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Sweet corn crop yield response to aerated drip irrigation under various irrigation water management strategies

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Abstract

In the era of decreasing irrigation water availabilities, the focus must be on decreasing crop production water footprints. The various irrigation water management like deficit irrigation, fertigation, and mulching along with MIS can help reduce water footprints. However, the effects of aerated drip irrigation on sweet corn performance under various options of irrigation water management are not yet examined elsewhere. So, it was assessed through field experiments for 2 years during the winter season of the year 2020-21 and 2021-22 at the research farm of the Junagadh Agricultural University campus at Junagadh having a soil texture of clay loam. Two air injection rates i.e. 0 and 12 % by volume of irrigation flow rate was imposed on 16 different treatment combinations of 2 irrigation levels (deficit irrigation-0.7 ET_c and full irrigation-1.0 ET_c {Crop Evapotranspiration}), 2 fertigation levels (deficit fertigation-0.7 RDF and full fertigation-1.0 RDF {Recommended Dose of Fertilizer}), 2 drip system type (surface drip and subsurface drip) and 2 mulch levels (mulch and no mulch). The aerated irrigation effects on the production of fresh cob yield were found different under various options of irrigation water management. Overall, on average, sweet corn cob yield increased by 8.94% due to aerated irrigation as compared to non-aerated and the results were found significant. The adoption of aerated subsurface drip irrigation under mulch with irrigation/fertigation scheduling at 1.0 ET_c/1.0 RDF would result in higher yield if adopted by farmers, in other words, the yield increase of fresh cob would be almost twice as compared to traditional practices with benefit cost ratio (B/C) as 3.01 for aerated treatment and 2.78 for non-aerated treatment for subsurface drip irrigation under mulch with irrigation/fertigation scheduling at 1.0 ET_c/1.0 RDF.

Keywords aerated irrigation, deficit irrigation, fertigation, mulch, surface drip, sweet corn cob

Introduction

The major constraint for agricultural production is the limiting water resources. Therefore, farmers have the limitation of enhancing the inadequate income for their family livelihood from farming. This has created a migration of farming communities towards cities and industries for better income and livelihood. This has raised the various issues like crowding urbanization, sanitary, domestic water supply, and health. On the other side, this has created a shortage of labor force for the farm. These issues have directed policymakers and scientific communities to make agriculture profitable through technological interventions [1-8]. The Saurashtra region in Gujarat state of India is a water scared region. The rainfall is uncertain and the major amount of annual rainfall is concentrated in the July-August months only. The potential for natural groundwater recharge is very less due to poor spatial and temporal distributions of monsoon rainfall. There are no scopes for the major irrigation projects. More than 80 % of the irrigated area is from scared groundwater resources.

Drip irrigation is the most adaptable and adopted irrigation water management technology in this region having arid and semi-arid climates, however, aerated drip irrigation technologies are not widely adopted yet. Aerated irrigation (AI) has emerged as a method to mitigate rhizosphere hypoxia caused by wetting the front with drip irrigation (SDI). The low concentration of dissolved oxygen in the irrigation water may cause root oxygen deficiency which in turn can lead to hypoxia in the plant root zone. This can reduce root and plant growth and increase diseases due to poor microbial activities under hypoxia, which will hamper the yield [3]. Aerated drip irrigation increases root respiration along with other benefits of drip irrigation. However, for unlocking the yield potential of the crops, the adoption of the new paradigms of irrigation water management strategies like mulching, deficit irrigation, and aerated irrigation are today's requirements.

Nowadays, people have become more health conscious. The sweet corn baby and cob are highly nutritive. Presently, the sweet corn crop is adopted by a few farmers only even though it is highly profitable due to the lack of water resources. Also, there is a lack of location-specific empirical-based recommended irrigation water management technologies to produce more per drop of water. Therefore, there is a dire need of developing decision-support tools to produce sweet corn cob with fewer amounts of inputs with lower water footprints because of the increasing scarcity of water [3, 6].

