INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 10, No. 6, p. 78-86, 2017

RESEARCH PAPER OPEN ACCESS

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

Nadira Mokarroma[1], Faruque Ahmed[1], Md Nurul Islam[2], A. F. M. Shamim Ahsan[1], A. K. M. Zonayed-Ull-Noor[3], K. A. M. Mustafizar Rahman[4], Imrul Mosaddek Ahmed[*1]

[1]*Plant Physiology Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh*

[2]*Agronomy Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh*

[3]*Seed Technology Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh*

[4]*Tuber Crop Research Center, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh*

Key words: Water stress, Quality, Sweet corn, Yield.

http://dx.doi.org/10.12692/ijb/10.6.78-86 Article published on June 16, 2017

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: 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). Water stress reduced SPAD value, leaf area index (LAI), total soluble solid (TSS) which ultimately reduced green cob yield in T_5 treatment. Among the treatments, T_1 and T_3 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 T_1 and T_3 (12.5, 11 and 12.3, 10.8) respectively. In case of soluble protein T_3 was higher (44%) whereas T_1 showed lowest result. Moreover, T_1 and T_3 treatments showed higher starch content (47 and 51%, respectively). But treatment T_2 and T_5 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 (T_3) would be suitable for sweet corn cultivation regarding water utilization.

* **Corresponding Author:** Imrul Mosaddek Ahmed ✉ Kbdimrul@yahoo.com

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: T_1=Well watered (Irrigation at 4, 6, 8 leaves 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). 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):

RWC (%) =100 [(fresh weight - dry weight)/ (turgid weight - dry weight)].

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 1. Yield and yield components of sweet corn at different irrigation treatment

Treatment	Cob length (cm)	Cob diameter (cm)	No. kernels per cob	Green cob weight (g cob^{-1})	Green cob yield (t ha^{-1})	Green Fodder yield (t ha^{-1})
T_1	22.42	4.22	575.30	356.25	12.96	23.17
T_2	15.90	2.96	350.63	213.65	8.61	16.56
T_3	19.01	4.01	448.76	295.36	10.80	20.21
T_4	17.88	3.65	380.56	285.58	9.57	17.98
T_5	14.70	2.69	302.30	180.85	6.85	14.67
LSD $_{(0.05)}$	2.33	0.81	15.13	9.56	2.14	2.56
CV (%)	9.2	5.9	41.97	25.51	12.9	11.6

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 T_1 followed by T_3. By contrast, RWC was significantly decreased under T_5, but no difference was observed in T_2 and T_4. 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.

