Original Research Article

Non Structural Carbohydrate Accumulation in Plant Parts of Rice Genotypes Grown under Drought and Open Field: A comparative Study

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Introduction

In agriculture, many abiotic stresses are the major constraint that affected the yield of crops. Amongst all, drought is the most serious stress for rice which deteriorates the rice yield production. Global climate change affects a variety of factors associated with drought and extreme drought land area is likely to increase from 1-30% by 2100 (Lijuan Miao et al., 2015). In Asia, around 130 million ha of paddy are annually affected by drought, thus limiting rice production worldwide (Rajiv et al., 2010; Rahimi et al., 2013). About 42% of India’s land area is facing drought, with 6% exceptionally dry-four times the spatial extent of drought last year, according to data for the week ending

A B S T R A C T

The present study was carried out in sixteen genotypes having different aptitude for tolerance to stress. Drought stress was imposed at early reproductive phase of growth. Despites of reduction in plant height and number of tillers, genotypes have shown least reduction in the grain yield under drought stress. Interestingly, genotypes like Sabour Sampann, Sabour Ardhjal and BRR-0028 showed higher adaptive responses with least reduction in plant height of less than 10% under drought than open field. Also, the number of tillers in BR-0028 and BRR-0063 were remained same in both the situation suggesting specificity of genotypic responses. Moreover, genotype BRR-0028, Sabour Sampann and Sabour Ardhjal showed higher yield retention with least reduction in the yield of only 25%, 30% and 31% respectively under drought stress. It implied the persuasion of accumulated CHO at unambiguous phase of growth period. CHO accumulated higher in leaf sheath (176.5 mg⁻¹ g fresh wt) at 45 days of growth which gradually decreased (93.29 mg⁻¹ g fresh wt) with increasing days in genotype Sabour Ardhjal at 75 days of growth. The same genotype revealed alter CHO accumulation in plant parts with highest in Culm (83.38 mg⁻¹ g fresh wt), three fold higher than the leaf blade and leaf sheath during drought stress. The result also supported by the higher LAI/LAD during the early reproductive phase between 45 to 60 days of growth and suggested to explicit longer period for assimilates accumulation and sink development for better grain yield in rice under reproductive drought.

Keywords
Rice, drought stress, Non structural carbohydrates, Grain yield, Growth parameters
March 26, 2019, from the Drought Early Warning System (DEWS), a real-time drought monitoring platform. The state like Bihar with 60% to 70% of cultivation is dependent on rainfall, any deviation, especially any deficit, is bound to impact production, particularly rice cultivation in the Kharif.

Drought has been identified as the single most critical threat to the world food security (Farooq et al., 2009), and one of major factors inhibiting physiological activities such as photosynthesis, decreasing growth and crop loss, reducing average yields for most major crop plants by more than 50 to 60% (Bray et al., 2000; Wang et al., 2003). Report also added, this significant lost in the yield is due to significant restriction in plant growth and development. Yield loss, induction of oxidative stress with loss of membrane integrity, semi-permeability, electrolyte leakage, loss in pigment content, decreased photosynthesis activity, alteration in osmotic adjustment water relation are commonly described responses of drought stress.

Plants intervention to drought stress is vast and immensely depends upon intensity and duration of stress as well as plants developmental stages. Plants undergo various morphological, physiological and biochemical changes upon drought stress, such changes become imperative to crop adaptation at specific developmental stage. Many reports revealed crop tolerant towards drought stress through various plant growth components. Despites of all adaptive response crops sometime failed to give better yield performance. However, in agriculture the key constituting element under stress is not only plant adaptation but its grain yield. Report also showed the relevance of effectual tolerant traits for grain yield rather than tolerant attributes alone (Nahakpam, 2017).

Moreover, besides being crops varietal disparity, every plant organ is ideally participated to fulfil metabolic and physiological processes in specific environmental conditions. Generally, for various physiological attributes, studies were carried out focusing on flag/or first leave. However, recent reports give a cross-talk on role of individual leave and its response towards temperature, light and other abiotic stress. Physiological responses such as photosynthetic rate of flag leaf were seemingly involved to stress tolerant attribute rather than contributing in grain yield for early reproductive drought stress in rice. This uncertainty of photosynthetic activities results in less photosynthate translocation to sinks. And so, under stress, plant growth (Xu and Huang, 2000; Nahakpam, 2017a and 2017b) and grain filling (Yang and Zhang, 2006) become more dependent on remobilized reserves that might have translocated from lower leaves.

In cereal crops, the contribution of stored non structural carbohydrates (NSC) to the grain yield can be more than 50% under stress conditions, but it is 5-33% in non-stress conditions (Hirano et al., 1998; Wardlaw and Willenbrink, 2000; Zhang et al., 2009). These results were observed in vegetable crops like potato and cereal crops like wheat, suggesting that culm and leaf reserves might act as a short-term buffer to maintain the supply of photosynthate to developing organs when the supply of photosynthate from source leaves cannot satisfy the requirement of sinks (Wardlaw and Willenbrink, 2000).

