Difference in yield and physiological features in response to different water regime of sweet corn cultivar

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Abstract

Sweet corn (Zea mays L.) producers desire high yields and high sugar content in the endosperm. Irrigation levels result in high yield, but their effect on sugar content is unclear. To study the effect of irrigation at different growth stages on growth and development of sweet corn, an investigation was conducted at the research field of Plant Physiology Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during rabi season of 2015-16. The treatment included: T₁ = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T₂ = Irrigation at 4-leaf stage, T₃ = Irrigation at 4-leaf stage + tasseling stage, T₄ = Irrigation at tasseling stage, T₅ = No irrigation after emergence (water stress). Water stress reduced SPAD value, leaf area index (LAI), total soluble solid (TSS) which ultimately reduced green cob yield in T₅ treatment. Among the treatments, T₁ and T₃ showed higher LAI (5 and 4), TSS (18.30% and 16.2%) and green cob yield (12.96 t/ha and 10.80 t/ha, respectively) compared to others. Total soluble sugar and reducing sugar was higher in T₁ and T₃ (12.5, 11 and 12.3, 10.8) respectively. In case of soluble protein T₃ was higher (44%) whereas T₁ showed lowest result. Moreover, T₁ and T₃ treatments showed higher starch content (47 and 51%, respectively). But treatment T₂ and T₅ produced the lowest green cob yield (8.61 t/ha and 6.85 t/ha, respectively). The results revealed that irrigation at 4-leaf stage and tasseling stage (T₃) would be suitable for sweet corn cultivation regarding water utilization.

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Introduction
Sweet corn (Zea mays L. var. saccharata) is an important grain-cum-fodder crop in many parts of the world. Moisture is the primary factor limiting the corn productivity in tropical countries (Mallikarjunaswamy et al., 1999). In Bangladesh sweet corn is a new crop. Their production areas are increasing day by day due to the nutritional value, change in the food habit and is used as raw or processed material of the food industry. However, higher yield of sweet corn depends on several factors like use of good quality seed, balanced use of fertilizer and proper management of irrigation water etc. Among them proper water management may play a vital role for higher yield. The higher green cob yield with increased moisture level was reported by Braunworth and Mack (1989).

Sweet corn is produced for human consumption either as a fresh or processed product. The kernel of it is translucent in fresh condition. Sweet corn is sweeter in taste than other types because its endosperms contain more sugar as well as starch. It is favorable for fresh consumption because of its delicious taste, delicate crust and soft sugary texture compared to other corn varieties. Sweet corn is a good and profitable crop for its short growing time (Alessi, 1975). Study on growth stage of sweet corn will help to adopt better crop management practices. When green cob is harvested it is possible to get green, succulent and nutritious fodder from harvested crop. Scarcity of irrigation water and unexpected dry spells during the growing period has prompted this study aimed at efficient use of irrigation water in enhancing both green cob and fodder yields of sweet corn. On the other hand, water stress on corn causes some deleterious effect on plant physiological processes, growth and yield. Cakir and Hirich (2004) found that water stress during the vegetative stage in an arid environment hindered root development of corn. Irrigation cost is increasing day by day. Besides, near future availability of irrigation water will be reduced under climate change situation. So, to find out suitable irrigation schedule which would be able to produce good yield under water scarce situation this experiment was conducted.

Materials and methods
Plant materials and experimental design
The experiment was conducted at the central research field of Plant Physiology Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during rabi season of 2015-16. The soil belongs to the Chhiata Series under Agro-Ecological Zone-28. The soil was clay loam and slightly acidic in nature (pH 6.1). Five treatments of irrigation included: T1=Well watered (Irrigation at 4, 6, 8 leaves stage, silking and tasseling stage), T2=Irrigation at 4-leaf stage, T3 = Irrigation at 4- leaf stage + tasseling stage, T4=Irrigation at tasseling stage, T5=No irrigation after emergence (water stress). The experiment was laid out in Randomized Complete Block (RCB) design with 4 replications.

The unit plot size was 4.2 m x 3 m. Pre-sowing irrigation was given to bring the soil at field capacity (zoe condition) at sowing. Seeds of sweet corn (cv. BARI sweet corn-1) were sown on November 12, 2015. A light irrigation was given in all the plots to ensure proper emergence. Fertilizers were applied at the rate of 150-60-90-200 kg/ha N, P, K and S as urea, triple super phosphate (TSP), muriate of potash (MOP) and gypsum. One third of N, whole amount of TSP, MOP and gypsum was applied as basal. Remaining 2/3 N was top-dressed at 30 days after sowing (DAS) and at 55 DAS. Irrigation was given as per treatment. Soil moisture content of the experimental plots was monitored (60 cm depth) throughout the growing season by gravimetric method every 10 days interval from 25 DAS to 90 DAS (Fig. 1).