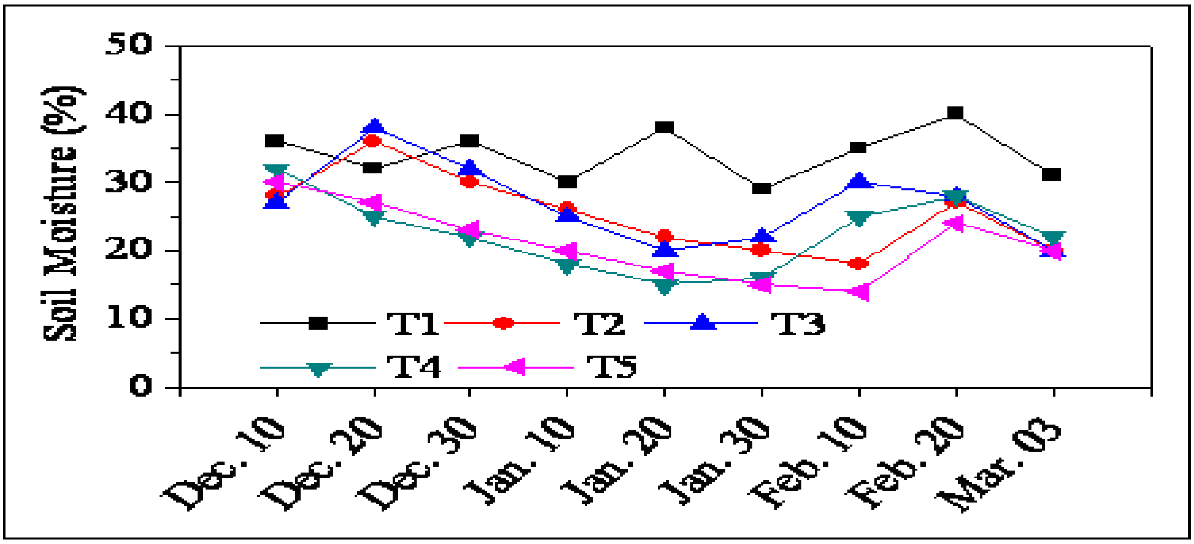

Fig. 1. Volumetric soil moisture at different irrigation treatments in sweet corn. T_1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T_2 = Irrigation at 4 leaf stage, T_3 = Irrigation at 4 leaf stage + tasseling stage, T_4 = Irrigation at tasseling stage, T_5 = No irrigation after emergence (water stress).

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 T_1 and T_5 which were well watered and under drought, respectively. However, plant height in T_2, T_3 and T_4 was more or less similar. Leaf dry weight was decreased significantly under all treatment (T_2, T_3, T_4 and T_5) relative to the control (T_1). However, the level of reduction differed among the treatments, with T_2 and T_3 showing less reduction than T_4 and T_5. 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% ETc 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 T_3, T_4, T_2 and T_5. 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 T_5 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).

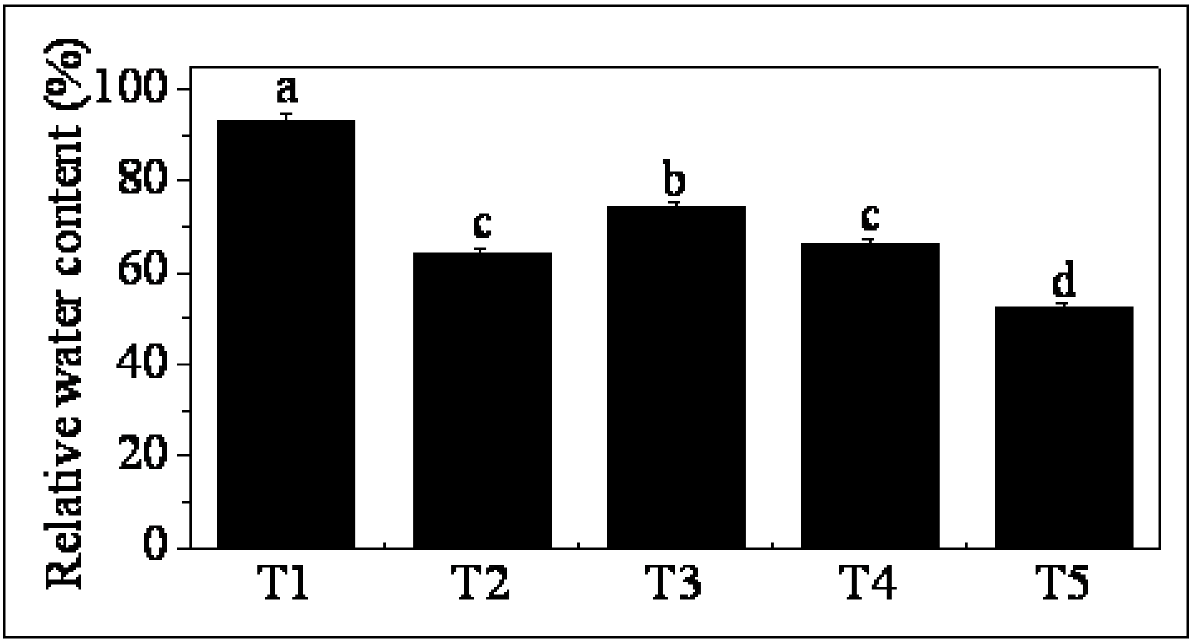

Fig. 2. Relative water content in sweet corn leaf at different irrigation treatments. Error bars represent SD values (n=5). Different letters indicate significant differences ($P < 0.05$) among the treatments. T_1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T_2 = Irrigation 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).