Therefore, an increasing evidence for considerable interlinking about contrasting responses with various crops yield is much at cross-talk. In previous findings on rice genotypes having partial tolerant attributes showed non-significant positive correlation of photosynthesis with grain yield. Further on
investigation has revealed a half way result that under reproductive drought, grain yield are more seemingly dependent on the lower leaves and culm reserve rather than the flag leaves. This result has also been supported by more chlorophyll stability in the third leaves with less reduction of the content. Zhang et al., (2009) workers have also mentioned undoubtedly the involvement of stem reserves and its translocation towards the grain under stress situation.

Earlier in rice crop, from the initiation of panicle primordia to around heading, involvement of five leaves that are functioning has also been discussed by Yoshida (1981). Diverse reports on carbohydrates reserve were analysed in wheat (Virgona and Barlow, 1991), potato (Zhang, et al., 2009), horticultural fruits (Hassan et al., 2017). In rice, it is also stated total reliance of grain filling and rice yield on the efficient transport of carbohydrates from the leaves reserve to seeds (Wang et al., 2015). Therefore, understanding the accumulation and distribution of carbohydrates to facilitate better grain yield in rice under water stress condition is a prerequisite.

**Materials and Methods**

**Experimental site and plant materials**

Experiments were carried out in sixteen genotypes of 120 days maturity group having different potentials of stress tolerance. The experiments were laid in the Rice research farm of Bihar Agricultural University, Sabour. Seeds were sown directly in randomized block design under two conditions, one in rain out shelter (to induced drought stress) and second in an open field condition. Drought was imposed by withholding irrigation from 45 days of growth to induced reproductive stress and soil moisture content was measured using soil gravimetric method. Data were recorded at three distinctive growth phases: vegetative phase (45 days of growth), in early booting phase (60 days of growth), in flowering phase (75 days of growth). Standard cultural practices were carried out throughout the crop seasons and hand weeding was done from time to time. All the experiments were performed in triplicate.

**Plant morphological observation and growth analysis**

Under the morphological parameters Plant height, number of tillers per plants was observed. Leaf area was calculated by using the formula \( l \times b \times k \), where \( l \) is the length of the leaf, \( b \) is the breadth of the leaf and \( k \) is the coefficient value that had been derived. Leaf area hill\(^{-1}\) was measured on the middle tiller as per the method given by Yoshida et al., 1976. LAI and LAD were also measured and calculated using the given formula:

\[
\text{LAI} = \frac{\text{Leaf area hill}^{-1}}{\text{Ground area}} \quad \text{and} \quad \text{LAD} = \frac{L_1 + L_2 \text{ hill}^{-1}}{2} \times (T_2 - T_1)
\]

Where \( L_1 \) is LAI at the first stage; \( L_2 \) – LAI at the second phase; \( T_2 - T_1 \) is the time interval in days

**Non structural carbohydrate (CHO) determination**

Plant samples were collected in the morning hour and immediately packed in the plastic bag. In the laboratory the plants were separated for Leaf blade, Leaf sheath and Culm. Thereafter, fresh samples were taken for estimation of total CHO using phenol-sulphuric acid and absorbance of the colour developed were recorded in 490 nm by method Dubois et al., 1956, using glucose as standard. All the experiments were performed in triplicate.
Statistical analysis

Data were analyzed using Analysis of Variance (ANOVA) for the variables measured to test for significant differences.

Results and Discussion

Morphological responses and growth variability under drought and open field

Diversity in genotypic responses was observed in terms of plant height and number of tillers (Table 1). Reduction in plant height under drought stress were noticed in all the genotypes studied however genotypes HS4 and HS6 showed maximum decreased with almost 40% reduction in plant height (Table 1) as compared to other genotypes. The reduction in plant height under drought has been supported by the previous research reported by many (Singh et al., 2018; Nahakpam 2017; Weng et al., 2014). Nevertheless, plant morphological responses towards drought stress are also showed by reduction in the number of tillers was distinctively observed under drought stress ranges from 4 to 8 numbers as to that of plants grown in open field which ranged from 6 to 11.