Growth measurement
Plants were gently uprooted and separated into roots and shoots. After measuring plant height, plants were separated into leaves and stems. Leaves and stems were then dried at 75 °C for 72 hours to constant weight and weighed.

Measurement of chlorophyll content
The chlorophyll content was measured as SPAD (Soil plant analyses development) value on intact fully expanded leaves (the second from the apex) using a chlorophyll meter-Minolta SPAD- 502 (Feibo et al., 1998) with 5 replicates.
Determination of relative water content

The relative water content (RWC) was determined in intact fully expanded leaves (the second from the apex). Samples were weighed quickly and immediately floated on double distilled water, in Petri dishes to saturate them with water for the next 24 h, in dark. The excessive water was blotted and turgor weight was taken. Dry weight of these samples was obtained, after dehydrating them at 80 °C for 72 h. Relative water content was calculated by placing the observed values in the following formula (Jones and Turner, 1978):

\[
\text{RWC} (%) = 100 \left( \frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}} \right)
\]

Measurement of leaf area

Leaf area was measured by an automatic area matter (LI- 3100C, LI-COR, USA). Leaf area indexes (LAI), were determined according to the formula of Gardner et al. (1985).

Kernel nutritive component measurement

Evaluation of kernel nutritive components was performed on 3 replications of 20 seeds at each harvest. Soluble protein was extracted from the seeds and determined according to the method of Coomassie brilliant blue G-250 staining (Li, 2000). Contents of total soluble sugar, reducing sugar and starch were determined by 3,5-dinitrosalicylic acid method (Jiang, 1999; Ahmed et al., 2013).

Measurement of total soluble solid (TSS %), yield and yield components

When the silks of cob turned to brown then a portion of the husk in the middle of the cob was separated and a kernel was punctured with fingernail to measure the TSS (%) in juice with Refractometer (Ataga 32 α Brix scale 0-32, Japan).

The green cobs were harvested according to the treatments. At harvest, 10 plants were randomly selected for collecting data on yield contributing characters and yield i.e. cob length, Cob diameter, number of kernels per cob, green cob weight, green cob and fodder yield.

Statistic analysis

All data presented were mean values of each treatment. Statistical analysis was performed using the Data Processing System (DPS) Software Package (Tang and Feng, 1997) using ANOVA followed by the Duncan’s Multiple Range Test (DMRT) to evaluate treatment effects (\(P < 0.05\)).

Results and discussion

Soil moisture content

Fig.1 shows the volumetric soil moisture content changes over time in five irrigation treatments. Soil moisture slightly declined in drought treatment (no irrigation after emergence).

Treatment \(T_1\) had highest moisture followed by \(T_3\). Treatment \(T_2\) had higher soil moisture at early stage than that of \(T_4\) and \(T_5\). Soil moisture content in \(T_4\) treatment increased at tasseling stage due to application of irrigation.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cob length (cm)</th>
<th>Cob diameter (cm)</th>
<th>No. kernels per cob</th>
<th>Green cob weight (g cob(^{-1}))</th>
<th>Green cob yield (t ha(^{-1}))</th>
<th>Green Fodder yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_1)</td>
<td>22.42</td>
<td>4.22</td>
<td>575.30</td>
<td>356.25</td>
<td>12.96</td>
<td>23.17</td>
</tr>
<tr>
<td>(T_2)</td>
<td>15.90</td>
<td>2.96</td>
<td>350.63</td>
<td>213.65</td>
<td>8.61</td>
<td>16.56</td>
</tr>
<tr>
<td>(T_3)</td>
<td>19.01</td>
<td>4.01</td>
<td>448.76</td>
<td>295.36</td>
<td>10.80</td>
<td>20.21</td>
</tr>
<tr>
<td>(T_4)</td>
<td>17.88</td>
<td>3.65</td>
<td>380.56</td>
<td>285.58</td>
<td>9.57</td>
<td>17.98</td>
</tr>
<tr>
<td>(T_5)</td>
<td>14.70</td>
<td>2.69</td>
<td>302.30</td>
<td>180.85</td>
<td>6.85</td>
<td>14.67</td>
</tr>
</tbody>
</table>