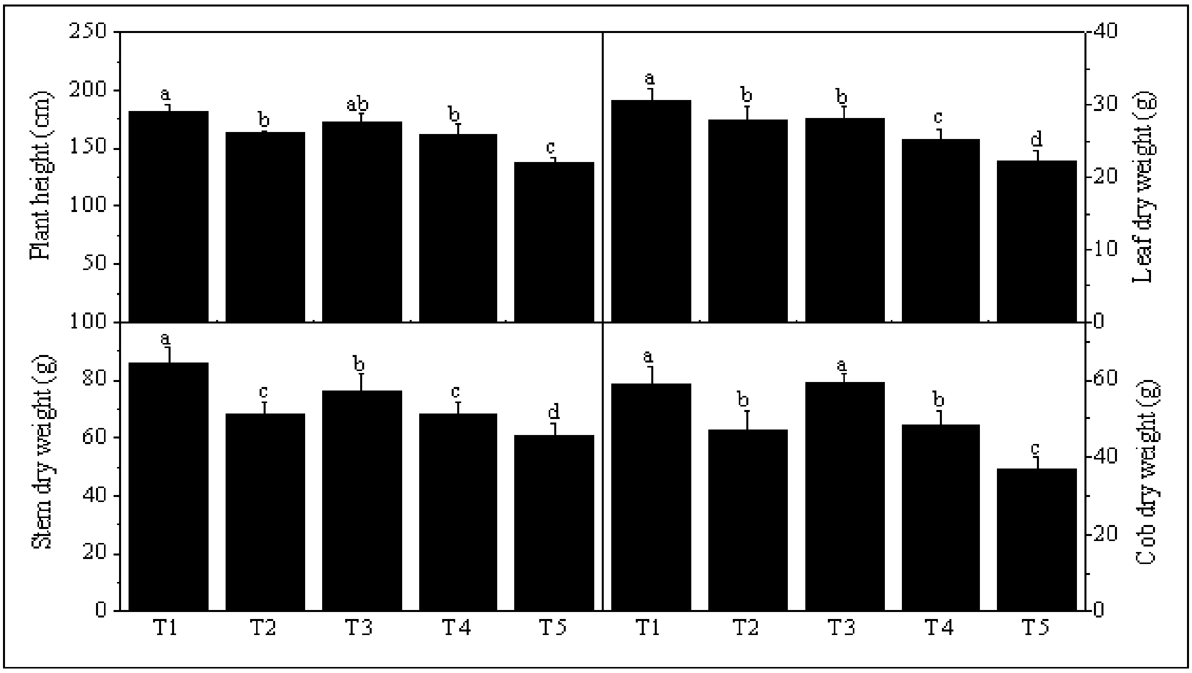

Fig. 3. Plant height and biomass accumulation with different irrigation treatment. Error bars represent SD values (n=5). Different letters indicate significant differences ($P < 0.05$) among the treatments. T_1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T_2 = Irrigation 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 trentment, affects on TSS (%) are shown in Fig. 5. TSS (% brix) value was statistically identical in different treatments except T_5. The highest TSS value was recorded in T_1 and the lowest TSS value was recorded in T_5. The highest content (18.30%) was observed when harvested at 22 DAS and declined before and after that time of harevest 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).