Interestingly, genotypes like Sabour Sampann, Sabour Ardhjal and BRR-0028 showed higher adaptive responses with least reduction in plant height of less than 10% under drought than open field. Also, the number of tillers in BR-0028 and BRR-0063 were remained same in both the growing situation. Non significant decreased in plant height were also noticed amongst the genotypes revealing higher adaptive potential and least affected by drought stress. To retain stability under drought stress reduction in leaf area, leaf expansion is common responses of plants that directly affect yields (Anjum et al., 2011; Hussain et al., 2008). However, maximum LAI and LAD at particular growth period are important traits that revealed the fate of plants grain yield (Devendra et al., 1983; Lopez et al., 1997). It further suggested that increased of LAD at later stage of growth period enhance biological yield but not the grain yield in rice. The present study of Leaf area at different days of growth (45 days, 60 days and 75 days) was recorded and LAI of respective intervals were calculated (Table 2). LAI reductions are more in the drought exposed plants from the open field plants. However, genotypes BRR-0028, HS2, HS6 and Sabhagi Dhan showed higher LAI ranging from 2.9 to 5.18 at 60 days of growth under drought from that of open field. Amongst the days of growth there were increased in LAI on 60 days from 45 days and again decreased when it went to 75 days but a gradual increased in LAI with increasing days of growth in the genotypes Sabour Ardhjal (3.47, 3.75, 4.97) had been recorded under drought. Similar, increased in LAI value with increasing days of growth period had also been noticed in the genotypes HS5, BRR-0054, BRR-0057, BRR-0063 under drought stress.

LAD of genotypes grown in open field showed longer duration ranged from 30 to 58 days in the second interval of 60-75 days than first interval of 45-60 days except in genotype HS4 (Table 2). LAD of genotypes grown under drought revealed maximum LAD in the first phase of interval between 45-60 days of growth and ranged from 31 to 60 days in the genotypes HS2 and Sahbhagi Dhan respectively. Our research findings also showed clearly that all the genotypes had longer days of LAD at 45 to 60 days of growth period with 54 to 60 days duration under drought (Table 2) and has positive correlation with grain yield (data not shown).
Table 1 Variation in the plant height and number of tillers at 60 days of growth affecting grain yield under drought and open field

| Genotypes         | Plant height (cm) | Number of tillers | Yield Kg/ha | % Decreased in grain yield |
|-------------------|-------------------|-------------------|-------------|----------------------------|
|                   | Open Field        | Drought           | Open Field  | Drought                    | Open Field | Drought |                        |
| Sabour Ardhajal   | 101.2             | 73.8              | 8           | 6                          | 6236       | 4271    | 31.51                    |
| BRR-0028          | 106.6             | 95.6              | 6           | 6                          | 6366       | 4723    | 25.81                    |
| Sabour Sampann    | 97.1              | 90                | 6           | 5                          | 7284       | 4252    | 41.63                    |
| Sabour Surbhit    | 99                | 91                | 10          | 7                          | 6543       | 3727    | 43.03                    |
| BRR-0054          | 100.2             | 76                | 7           | 5                          | 6761       | 4240    | 37.29                    |
| BRR-0057          | 97.7              | 87                | 6           | 5                          | 7213       | 4173    | 42.15                    |
| BRR-0063          | 100               | 77                | 8           | 8                          | 7011       | 4107    | 41.42                    |
| BRR-0078          | 101               | 86                | 10          | 6                          | 7083       | 4000    | 43.53                    |
| MTU-10            | 102               | 94.4              | 6           | 5                          | 7306       | 4283    | 41.38                    |
| HS1               | 99.3              | 83.5              | 6           | 5                          | 6989       | 4213    | 39.72                    |
| HS2               | 108               | 78.5              | 11          | 6                          | 6951       | 4230    | 39.15                    |
| HS3               | 97.4              | 82                | 9           | 7                          | 7701       | 3973    | 48.41                    |
| HS4               | 100               | 62                | 8           | 4                          | 7089       | 4780    | 32.57                    |
| HS5               | 94                | 79                | 8           | 6                          | 6842       | 4261    | 37.72                    |
| HS6               | 102               | 63                | 6           | 5                          | 7203       | 4364    | 39.41                    |
| Sahbhagi Dhan     | 91                | 76                | 7           | 5                          | 7504       | 5187    | 30.88                    |
### Table 2 Growth analysis parameters: Leaf area, Leaf area index (LAI) and Leaf area duration (LAD) of rice grown in drought and open field