The agricultural production system passes through the various abiotic stresses of unfavorable physical /chemical states of soil and environment as well as biotic stresses related to animals, insects, diseases, and weeds for all the crops. The anoxia or hypoxia conditions in the plant's rhizosphere can arise in the case of soil saturation for a longer period because of several causes such as flooding, soil compaction, extreme irrigation, deprived drainage, etc. This unfavorable environment of the rhizosphere damagingly impacts on below ground biomass like root length, density, thickness, etc, and above ground biomass, yield attributes, yield, and its quality [9-10]. Either anoxia or hypoxia hinders root respirations and enforces stomatal closure thus resulting in reduced photosynthesis and transpiration rate, leaf chlorophyll, and protein content [10-11]. The hypoxia condition significantly increases the activity of glutamate synthase and nitrate reductase, along with levels of ammonium, nitrate, heat-stable proteins, amino acids, hydrogen peroxide, and polyamines in the soil as reported by Gao et al., [12].

Past research made across the globe shows that oxygenation is required in the case of subsurface drip irrigation because of oxygen deficiency in plants' rhizosphere. The farmers need to adopt the package of water management practices like mulching, deficit irrigation/fertigation along with subsurface irrigation for minimizing the water footprints in this water scared region. Therefore, the present investigation was planned to evaluate the aerated drip irrigation effects on fresh green cob yield of sweet corn under the umbrella of various irrigation water management technology options like deficit irrigation, deficit fertigation, mulching, and subsurface drip irrigation.

Methodology

Study area

The experiment was conducted at the Research and Demonstration farm of the Soil and Water Conservation Engineering Department, College of Agricultural Engineering and Technology, Junagadh

Agricultural University, Junagadh. The climate of the study area is the subtropical and semi-arid type with an average annual rainfall of 900 mm and average annual pan evaporation of 5.6 mm day-1 during the period of the last 35 years. The area is characterized by a climatic condition of fairly cold and dry winter, hot and dry summer, and warm and moderately humid during monsoon. According to weather data recorded for 365 days of the last 35 years at the JAU observatory located near the experimental site, the monthly mean of daily max temperature, min temperature, relative humidity, wind speed, bright sunshine hours, and pan evaporation during the rabi season ranged from 30.2 °C to 38.9 °C, 12.2 °C to 22.2°C, 62.2 % to 74.4 %, 3.5 km/hr to 6.6 km/hr, 8.1 to 9.5 hours and 4.6 to 9.5 mm, respectively.

Experimental design

The adopted statistical design was a large plot technique. Two air injection rates i.e. 0 and 12 % by volume of irrigation flow rate [13] imposed on 16 different treatment combinations of 2 irrigation levels (deficit irrigation-0.7 ETc and full irrigation-1.0 ETc), 2 fertigation levels (deficit fertigation-0.7 RDF and full fertigation-1.0 RDF), 2 drip system type (Surface and subsurface drip), 2 mulch level (mulch and no mulch) and a farmers practices taken as a control.

Agronomic practices

During the first year (2020-21) and second year (2021-22) of experimentation, the sweet corn crop (Sugar-75 variety) was sown on December 8, 2020, and November 19, 2021. The recommended dose of fertilizer (RDF) and seed rate were 120: 60: 60: N: P_2O_5: K_2O kg/ha and 7.5 kg/ha respectively. The plant density was maintained as 53333 nos/ha. The inter-culturing, hand weedings, and plant protection measures were taken as per the requirements. In all the treatments, the plant geometry was adopted in a paired row having a spacing of 0.25m x0.4mx1.1m to maintain the recommended plant density. In the control, the plant geometry of 0.2m x 0.75m, 100% phosphorous and 50% of nitrogen and potash as basal, and the rest of RDF in 2 splits adopted as per the farmers' practices. The crop was irrigated through flood irrigation.

Irrigation system

The raised beds (15cm height x 0.6m top width x 0.75m base width) were made at 1.5m center to center spacing. The in-line lateral of 16 mm diameter having 0.4 m emitter spacing and 2 l ph emitter discharges was used. The in-line lateral was buried at 15cm below the ground surface for the subsurface drip irrigation treatments. One in-line lateral had served one pair of rows on each raised bed. The 16mm water meters were fitted to laterals to measure the irrigation water. The aerated irrigation was given using a venturi installed in the head unit. It simply sucks the air from the atmosphere and mixes it with water to increase the dissolved oxygen (DO) in flowing water, thus helping reduce hypoxia in the root zone. The air rotameter was fitted to venturi suction pipe to regulate the required air flow rate at the rate of 12% of water flow.