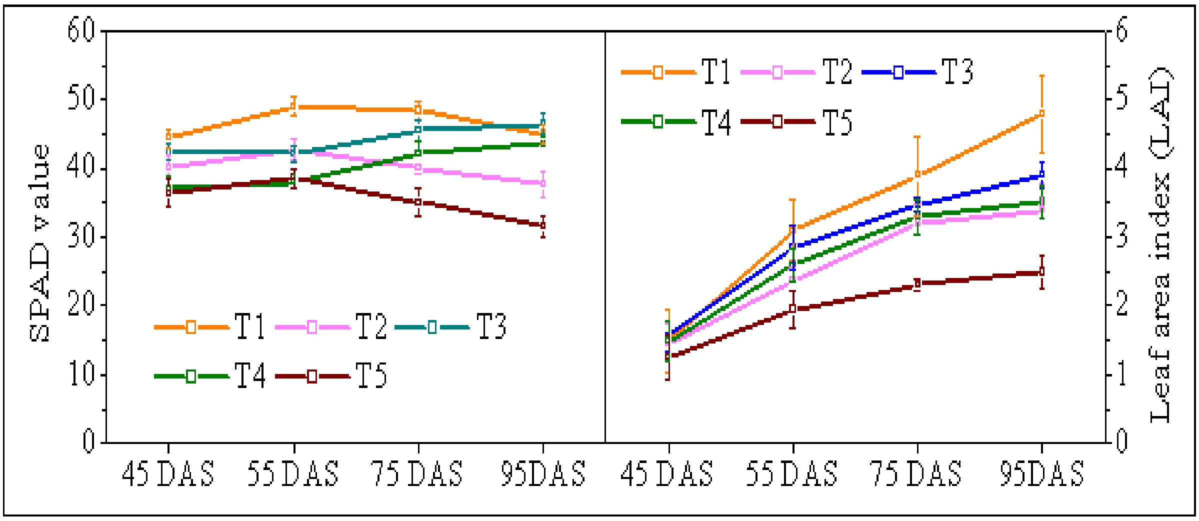

Fig. 4. Changes of SPAD value and leaf area index with different irrigation treatment. Error bars represent SD values (n=5). T_1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T_2 = Irrigation at 4 leaf stage, T_3 = Irrigation at 4 leaf stage + tasseling stage, T_4 = Irrigation at tasseling stage, T_5 = No irrigation after emergence (water stress).

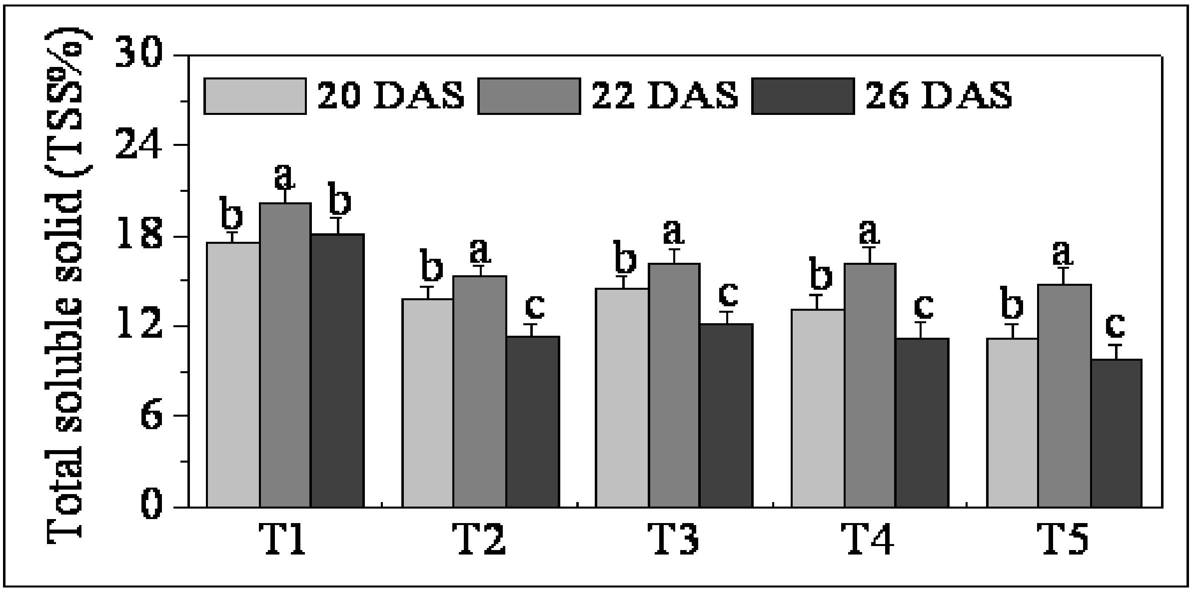

Fig. 5. TSS (%) at different days after silking (DAS) in different irrigation treatment. Error bars represent SD values (n=5). Different letters indicate significant differences (*P* < *0.05*) among the treatments. T_1 = Well watered (Irrigation at 4, 6, 8 leaf stage, silking and tasseling stage), T_2 = 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).

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 T_3, T_4 and T_5 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.