| Genotypes            | Leaf area Index (LAI) |  | Leaf area duration (LAD) |  |
|----------------------|-----------------------|---------------------|----------------------|---------------------|
|                      | Open Field            | Drought             | Open Field            | Drought             |
|                      | 45 days | 60 days | 75 days | 45 days | 60 days | 75 days | 45 -60days | 60 -75 days | 45 -60days | 60 -75 days |
| Sabour Ardhajal      | 3.52bc | 5.26a  | 3.86bc | 3.47b  | 3.75bc | 4.97a  | 55.88a    | 58.43a    | 54.19ab | 55.64a      |
| BRR-0028             | 3.26c  | 3.41c  | 3.80bc | 3.63b  | 4.11b  | 3.85b  | 37.57c    | 49.09b    | 58.09a | 52.27ab     |
| Sabour Sampann       | 4.33a  | 4.21b  | 3.36d  | 2.09d  | 3.15b  | 2.52c  | 46.57b    | 51.75a    | 54.32ab | 47.50b      |
| Sabour Surbhit       | 2.95cd | 3.85bc | 3.92b  | 2.05d  | 3.00c  | 2.44d  | 34.45c    | 33.24c    | 32.91ab | 25.83d      |
| BRR-0054             | 2.41d  | 3.83bc | 4.54a  | 2.13d  | 3.46c  | 3.97a  | 31.78c    | 32.76a    | 41.91c | 55.69a      |
| BRR-0057             | 2.98c  | 3.45a  | 3.66c  | 2.41d  | 3.36c  | 3.94a  | 38.17bc   | 45.79b    | 35.82d | 32.27cd     |
| BRR-0063             | 3.02cd | 3.48c  | 3.74c  | 2.49c  | 2.92d  | 3.41b  | 38.75bc   | 44.15b    | 33.07d | 32.49cd     |
| BRR-0078             | 3.20c  | 4.25b  | 3.76c  | 2.95b  | 3.85bc | 3.60b  | 35.85c    | 37.09c    | 56.95ab | 55.82ac     |
| MTU-10               | 3.12c  | 5.63a  | 4.59a  | 2.19d  | 3.25c  | 3.73b  | 35.60c    | 39.12c    | 55.76ab | 37.34c      |
| HS1                  | 3.26c  | 3.55c  | 3.57d  | 2.44c  | 2.53d  | 2.13e  | 32.02c    | 43.41b    | 37.24cd | 34.91c      |
| HS2                  | 3.07cd | 3.26   | 4.21b  | 2.76bc | 3.46c  | 2.41d  | 34.99c    | 38.59c    | 31.65d | 21.51d      |
| HS3                  | 2.55d  | 3.59c  | 3.46c  | 2.55c  | 3.12cd | 2.22e  | 43.58b    | 30.36d    | 42.55c | 40.08b      |
| HS4                  | 2.12d  | 2.65d  | 3.25d  | 2.02d  | 3.55c  | 3.09b  | 35.77c    | 36.75c    | 47.81b | 42.30b      |
| HS5                  | 3.29c  | 4.14b  | 4.54a  | 2.78bc | 3.84bc | 3.91a  | 35.74c    | 37.63c    | 37.13  | 34.12c      |
| HS6                  | 2.04d  | 3.89bc | 3.25   | 3.78a  | 4.29b  | 3.37bc | 44.44b    | 53.58a    | 55.51ab | 49.94ab     |
| Sahbhagi Dhan        | 3.98b  | 4.70b  | 4.92a  | 3.94a  | 5.18a  | 4.76a  | 40.15bc   | 47.20b    | 60.94a | 59.58a      |

Values with different alphabets are significantly different at $P \leq 0.05$
### Table 3
Changing patterns of CHO accumulation (mg⁻¹ g fresh wt) in different plant parts of rice Leaf blade, Leaf Sheath, Leaf culm and grain grown of rice genotypes grown in an open field

| Growth period | Genotypes       | 45 days | 60 days | 75 days | Grain |
|---------------|-----------------|---------|---------|---------|-------|
|               | Leaf blade      | Sheath  | Culm    | Leaf blade | Sheath  | Culm    | Leaf blade | Sheath  | Culm    | Spice   |
|               | Sabour Ardhajal |         |         |          |        |         |          |        |         |         |
| 45 days       | 106.56d         | 176.5a  | 78.81d  | 91.02b   | 94.35d | 71.04e  | 86.58de   | 93.29c | 67.73d  | 253.1a  |
| BRR-0028      | 97.92d          | 138.75c | 95.46c  | 89.89c   | 104.36c| 73.26c  | 86.63de   | 92.17c | 56.63e  | 167.6cd |
| Sabour Sampann| 131.04a         | 162.16b | 112.11b | 82.14cd  | 104.34c| 86.58d  | 81.07e    | 111.08b| 84.41b  | 169.8cd |
| Sabour Surbhit| 114.27c         | 129.92d | 94.37c  | 97.72b   | 114.33b| 89.91d  | 147.63b   | 127.75a| 84.84b  | 125.4e  |
| BRR-0054      | 96.57d          | 118.71e | 91.02   | 95.41bc  | 115.02b| 95.46c  | 76.39f    | 109.05b| 91.08a  | 85.47f  |
| BRR-0057      | 106.56d         | 118.81e | 104.34bc| 96.57b   | 114.36b| 102.12b | 87.74de   | 91.05c | 85.52b  | 162cd   |
| BRR-0063      | 76.59f          | 118.47e | 88.8d   | 77.7d    | 113.22b| 75.48e  | 78.85f    | 93.96c | 76.61c  | 136.6de |
| BRR-0078      | 74.37ef         | 97.48   | 92.13c  | 87.69c   | 115.44b| 99.9c   | 89.97de   | 98.86c | 94.41a  | 136.5de |
| MTU-10        | 124.32b         | 169.88ab| 98.84c  | 121.02a  | 92.14d | 98.82c  | 87.73de   | 83.41d | 63.63d  | 173.2c  |
| HS1           | 135.42a         | 139.86c | 68.82e  | 97.7b    | 111c   | 85.47d  | 95.53c    | 93.27c | 76.6c   | 178.7c  |
| HS2           | 77.7e           | 125.43d | 103.2c3 | 95.46bc  | 87.69d | 74.37e  | 93.31c    | 86.61d | 72.18c  | 196.57b |
| HS3           | 89.91e          | 113.22e | 130.98a | 85.46c   | 95.6c  | 99.9c   | 152.07a   | 96.62c | 96.6a   | 96.57f  |
| HS4           | 106.56d         | 133.2c  | 75.48d  | 88.8c    | 117.66b| 58.83f  | 87.71de   | 98.86c | 72.15c  | 181c    |
| HS5           | 88.8d           | 128.03d | 119.88b | 89.91c   | 77.7e  | 89.91d  | 107.57c   | 78.82e | 81.07b  | 147.7d  |
| HS6           | 113.75c         | 138.22c | 73.26d  | 79.92d   | 89.91d | 79.92e  | 92.2d     | 82.97d | 84.39b  | 157.6d  |
| Sahbhagi Dhan | 139.86a         | 141.02bc| 121.02ab | 95.46bc  | 145.46a| 122.1a  | 87.72de   | 98.83c | 95.5a   | 148.7d  |