Irrigation and fertigation scheduling

The reference evapotranspiration was estimated as per the Penman-Monteith method given in FAO-56 [14] using the observed daily weather data of day maximum/minimum temperature, day maximum/minimum relative humidity, wind speed, bright sunshine hours, and location parameters like altitude, longitudes, and latitudes [14]. The daily reference evapotranspiration was also estimated by the pan evaporation method just for comparison only. However, the irrigation scheduling for the sweet corn crop was made using the reference evapotranspiration estimated by Penman-Monteith method as recommended by FAO. The crop evapotranspiration was calculated as multiplications of reference evapotranspiration (ETo) and stages wise adjusted Kc value given by FAO-56 [14]. The adjusted crop coefficient (Kcadj) for the sweet corn crop was found as 0.27 during 0-20 DAS, 0.27 to 1.31 during 21-50 DAS, 1.31 during 51-100 DAS and 1.31 to 1.21 during 101 to

110 DAS. The deficit irrigation was given at 70% of ETc ie. 70% of crop water requirement while the deficit fertigation was given at 70% of the recommended dose of fertilizer (RDF). The irrigation and fertigation were scheduled respectively at 3 and 9 days intervals as per the treatments. The irrigation interval was taken as 3 days so that the required wetted strip between two rows of pairs would be obtained for the required irrigation time considering the soil texture [1].

The cropping period of sweet corn is about 100 days consisting of different vegetative and reproductive stages. The vegetative stage starts from VE (emergence) and covers V1 to V10 (vegetative growth of the sweet corn starting from 1 to 10 leaves respectively) and VT (tasseling) among which VT is the most sensitive stage to moisture stress. The reproductive stage starts from R1 (silking) to R3 (milking i.e cob harvesting stage).

Results and Discussion

Climate

The meteorological information such as temperature, relative humidity, daily bright sunshine, pan evaporation, thermal heat units, and reference evapotranspiration during the experimentation of both years (First year: December 21 to March 21, Second year: November 21 to February 2022) are depicted in Figure 1 (A to F) respectively.

Minimum and maximum day temperature

Day minimum and maximum temperature observed from the date of sowing to 100 days after sowing during both the years of 2020-21 and 2021-22 are shown in Figure 1(A). The day minimum and maximum temperatures were respectively varying from 6.7 °C to 23.4 °C and 24.5 °C to 38.9 °C during the year 2020-21 and 6.1 °C to 23.6 °C and 23 °C to 34.5 °C during 2021-22. The daily mean temperature during the year 2020-21 and 2021-22 was observed as 16.55 °C to 31.1 °C and 15.45 °C to 28.3 °C respectively. During the earlier growth stages, the sweet corn crop was exposed to cooler climates while warmer during the latter growth stages in the first year as compared to the second year and vice versa for the second year.

Minimum and maximum day relative humidity (Rh)

Day minimum and maximum Rh observed during experimentation of both the years 2020-21 and 2021-22 are shown in Figure 1(B). The lowest and highest day minimum Rh was observed as 9 % and 60 % respectively during the year 2020-21 and 19 % and 82 % during the year 2021-22 while the lowest and highest day maximum Rh was observed as 36 % and 96 % respectively during the year 2020-21 and 19 % and 98 % during the year 2021-22. The mean day Rh varied from 27.5 % to 76 % during the first year and 24 % to 85.5 % during the second year. The atmosphere during the second year was more humid than the first year. It was also reflected in pan evaporation; reference evapotranspiration and crop evapotranspiration which all were lower during the second year as compared to the first year.

Bright sunshine hours

The bright sunshine hours were observed varying from 0.1 h to 10.6 h with an average of 7.0 h during the year 2020-21 and from 0.1 h to 10.4 h with an average of 7.4 h during the year 2021-22 (Figure 1C). It indicated that more energy was available to crop during the year 2021-22 as compared to the year 2020-21.