LSD (0.05)

<table>
<thead>
<tr>
<th>Cob length (cm)</th>
<th>2.33</th>
<th>0.81</th>
<th>15.13</th>
<th>9.56</th>
<th>2.14</th>
<th>2.56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cob diameter (cm)</td>
<td>9.2</td>
<td>5.9</td>
<td>41.97</td>
<td>25.51</td>
<td>12.9</td>
<td>11.6</td>
</tr>
</tbody>
</table>

\(T_1\) = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), \(T_2\) = Irrigation at 4 leaf stage, \(T_3\) = Irrigation at 4 leaf stage + tasseling stage, \(T_4\) = Irrigation at tasseling stage, \(T_5\) = No irrigation after emergence (water stress).
Relative water content (RWC)

Effects of different regime treatments on RWC are shown in Fig 2. Relative water content in sweet corn leaf was higher in T1 followed by T3. By contrast, RWC was significantly decreased under T5, but no difference was observed in T2 and T4. Tafrishi et al. (2013) reported similar result, where RWC decreased significantly in 60% water treatment. A reduction in RWC decreased fresh ear and kernel yield.

Fig. 1. Volumetric soil moisture at different irrigation treatments in sweet corn. T1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T2 = Irrigation at 4 leaf stage, T3 = Irrigation at 4 leaf stage + tasseling stage, T4 = Irrigation at tasseling stage, T5 = No irrigation after emergence (water stress).

Plant height and biomass accumulation content

Plant height, dry weight of leaf, stem and cobs were shown in Fig. 3. Plant height was significantly different between T1 and T5 which were well watered and under drought, respectively. However, plant height in T2, T3, and T4 was more or less similar. Leaf dry weight was decreased significantly under all treatment (T2, T3, T4 and T5) relative to the control (T1). However, the level of reduction differed among the treatments, with T2 and T3 showing less reduction than T4 and T5. Similar pattern was observed in case of stem and cob dry weight. Tafrishi et al. (2013) reported that deficit irrigation decreased the fresh ear yield in sweet corn varieties. Even though kernel and fresh ear yield decreased by water decrease, RWC and WUE did not decrease significantly in 100% and 80% ETo water treatments. Stone et al. (2001), Osborne et al. (2002), and Moser et al. (2006), also reported that biomass was reduced by moisture stress. Stone et al. (2001) stated that yield was related strongly to biomass especially that accumulated after silking. Biomass also was reduced by water deficit.

SPAD values

Leaf greenness which is expressed by SPAD value is shown in Fig. 4. Chlorophyll pigment is the cause of greenness which is changed by environmental stress on the plants (Albert, 1977). In this study the highest SPAD value was in control treatment followed by T3, T4, T2 and T5. The time-dependent response pattern for SPAD value to different treatments was diverse and decrease in later stage. This result is in agreement with the findings of Albert (1977).

Leaf area index (LAI)

The changes of LAI over time in different treatment are shown in Fig 4. LAI increased with the progress of growth stages in different treatments and reached at pick at 95 DAS (Fig. 4). Drought caused reduction in LAI. At 95 DAS in irrigated treatment it ranged from 4.5 to 5, while in T5 treatment it was 2.5. Rosenthal et al. (1987) reports adverse effects on stem height, cumulative leaf area, leaf area indices and biomass production of sorghum as soil water deficits developed.
Water deficits also affected total number of leaves, rates of individual leaf emergence from the whorl, leaf extension and senescence of sorghum (Arkin et al., 1983).

**Fig. 2.** Relative water content in sweet corn leaf at different irrigation treatments. Error bars represent SD values (n=5). Different letters indicate significant differences ($P < 0.05$) among the treatments. $T_1$ = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), $T_2$ = Irrigation at 4-leaf stage, $T_3$ = Irrigation at 4-leaf stage + tasseling stage, $T_4$ = Irrigation at tasseling stage, $T_5$ = No irrigation after emergence (water stress).