Values with different alphabets are significantly different at P ≤ 0.05
### Table 4: Changing patterns of CHO accumulation in different plant parts of rice

**Leaf blade, Leaf Sheath, Leaf culm and Grain of rice grown in drought situation**

| Growth period | Genotypes        | 45 days |          | 60 days |          | 75 days |          | Grain |
|---------------|------------------|---------|----------|---------|----------|---------|----------|-------|
|               | Leaf blade       | Sheath  | Culm     | Leaf blade | Sheath  | Culm     | Leaf blade | Sheath  | Culm     |         |
|               | Sabour Ardhajal  | 56.61e  | 65.63c   | 69.05d   | 63.653e  | 77.69d   | 84.38c    | 74.37b  | 75.52c   | 79.92c  | 178.8a |
|               | BRR-0028         | 48.84f  | 74.4b    | 86.63a   | 73.22d   | 89.9bc   | 79.01d    | 74.36b  | 79.92bc  | 82.15b  | 125.4de|
|               | Sabour Sampann   | 73.26c  | 83.29ab  | 72.18c   | 81c      | 69.88e   | 75.83d    | 69.92c  | 74.36c   | 79.92c  | 113.2ef|
|               | Sabour Surbhit   | 72.15c  | 77.74b   | 77.72bc  | 115.44a  | 75.48d   | 79.9d     | 99.9a   | 103.23a  | 66.61d  | 98.6f  |
|               | BRR-0054         | 51.06e  | 71.08b   | 74.73c   | 83.25c   | 86.56c   | 88.79b    | 77.7b   | 73.26c   | 43.29e  | 66.6f  |
|               | BRR-0057         | 78.86bc | 68.85c   | 77.74bc  | 79.92d   | 81.03c   | 92.13ab   | 74.35b  | 69.93d   | 76.59c  | 135.5d |
|               | BRR-0063         | 68.82   | 76.64b   | 86.63a   | 88.8c    | 79.92d   | 87.69b    | 68.81c  | 76.59bc  | 79.48c  | 164.3bc|
|               | BRR-0078         | 58.83e  | 61.08c   | 83.28a   | 92.11b   | 93.24b   | 96.57ab   | 76.59b  | 85.47ab  | 164.28a | 127.7de|
|               | MTU-10           | 52.17e  | 64.42c   | 78.84b   | 97.68a   | 91.02b   | 92.94b    | 82.14ab | 81.03b   | 73.26c  | 137.6d |
|               | HS1              | 53.28e  | 45.51d   | 53.3e    | 107.67a  | 105.45a  | 91.02b    | 89.91ab | 39.96f   | 86.58b  | 151bc  |
|               | HS2              | 52.17e  | 49.95d   | 66.6d    | 104.34a  | 91.02b   | 108.78a   | 86.58ab | 46.62e   | 74.25c  | 170.9b |
|               | HS3              | 89.95a  | 92.16a   | 96.61a   | 78.76d   | 98.79b   | 89.11b    | 74.37b  | 71.04cd  | 74.37c  | 136.5d |
|               | HS4              | 78.84bc | 69.96c   | 79.94b   | 74.37d   | 67.69e   | 84.38c    | 67.71c  | 77.7bc   | 73.26c  | 126.58de|
|               | HS5              | 85.5b   | 75.53b   | 81.03a   | 96.57b   | 93.24b   | 101.01a   | 77.7b   | 76.62bc  | 78.26c  | 118.8e |
|               | HS6              | 94.41a  | 86.6a    | 76.64c   | 91.33b   | 75.8d    | 77.69d    | 77.7b   | 73.26c   | 77.92c  | 144.3cd|
|               | Sahbhagi Dhan    | 65.49d  | 32.19e   | 54.39e   | 99.9a    | 88.8c    | 102.12a   | 83.25ab | 78.81b   | 84.36b  | 122.1de|