Daily pan evaporation

The daily pan evaporation and cumulative pan evaporation at various days after sowing during the year 2020-21 and 2021-22 were depicted in Figure 1(D). The daily pan evaporation was observed varying from 2.8 mm to 9.3 mm with an average of 5.4 mm during the year 2020-21 and from 0.9 mm to 7.1 mm with an average of 4.5 mm during the year 2021-22. The lower pan evaporation during the year 2021-22 was due to a more humid and less warm environment as compared to the year 2020-21. It could also be seen that cumulative pan evaporation from sowing to 100 days after sowing remained higher during 2020-21 as compared to 2021-22. The total pan evaporation from sowing to 100 days after swing was observed as 546.55 mm & 456.90 mm during the year 2020-21 & 2021-22 respectively.

Thermal heat units

The daily thermal heat units available for the physiological growth of sweet corn crop was taken as the difference between the daily mean temperature and base temperature of 10 °C for the sweet corn crop. The cumulative thermal heat units from sowing to 100 days after sowing for the 2 years of experimentation are depicted in Figure 1(E). It can be seen that the thermal heat units accumulated from sowing to 25, 50, 75, and 100 days after sowing during the first year 2020-21 were found as 292.5, 533.45, 826.05, and 1257.5 degree-days respectively. The thermal heat units available to crop from 0 to 88 days after sowing were lower during the first year as compared to the second year. However, after 88 days, it was lower for the second year as compared to the first year. During the second year, the accumulated thermal heat units available to sweet corn plants were found as 358.2, 650.4, 880.6, and 1200.9 degree-days at 25, 50, 75, and 100 days after sowing. The warmer weather i.e. degree days was available during the second year as compared to the first year up to the flowering stage helped for higher crop production. Similar results were also found by Williams and Lindquist [15].

Reference Evapotranspiration

The average daily pan evaporation during the 100 days season was found as 5.47 mm/day and 4.57mm/day during the year 2020-21 and 2021-22 respectively. The total reference evapotranspiration of 100 days estimated by the pan evaporation method was found as 382.59 mm and 319.83 mm respectively during the first and second year respectively while that estimated by Penman-Monteith method was found as 364 mm and 313 mm respectively. The differences between reference evapotranspiration estimated by both methods were negligible. The cumulative reference evapotranspiration estimated by both methods from sowing to 100 days after sowing during the first year 2020-21 were remained consistently higher because of lower relative humidity than that of the second-year 2021-22.

Water consumption

The soil moisture was found stored in the root zone due to monsoon rainfall. At the sowing and harvesting time, the differences in soil moisture were measured. The decrease in the soil moisture storage was taken as green water utilization by the sweet corn crop as it is rainwater storage. The average of the soil moisture utilized by the sweet corn crop was found as 25 mm and 14 mm under the treatments of irrigation levels of 70 % and 100 % crop evapotranspiration. The total irrigation applications were found as 216 mm and 303 mm using groundwater (as blue water) under the treatments of irrigation levels of 70 % and 100 % crop evapotranspiration. Therefore, the total water utilized (Green and blue water) was found as 241 mm and 317 mm respectively under treatments of irrigation levels of 70 % and 100 % ETc. The blue and green water under control were found as 390 and 24 mm respectively.

Fresh cob yield

The comparisons of fresh green cobs obtained under various levels of aeration, irrigation, fertigation, and surface and subsurface drip with and without mulch for sweet corn are shown in Table 1. The cob yield under control (farmers' practices) was found as 13890 kg/ha. It can be seen that the lowest of 15201 kg/ha and highest of 27667 kg/ha fresh green cob yields were observed under treatment

