9 | 16.8 | 16.1 | 13.1 | 11.5 | 20.6 | 16.3 | 41.1 | 39.6 |
| Soksu Ajoha | 112.1 | 86.2 | 24.2 | 16.7 | 13.3 | 10.5 | 21.3 | 20.8 | 39.1 | 33.4 |
| Soksu Abara | 81.6 | 63.5 | 15.0 | 13.3 | 10.3 | 9.1 | 21.3 | 16.1 | 33.1 | 36.2 |
| Chubok Abara | 79.4 | 63.0 | 15.8 | 14.0 | 11.4 | 10.0 | 20.1 | 15.4 | 36.5 | 39.4 |
| Bijor Soksu | 85.6 | 57.6 | 14.2 | 13.3 | 9.5 | 8.9 | 23.0 | 16.2 | 29.5 | 35.4 |
| Inglongkiri | 78.9 | 71.8 | 26.3 | 25.8 | 12.8 | 12.5 | 18.8 | 17.5 | 38.5 | 43.5 |
| Mean | 90.7 | 71.8 | 18.7 | 16.5 | 11.7 | 10.4 | 20.9 | 17.0 | 36.3 | 37.9 |
| | SED (±) | CD (0.05) | Sed ± | CD 5% | SED (±) | CD (0.05) | SED (±) | CD (0.05) | SED (±) | CD (0.05) |
| Treatment (T) | 3.5 | 44.8 | 0.8 | 10.5 | 0.3 | 4.4 | 0.9 | 11.4 | 1.4 | n.s. |
| Variety (V) | 6.1 | 15.7 | 1.4 | 3.7 | 0.6 | 1.5 | 1.6 | n.s. | 2.4 | 6.1 |
| T × V interaction | 8.6 | n.s. | 2.0 | n.s. | 0.8 | n.s. | 2.2 | n.s. | 3.4 | n.s. |

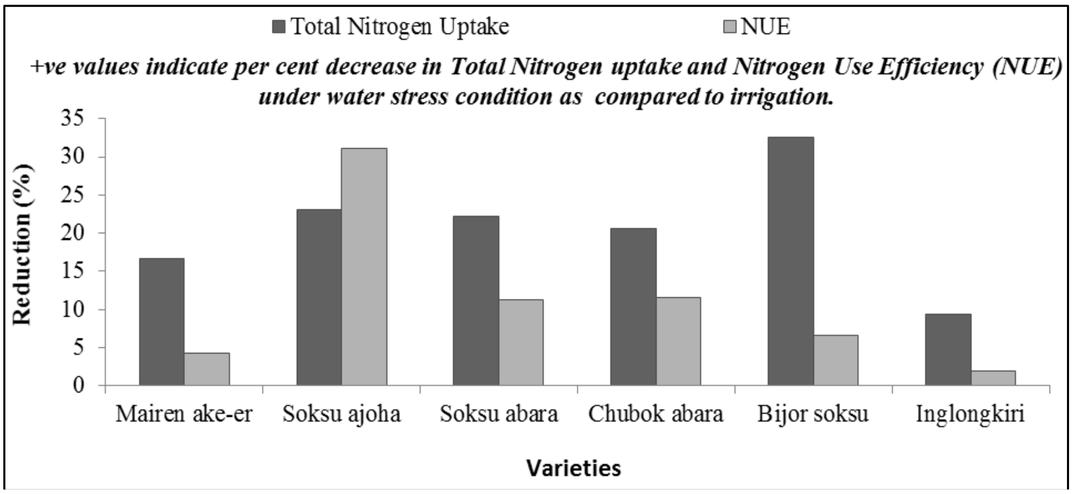


**Fig 4:** Changes of Total Nitrogen uptake and Nitrogen Use Efficiency (NUE) under water stress as compared to irrigation

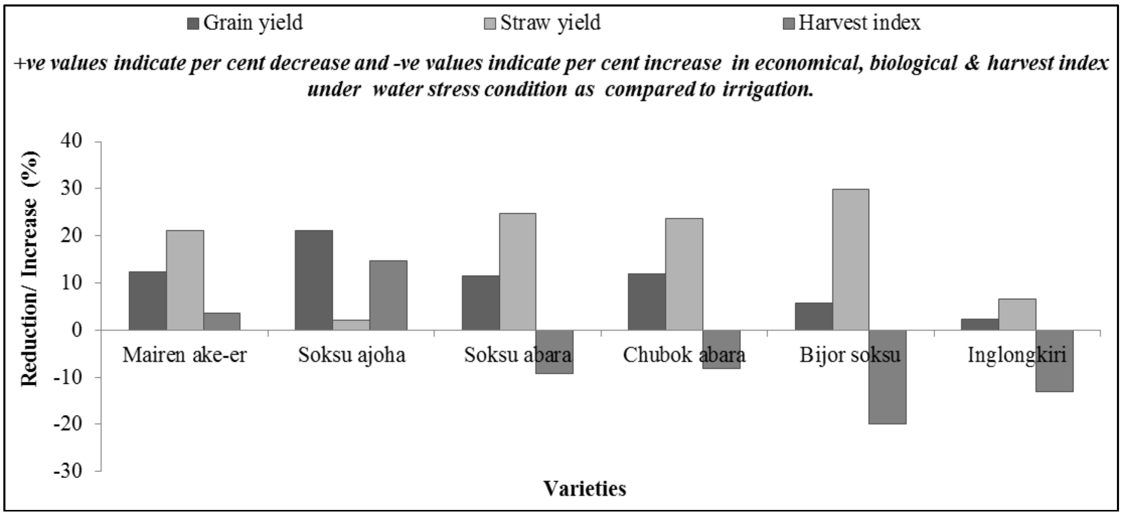


**Fig 5:** Changes of Economical, Biological yield and Harvest Index under water stress as compared to irrigation

The Real Time Nitrogen Management (RTNM) approach was followed for application of N in splits based on the SPAD values of the varieties and growing conditions (water stress: non- irrigated and irrigation). In spite of receiving equal amount of nitrogen (130Kgha$^{-1}$) by all the varieties corresponding to SPAD values during their period of growth, Inglongkiri could maintain higher N uptake in grains, boost NUE, and exhibit higher yield in response to the whole dose of applied Nitrogen.

## Conclusion

In the foregoing study, Inglongkiri was found to be the physiologically most efficient among the varieties tested. This variety possesses the adaptive traits, especially higher N use efficiency, higher yield and yield attributes under water stress (physiological drought) condition. Therefore, Inglongkiri can be a potential donor in breeding programme for direct seeded upland with limited moisture condition, and can be grown suitably under agro-climatic conditions of Assam during Rabi season. Furthermore, to achieve an optimum yield, the cumulative dose of nitrogen as envisaged in the RTNM approach, may be applied in splits up-to 130 kgha$^{-1}$ based on the SPAD values of upland rice crop under water stress condition.

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