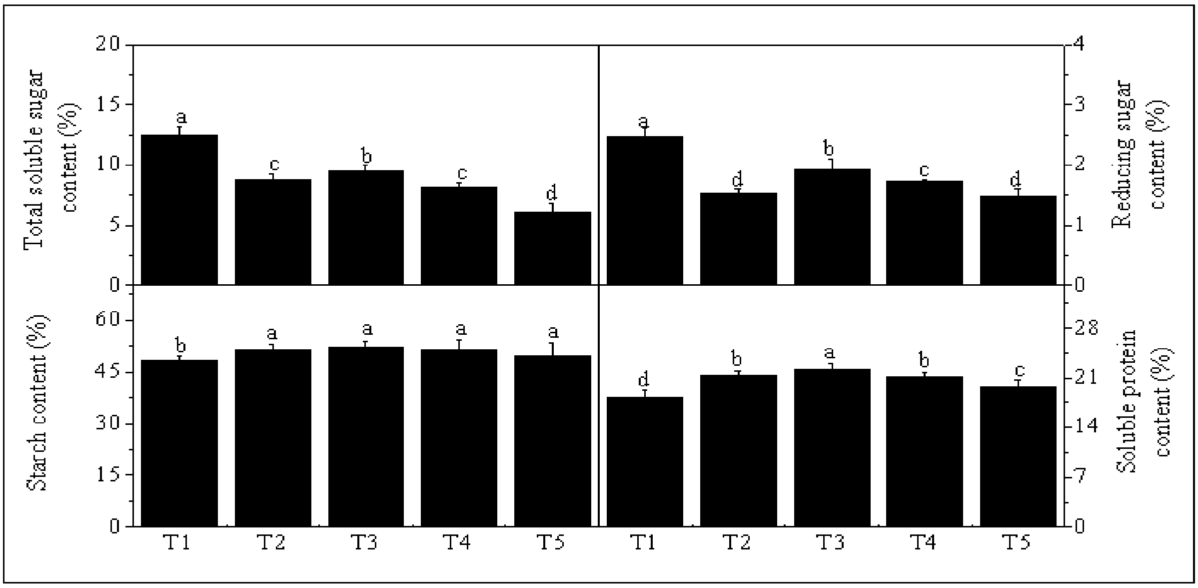

Fig. 6. The changes of nutritive components (total soluble sugar, reducing sugar, starch, and soluble protein) with different irrigation treatment. Error bars represent SD values (n=5). Different letters indicate significant differences ($P < 0.05$) among the treatments. T_1 = Well watered (Irrigation 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).

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 T_1 while the shortest cob length (14.70 cm) was found in T_5. Identical cob length was recorded in T_1 and T_3. Maximum cob diameter was obtained from T_1 treatment (4.22 cm) which was identical with T_3. Minimum cob diameter was recorded in T_5. Green cob yield differed significantly in different irrigation treatments. The highest green cob yield (12.96 t ha^{-1}) was recorded in T_1, which was statistically similar with T_3 (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 T_5 (6.85 t ha^{-1}) which was identical with T_2. The highest green fodder (23.17 t ha^{-1}) yield of sweet corn was recorded in T_1 followed by T_3 and the lowest green fodder (14.67 t ha^{-1}) yield was found in T_5.

Conclusion

It can be concluded that two irrigation i.e. one irrigation at 4- leaf stage and another at tasseling stage (T_3) 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.

Acknowledgement

The research was supported by main project of Bangladesh Agricultural Research Institute. The sweet corn seed is kindly provided by plant breeding division, Bangladesh Agricultural Research Institute, Gazipur-1701.

References

Ahmed IM. 2010. Annual research report. Agronomy Divivision, Bangladesh Agricultural research Institute, Bangladesh. 5-9.

Ahmed IM, Cao FB, Han Y, Nadira UA, Zhang GP, Wu FB. 2013. Differential changes in grain ultrastructure, amylase, protein and amino acid profiles between Tibetan wild and cultivated barleys under drought and salinity alone and combined stress. Food Chemistry **141,** 2743-2750. https://doi.org/10.1016/j.foodchem.2013.05.101

Albert RS, Thornber JP. 1977. Water stress effects on content and organization of chlorophyll in mesophyll and chloroplasts of maize. Plant Physiology **59,** 351-353. http://dx.doi.org/10.1104/pp.59.3.351

Alessi J 1975. Response of an early maturing corn hybrid to planting date and population in northern Dacuta. Agronomy Journal **67,** 762-765. http://dx.doi.org/10.2134/agronj1975.00021962006700060009x

Arkin GF, Rosenthal WD, Jordan WR. 1983. A sorghum leaf area model. ASAE Tech paper 83-2098. American Society of Agriculture Engeneers. St Joseph, Mich. P. 25

Braunworth WS, Mack HJ. 1989. Crop-water production functions for sweet corn. Journal of American Society of Horticultural Science **114,** 210-215.