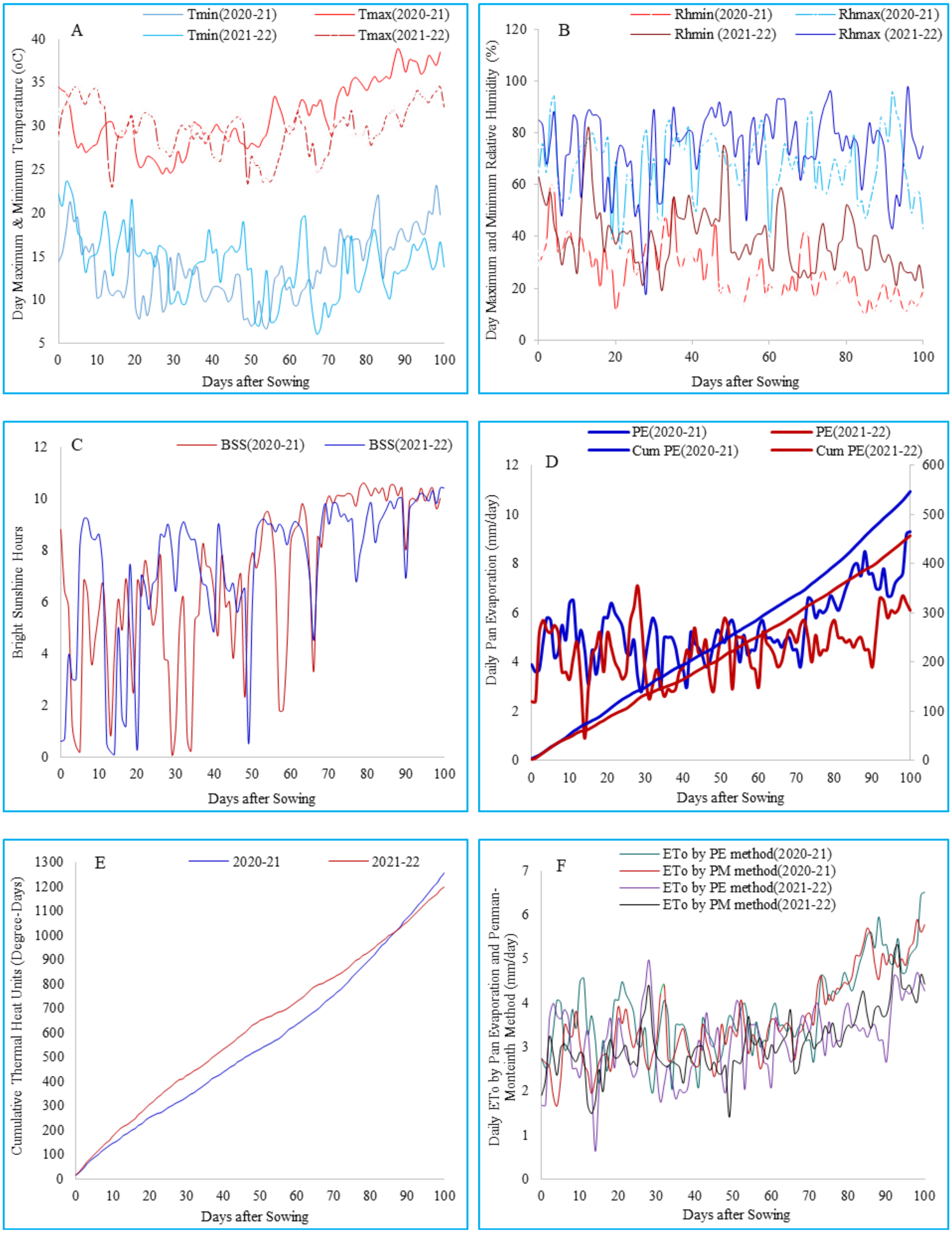

Figure 1. The variation of (A) Day maximum and minimum temperature (B) Day maximum and minimum relative humidity (C) Bright sunshine hours (D) Daily pan evaporation (E) Cumulative thermal heat units (F) Reference Evapotranspiration at various days after sowing during 2020-21 and 2021-22

having surface drip irrigation (non-aerated) with irrigation/ fertigation schedules at 0.7 ETc /0.7 RDF without mulch and treatment having sub-surface drip irrigation with irrigation/ fertigation scheduled at 1.0 ETc /1.0 RDF under mulch (aerated) respectively, which were higher by 13.56 % and 99.18 % as compared to control (farmers practices). The treatment effects of aerated irrigation on fresh green cobs were affected by irrigation/ fertigation level, surface/subsurface drip, and with/without mulch. The fresh green cobs were found to increase by treatment effects of aeration level under all irrigation water management options. It can be seen that the fresh green cobs were increased by 8.94% due to aerated irrigation as compared to non-aerated irrigation. The data presented in Table 1, shows that aerated irrigation is more effective under treatments of full irrigation, full fertigation, and subsurface drip irrigation and mulch adoptions.