Values with different alphabets are significantly different at \( P \leq 0.05 \)
An increase in plant leaf area even under drought stress is defined as a function of growth habit differences on leaf growth that determines the light interception capacity of a crop thus resulted in an increase in dry matter production (Weraduwage et al., 2015; Lopez et al., 1997). Increased LAI and LAD under drought at early stage is a result of earlier and more rapid leaf production in the vegetative growth phase and promote longer period for sink development and thus the grain yield (Cabrera-Bosquet et al., 2011; Yoshida & Ahn 1968; Devendra et al., 1983).

Non structural CHO accumulation in different parts of plants under drought and open field

Table 3 represents the patterns of accumulation and distribution of CHO in different parts of the plant at three phases of growth period. CHO accumulation was estimated on leaf blade, leaf sheath and culm at different days of growth and results revealed that Total CHO accumulation was decreased with increasing days of growth in open field condition. Accumulation of CHO in different part of plants showed maximum in leaf sheath than that of leaf blade and culm in all the period. Maximum accumulation of CHO in the grain was observed in the genotype Sabour Ardhjal with 253.1 mg\(^{-1}\)g fresh wt and lowest accumulation was noted in the genotype BRR-0054 with 85.47 mg\(^{-1}\)g fresh wt. Moreover, highest leaf sheath accumulation of CHO was in the genotype Sabour Ardhjal with 176.5 mg\(^{-1}\)g fresh wt and followed by the genotype MTU-10 (169.88), Sabour Sampann (162.16), Sabhagi Dhan (141.02), HS1 (139.86) and BRR-0028 (138.75) mg\(^{-1}\)g fresh wt respectively at 45 days of growth.

However, the accumulation pattern of CHO under drought exposed plant showed variation amongst the genotypes with increasing days of growth and accumulation was found to be highest in the culm as compared from that of leaf sheath and leaf blade (Table 4). In contrast from the open field genotypes in drought stress showed higher accumulation of CHO in 60 days and 75 days than 45 days of growth. Also, accumulation of CHO in plant parts were shown highest in culm with 86.58 mg\(^{-1}\)g fresh wt (HS1) followed by in genotype Sahbhagi Dhan with 84.36 mg\(^{-1}\)g fresh wt and 79.92 mg\(^{-1}\)g fresh wt in Sabour Ardhjal and Sabour Sampann at 75 days of growth. Under drought stress, grain accumulation of CHO was observed highest in the genotypes Sabour Ardhjal (178.8 mg\(^{-1}\)g fresh wt), HS2 (170.9 mg\(^{-1}\)g fresh wt) and BRR-0063 (164.3 mg\(^{-1}\)g fresh wt) respectively. The least grain accumulation of CHO was noticed in genotype BRR-0054 with 66.6 mg\(^{-1}\)g fresh wt in similar pattern as grown in the open field.

Grain yield and CHO contribution rate in the grain under drought and open field

Genotypes grain yields ranged from 7504 kg/ha to 6143 5g/ha in genotypes Sahbhagi Dhan and Sabour Surbhit respectively under open field conditions whereas 5787 kg/ha and 3757 kg/ha were noted in the same genotypes under drought stress (Table 1). Grain yield reduction under drought stress was observed to be genotypic specific and varies in the value with the decreasing percent ranged of 25.81 (BRR-0038) to 48.41 (HS3). Others genotypes showed almost at the average decreased % of 35 to 43 under drought stress as compared from grain yield in open field (Table 2).

Reduction in the accumulation percent of CHO under drought stress was distinctive in different parts of the plant including in grains (Table 4). Insignificant increased percent of CHO accumulation in Culm of few genotypes at 60 days and 75 days were observed under drought from that of open field condition.
However, genotype BRR-0078 (74.04%) and BRR-0028 (45.06%) had shown a significant increased in percent in Culm at 75 days of growth. As far as CHO accumulation in grain is concerned, genotype HS3 revealed 41.35% increased in drought stress (Table 4).