Cakir, Hirich R. 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field crops Research **89,** 1-16. https://doi.org/10.1016/j.fcr.2004.01.005

Feibo W, Lianghuan W, Fuhua X. 1998. Chlorophyll meter to predict nitrogen sidedress requirements for short-season cotton (*Gossypium hirsutum* L.). Field Crops Research **56,** 309-314. https://doi.org/10.1016/S0378-4290(97)00108-1

Gardner FP, Pearce RB, Mitchel RL. 1985. Physiology of crop plants. Iowa State University Press, USA, 186-208.

Jiang DA. 1999. Experiment Guidance for Plant Physiology. Science and Technology Press of Chengdu University, Chengdu, 63-65.

Jones MM, Turner NC. 1978. Osmotic adjustment in leaves of sorghum in response to water deficits. Plant Physiology **61,** 122-126. http://dx.doi.org/10.1104/pp.61.1.122

Khan GM, Dand GM, Shaw MH, Maruti A, Bali S, Singh KB. (1996) Response of intercropping system involving maize to irrigation level in Kashmir Valley. Indian Journal of Agricultural Science **66,** 272-275.

Kleinhenz MD. 2003. Sweet corn variety trials in Ohio: recent top performers and suggestions for future evaluations. Horticultural Technology **13,** 711-718.

Kumari J, Gadag RN, Jha GK. 2006. Heritability and correlation studies in sweet corn for quality traits, field emergence and grain yield. Monthly News Letter, Indian Agricultural Research Institute **80,**18-19.

Li HS. 2000. Principles and Techniques of Plant Physiological Biochemical Experiment. Higher Education Press, Beijing, 164-169.

Mallikarjunaswamy SN, Ramachandrappa BK, Nanjappa HV. 1999. Effect of Scheduling Irrigation at Different Phenophases of Sweet Corn (*Zea mays saccharata*) and Delineation of Critical Stages Based on Stress Day Index. Journal of Agronomy and Crop Science **182,** 161-166. http://dx.doi.org/10.1046/j.1439-037x.1999.00276.x

Moser SB, Feil B, Jampatong S, Stamp P. 2006. Effect of pre-anthesis drought nitrogen fertilizer rate and variety on grain yield, yield components and harvest index of tropical maize. Agricultural Water Management **81,** 41-58. https://doi.org/10.1016/j.agwat.2005.04.005

Osborne SL, Schepers JS, Francis DD, Schlemer MR. 2002. Use of spectral radiance to estimate in-season biomass and grain yield in nitrogen and water-stressed corn. Crop Science **42,** 165-171. http://dx.doi.org/10.2135/cropsci2002.0165

Randle WM, Davis DW, Groth JV. 1984. The effects of corn leaf rust on maturity and quality of fresh market ears of sweet corn. Journal of American Society of Horticutural Science **109,** 654-648.

Rosenthal WD, Arkin GF, Shouse PJ, Jordan WR. 1987. Water deficit effects on transportation and leaf growth. Agronomy Journal **79,** 1019-1026. http://dx.doi.org/10.2134/agronj1987.00021962007900060014x

Stone PJ, Wilson DR, Reid JB, Gillespie RN. 2001. Water deficit effects on sweet corn. I. Water use, radiation use efficiency growth and yield. Crop and Pasture Science **52,** 103-113. http://dx.doi.org/10.1071/AR99146

Tafrishi SG, Amir A, Tavakoli H, Khorasani SK, Joleini M. 2013. Impacts of Drought Stress and Planting Methods on Sweet Corn Yield and Water Use Efficiency. Journal of Plant Physiology and Breeding. **3,** 23-31.

Tang Q, Feng M. 1997. Practical statistics and its DPS statistical software package. China Agriculture Press, Bejing.

Yan QC. 2001. Seed Science. China Agricultural Press, Beijing, p.7-127