Effects of aerated irrigation under no mulch and mulch

The average effects of air injection under irrigation water management strategies of various irrigation/fertigation levels and drip irrigation types are depicted in Table 2. It can be seen that aerated irrigation can help to increase the fresh cob yield of sweet corn by the tune of 8.2 % and 9.62 % respectively under no mulch and mulch. The aerated irrigation is more effective if the mulching is adopted as the yield increase under no mulch and mulch were 49.23 and 66.37% as compared to the control. The reason would be that there could be a more favorable environment for microorganism growth due to the optimal root zone environment under mulch. The mulch application decreases heat loss radiation from the soil at night and increases the reflection of solar radiation in the day thus, resulting in increased minimum temperature and decreased maximum temperature and hence reducing diurnal variation in topsoil temperature [16] which promotes a favorable environment for the growth of soil microorganism. Having a less-variable soil temperature and topsoil water content closer to field capacity commonly errands healthy growth of microorganisms and crops causing higher crop yield [17], particularly for low readily available water-holding capacity soils [18] or low albedo. An increase in nutrient and water uptake can be caused by higher soil water content in the surface soil and less diurnal top-soil temperature variation [19, 20], which would intensify the effect of mulch and aerated irrigation on growth and development.

Effects of aerated irrigation under surface and subsurface drip

The average effects of air injection under irrigation water management strategies of various irrigation/fertigation levels and mulch levels showed that it can help to increase the fresh cob yield of sweet corn by 6.25 % and 12.02 % under surface and sub-surface drip irrigation respectively. The aerated irrigation is more effective under subsurface drip as compared to surface drip because the yield increase was 75.80 and 51.95% respectively as compared to the control. The reason would be that there could be more deficiency of oxygen in the root zone because of higher soil moisture under the subsurface drip. The present results show that the fresh green cob yield was higher than that of surface drip, particularly to reduce losses of evaporation from wet soil. The higher performance of sweet corn crops under subsurface drip irrigation over surface drip was found in the present research. It was also supported by Lamm and Trooien [21]. They also reported that nitrogen fertigation was a very effective management tool with SSDI, serving a maximize corn grain yield, while gaining high efficiencies of nitrogen and water use.

Effects of aerated irrigation under deficit and full fertigation

The average effects of air injection under irrigation water management strategies of various mulch levels, drip irrigation types, and irrigation levels level showed that it can increase the fresh cob yield of sweet corn by 8.19 % and 9.58 % under deficit and full fertigation respectively. The aerated irrigation is more effective under full fertigation as compared to deficit fertigation because the yield increase was 71.15 and 44.45% respectively as compared to control. The reason would be that aerated irrigation helped to have more nutriment availabilities because of more doze of nutriment

Table 1. Effects of air injection on sweet corn cob yield under various irrigation water management strategies

SN.	Irrigation level	Fertigation level	Drip system type	Mulch level	Fresh cob yield (kg/ha)		Yield increase (%) as compared to control	Yield increase (%) due to air injection
					0% air injection	12% air injection		
1	70% of ETc	70% of RDF	SDI	NM	15201	15680	12.88	3.15
2	70% of ETc	70% of RDF	SDI	Mulch	17724	18539	33.47	4.60
3	70% of ETc	70% of RDF	SSDI	NM	17577	19288	38.86	9.73
4	70% of ETc	70% of RDF	SSDI	Mulch	19293	21484	54.67	11.36
5	70% of ETc	100% of RDF	SDI	NM	18032	18880	35.93	4.70
6	70% of ETc	100% of RDF	SDI	Mulch	20304	21634	55.75	6.55
7	70% of ETc	100% of RDF	SSDI	NM	20553	22658	63.13	10.24
8	70% of ETc	100% of RDF	SSDI	Mulch	21705	24180	74.08	11.40
9	100% of ETc	70% of RDF	SDI	NM	17605	18398	32.45	4.50
10	100% of ETc	70% of RDF	SDI	Mulch	20234	21610	55.58	6.80
11	100% of ETc	70% of RDF	SSDI	NM	19420	21566	55.26	11.05
12	100% of ETc	70% of RDF	SSDI	Mulch	21303	23945	72.39	12.40
13	100% of ETc	100% of RDF	SDI	NM	21429	22865	64.62	6.70
14	100% of ETc	100% of RDF	SDI	Mulch	23721	25809	85.81	8.80
15	100% of ETc	100% of RDF	SSDI	NM	23444	26493	90.73	13.00
16	100% of ETc	100% of RDF	SSDI	Mulch	24363	27667	99.18	13.56
	Average	-	-	-	20119	21919	57.80	8.94
17	Control (Farmers traditional practices)				13890	-	-	-
S.Em.±					**281.48**			
C.D. at 5 %					**795.24**			
C.V. %					**10.71**			