Grain yield is much affected by drought stress and reduction of yield almost up to 50% in genotype HS3 (Table 1). However, retention of grain yield in few other genotypes such as BRR-0028, HS1, HS4 are less as compared to the open field grown plants. Result is an indication to the plants photo-assimilates accumulation capability at specific growth period. Longer period for sink development influence by the higher LAI and LAD at 45 days to 60 days duration is also one of the biggest reasons in contribution to final grain yield. Role of NCS in final grain yield is tremendous, about 85% of CHO (mainly starch) form in the grain is due to assimilates supplied by the early growth stage and it is contributed by differential accumulation in different part of the plants (Yoshida, 1981; Zhang et al., 2016, Miyake, 2016). Every plant organ ideally participates to fulfill metabolic and physiological processes in specific environmental conditions (Moura et al., 2017).

Rice plant comprises of leaves that are physiologically different in age and activity. At early stages of leaf growth, increases in plant biomass are associated with elongation. After completion of elongation, the weight continues to increase because of an accumulation of proteins and starch and for future developmental stages, thus suggesting the importance of accumulated reserve foods in plant development. Also, different growth parameters such as leaf area index, leaf area duration, dry matter accumulation and crop growth rate are influenced significantly influenced by all the competition durations (Yoshida, 1981).

The study suggested the genotypic potential in accumulation of CHO at leaf blade, leaf sheath and Culm. During drought stress accumulation of CHO are higher in Culm from leaf blade and leaf sheath (Table 4). This result has been supported by Pandey and Shukla (2015) and suggesting the decreased of photosynthesis at the same site causing feedback inhibition.

Therefore increased accumulation of CHO in Culm and to continue increase more till 75 days of growth might be the explanation of Culm contribution in stability and increased of grain yield. It also implied to the importance of growth period Wang et al., (2015) study on transgenic high yielding rice reported that grain filling was accelerated at particular stages of growth duration.

This acceleration in grain filling is generally due to continuous supplication of photo assimilates which has been transported from the lower leaves to the grain. It implied to the improvement in rice yield by increasing grain size with maximum sucrose loading and seed development depends on the accumulation of sugars and storage protein during grain filling (David et al., 2014) and maximizing apparent contribution rate of CHO in grain yield is depend on the prolonged accumulation potential in both the early and later phase of drought.

Participation of non structural CHO accumulation at particular growth period alter CHO accumulation amongst the part of plant, whereby Culm having shown maximum CHO accumulation aptitude for early reproductive drought stress rather than the leaf blade and leaf sheath.

Result has also provided an insight to unravel the involvement of different leaves translocation of CHO to sink for better grain yield under reproductive drought stress.
Acknowledgements

Authors would like to thank Directorate of Research, Bihar agricultural University, Sabour, Bihar for the financial supported extended during the research work. This research paper content BAU COMMUNICATION NO. 824/2020.

Conflict of interest

All the authors have contributed equally

References

Anjum, SA, Xie X, Wang LC, Saleem MF, Man C and Lei W. 2011. Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research 6:2026-2032.

Bray EA, Bailey-Serres J and Weretilnyk E. 2000. Responses to abiotic stresses. In: Biochemistry and Molecular Biology of Plants (Eds.) Gruissem W, Buchnnan B and Jones R.. American Society of Plant Physiologists. Rockville. MD Pp.1158-1249.

Cabrera-Bosquet L, Molero G, Stellacci AM, Bort J, Nogues S and Araus JL. 2011. NDVI as a potential tool for predicting biomass, plant nitrogen content and growth in wheat genotypes subjected to different water and nitrogen conditions. Cereal Research Communications 39:147-159.

David MB, Wang L and Ruan YL. 2014. Understanding and manipulating sucrose phloem loading, unloading, metabolism, and signalling to enhance crop yield and food security. Journal of Experimental Botany 65:1713-1735.

Dubois M, Gilles KA, Hamilton JK, Rebers PA and Smith F. 1956. Colorimetric method for determination of sugars and related substances 28:350-356.

Farooq M, Wahid A, Kobayashi N, Fujita D and Basra SMA. 2009. Plant drought stress: effects, mechanisms and management. Agronomy for Sustainable Development 29:185-212.

Hirano M, Sugiyama M and Hatakeyama Y. 1998. Effect of the Application of Rice Bran on the Carbohydrate Metabolism in Leaves and Stems of Rice Variety Hitomebore Cultured with the Practice of No Nitrogen. Jpn. J. Crop Sci. 67: 208-215.

Hussain M, Malik MA, Farooq M, Ashraf MY and Cheema MA. 2008. Improving drought tolerance by exogenous application of glycine betaine and salicylic acid in sunflower. J. Agron. Crop Sci. 194:193-199.

Lijuan M, Peilong Y, Bin H, Lizi C and Xuefeng C. 2015. Future Climate Impact on the Desertification in the Dry Land Asia Using AVHRR GIMMS NDVI3g Data. Remote Sensing 7:3863-3877.

Lopez F, Chauhan YS, Chauhan and Johansen C. 1997. Effects of Timing of Drought Stress on Leaf Area Development and Canopy Light Interception of Short- duration Pigeonpea. Journal of Agronomy and Crop Science 178:1-7.