**Fig. 3.** Plant height and biomass accumulation with different irrigation treatment. Error bars represent SD values (n=5). Different letters indicate significant differences ($P < 0.05$) among the treatments. $T_1$ = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), $T_2$ = Irrigation at 4 leaf stage, $T_3$ = Irrigation at 4 leaf stage + tasseling stage, $T_4$ = Irrigation at tasseling stage, $T_5$ = No irrigation after emergence (water stress).
Total soluble solid (TSS%)

Under the different water regime treatment, affects on TSS (%) are shown in Fig. 5. TSS (% brix) value was statistically identical in different treatments except T5. The highest TSS value was recorded in T1 and the lowest TSS value was recorded in T5. The highest content (18.30%) was observed when harvested at 22 DAS and declined before and after that time of harvest in well water condition (Ahmed et al., 2010). This might be due to increasing temperature and growth stage of crop. Many authors stated that the refractometer, which measures TSS, has been utilised as a rapid, preharvest method to determine sweet corn sugar content (Randle et al., 1984; Kleinhenz, 2003).

![Graph of SPAD value and leaf area index with different irrigation treatment](image)

**Fig. 4.** Changes of SPAD value and leaf area index with different irrigation treatment. Error bars represent SD values (n=5). T1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T2 = Irrigation at 4 leaf stage, T3 = Irrigation at 4 leaf stage + tasseling stage, T4 = Irrigation at tasseling stage, T5 = No irrigation after emergence (water stress).

![Graph of TSS (%) at different days after silking (DAS) in different irrigation treatment](image)

**Fig. 5.** TSS (%) at different days after silking (DAS) in different irrigation treatment. Error bars represent SD values (n=5). Different letters indicate significant differences (P < 0.05) among the treatments. T1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T2 = Irrigation at 4 leaf stage, T3 = Irrigation at 4 leaf stage + tasseling stage, T4 = Irrigation at tasseling stage, T5 = No irrigation after emergence (water stress).
Changes of nutritive components during seed development

The effects of different water regime on total soluble sugar, reducing sugar, starch, and soluble protein are shown in Fig. 6. Both of total soluble sugar and reducing sugar contents in the kernels decreased gradually in T3, T4, and T5 due to the limited irrigation. Starch, transformed from soluble sugar during seed development, accumulated in seed endosperm. In our current study, starch content in the kernels increased with small changes among the treatment during seed development. Similarly, the soluble protein content of the kernels harvested in different treatments changed slightly from 10.26% to 12.92%. The present study shows that the contents of total soluble sugar and reducing sugar decreased gradually throughout the development stages, and the contents of starch and soluble protein in seeds increased, which is consistent with previous reports (Yan, 2001). Kumari et al. (2006) also reported total sugar, reducing sugar and non-reducing sugar content were positively and significantly correlated with TSS.

![Fig. 6. The changes of nutritive components (total soluble sugar, reducing sugar, starch, and soluble protein) with different irrigation treatment. Error bars represent SD values (n=5). Different letters indicate significant differences (P < 0.05) among the treatments. T1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T2 = Irrigation at 4 leaf stage, T3 = Irrigation at 4 leaf stage + tasseling stage, T4 = Irrigation at tasseling stage, T5 = No irrigation after emergence (water stress).]

Yield and yield components

Yield and yield components of sweet corn cob at different irrigation levels is presented in Table 1. Among the treatments, the highest cob length (22.42 cm) was found in T1, while the shortest cob length (14.70 cm) was found in T5. Identical cob length was recorded in T1 and T3. Maximum cob diameter was obtained from T1 treatment (4.22 cm) which was identical with T3. Minimum cob diameter was recorded in T5. Green cob yield differed significantly in different irrigation treatments. The highest green cob yield (12.96 t ha⁻¹) was recorded in T1, which was statistically similar with T3 (10.8 t/ha). The higher green cob yield with frequent irrigations has been attributed to more number of cobs per plant, cob length, number of kernel cob diameter, number of grains per cob and green cob weight. These results confirm the findings of Khan et al. (1996). The lowest green cob yield was found in T5 (6.85 t ha⁻¹) which was identical with T2. The highest green fodder (23.17 t ha⁻¹) yield of sweet corn was recorded in T1 followed by T3 and the lowest green fodder (14.67 t ha⁻¹) yield was found in T5.

Conclusion

It can be concluded that two irrigation i.e. one irrigation at 4-leaf stage and another at tasseling stage (T3) would be suitable for sweet corn cultivation regarding water utilization.
Maintenance of higher plant water status helps to improve the quality and yield of sweet corn. Also, it can be confirmed that the vegetative stage followed by tasseling and silking are critical for moisture stress, as indicated by the crop susceptibility factors.

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