Hassan M, Hassani G, Bahram Nejad K and Alizadeh K. 2017. The Influence of the Leaf to Yield Ratio on Carbohydrate Reserves in Grapevine Vitis vinifera L. Qizil Uzom. Int. J. Pure App. Biosci 5:40-52.

Miyake H. 2016. Starch Accumulation in the Bundle Sheaths of C3 Plants: A Possible Pre-Condition for C4 Photosynthesis. Plant Cell Physiol 57: 890–896.

Moura DS, Brito GG, Campos AD, Moraes IL, Porto FGS, Teixeira SB, Fagundes PRR, Andres A, Schreiber S and Deuner S. 2017. Non-Structural carbohydrates accumulation in contrasting rice genotypes subjected to high night temperatures. Journal of Agricultural Science 9:12.

Nahakpam S. 2017a. Effectual tolerant traits for grain yield in rice genotypes grown under drought. Journal of Pharmacognosy and Phytochemistry 1:890-897.

Nahakpam S. 2017b. Chlorophyll Stability: A Better Trait for Grain Yield in Rice under Drought. Indian Journal of Ecology 44:77-82.
Pandey V and Shukla A. 2015. Acclimation and tolerance strategies of rice under drought stress. Rice Science 22:147-161.

Rajiv S, Thivendran P and Deivannai S. 2010. Genetic divergence of rice on some morphological and physicochemical responses to drought stress. Pertanika J Trop. Agric. Sci. 33:315-328.

Rahimi M, Dehghani H, Rabiei B and Tarang AR. 2013. Evaluation of rice segregating population based on drought tolerance criteria and biplot analysis. Int. J Agric. Crop sci. 5:194-199.

Singh SP, Kumar A, Satyendra, Kumar M, Nahakpam S, Sinha S, Smrity, Sundaram P, Kumar S and Singh PK. 2018. Identification of Drought Tolerant Rice (Oryza sativa L.) Genotypes Using Drought Tolerance Indices under Normal and Water Stress Condition. Int.J.Curr.Microbiol.App.Sci.7:4757-4766.

Virgona JM and Barlow EWR. 1991. Drought stress induces changes in the non structural carbohydrate composition of wheat stems. Aust. J. Plant Physiol 18: 239-247.

Wang L, Qingtao L, Wen X and Congming L. 2015. Enhanced Sucrose Loading Improves Rice Yield by Increasing Grain Size Plant Physiology 169:2848-2862.

Wang W, Vinocur B and Altman A. 2003. Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta 218:1-14.

Wardlaw IF and Willenbrink J. 2000. Mobilization of fructan reserves and changes in enzyme activities in wheat stems correlate with water stress during kernel filling. New Phytol. 148:413-422.

Weng X, Wang L, Wang J, Yong H, Hao D, Caiguo X, Xing Y, Xianghua L, Xiao J and Zhang Q. 2014. Grain Number, Plant Height, and Heading Date7 Is a Central Regulator of Growth, Development, and Stress Response. Plant Physiology 164:735-747.

Weraduwage SM, Chen J, Anozie FC, Morales A, Weise SE and Sharkey TD. 2015. The relationship between leaf area growth and biomass accumulation in Arabidopsis thaliana. Front. Plant Sci. 6:167.

Xu Q and Huang B. 2000. Effects of differential air and soil temperature on carbohydrate metabolism in creeping bentgrass. Crop Sci. 40: 1363-1368.

Yang J and Zhang J. 2006. Grain filling of cereals under soil drying. New Phytol. 169 : 223-236.

Yoshida S. 1981. Fundamentals of rice crop science. Los Baños: IRRI.

Yoshida S and Ahn SB. 1968. The accumulation process of carbohydrate in rice varieties in relation to their response to nitrogen in the tropics. Soil Science and Plant Nutrition 14:4.

Yoshida S, Frono DA, Cock J and Gomez KA. 1976. Laboratory Manual for Physiological Studies of Rice, IRRI, Philippine 3.

Zhang X, Jitsuyama Y, Terauchi T and Iwama K. 2009. Effects of Drought and Shading on Non-structural Carbohydrate Stored in the Stem of Potato. Plant Prod.Sci.12:449-452.

Zhang W J, Wu L M, Ding Y F, Weng F, Wu X R, Li G H, and Wang SH. 2016. Top-dressing nitrogen fertilizer rate contributes to decrease culm physical strength by reducing structural carbohydrate content in japonica rice. Journal of Integ. Agri. 15(5): 992-1004.

How to cite this article:

Eity Kumari, Sareeta Nahakpam and Sweta Sinha. 2020. Non Structural Carbohydrate Accumulation in Plant Parts of Rice Genotypes Grown under Drought and Open Field: A comparative Study. Int.J.Curr.Microbiol.App.Sci. 9(09): 600-611.
doi: https://doi.org/10.20546/ijcmas.2020.909.076