ETc =Crop evapotranspiration, RDF=Recommended dose of fertilizer, SDI=surface drip irrigation, SSDI=Subsurface drip irrigation, M=mulch and NM=No mulch

under full fertigation level. These results are in toeing line with those obtained by Hassanein et al., [22]. The results on corn response to fertigation level found by Bibe et al., [23] were contradictory. They showed that significantly higher fodder yield, grain yield, and biological yield was observed with 100 % RDF through a drip which was at par with 75 % RDF through the drip.

Effects of aerated irrigation under deficit and full irrigation

The average effects of air injection under irrigation water management strategies of various mulch levels drip irrigation types, and fertigation levels showed that it can increase the fresh cob yield of sweet corn by 7.95% and 9.81 % under deficit and full irrigation respectively. Aerated irrigation is more effective under full irrigation as compared to deficit irrigation because the yield increases were 69.5% and 46.10% respectively as compared to control. Bibe et al., [23] also found that drip irrigation at 1.0 PE registered a significantly higher yield of maize than 0.6 PE and was at par with 0.8 PE. The reason is that under deficit irrigation there would be less deficiency of oxygen as compared to full irrigation.

Table 2. Average effects of aerated irrigation under various irrigation water management strategies

Irrigation water management strategies	Average fresh cob yield (kg/ha)		Yield increase (%) as compared to control	Yield increase (%) due to air injection
	0% air injection	12% air injection		
Strategies-1	**Mulch**			
No Mulch	19158	20729	49.23	8.20
25µ SB plastic mulch	21081	23109	66.37	9.62
Strategies-2	**Surface and subsurface drip irrigation**			
Surface drip irrigation	19864	21105	51.95	6.25
Sub surface drip irrigation	21798	24418	75.80	12.02
Strategies-3	**Fertigation level**			
Deficit fertigation (0.7 RDF)	18545	20064	44.45	8.19
Full fertigation (1.0 RDF)	21694	23773	71.15	9.58
Strategies-4	**Irrigation level**			
Deficit irrigation (0.7 ETc)	18799	20293	46.10	7.95
Full irrigation (1.0 ETc)	21440	23544	69.50	9.81
S.Em.±	**281.48**			
C.D. at 5 %	**795.24**			
C.V. %	**10.71**			

Discussion

The fresh green cob yield of the sweet corn crop was influenced by aerated irrigation under all treatments combinations of surface drip and sub-surface drip irrigation, mulch and non-mulch, full irrigation and 30 % deficit irrigation as well as full RDF and 30 % deficit fertilizer. However, in the present study, the aerated irrigation effect was less under surface drip as compared to subsurface drip to increase the yield. The reason might be the hypoxia conditions in the plant rhizosphere during and after irrigation under the subsurface drip. Similar results were also found by Abuarab et al., [24]. They evaluated the effect of air injection into the irrigation stream in subsurface drip irrigation on the performance of corn. They found that the effects of aerated irrigation were more in subsurface irrigation as compared to surface drip irrigation. Yield increases due to air injection were 37.78% and 12.27% greater in 2010 and 38.46% and 12.5% in 2011 under the subsurface and subsurface drip treatments, respectively. Data from this study indicated that corn yield can be improved under surface drip if the dripping water is aerated. Subsurface drip irrigation (SSDI) has shown great potential for improving water use efficiency, reducing irrigation water application, and minimizing the potentially negative environmental effects of irrigation. However, oxygen deficiency in the soil caused by sustained wetting fronts under SSDI can negatively impact root aeration [25]. Moreover, crop roots preferentially grow near the drip head [26], which exacerbates the harm of soil hypoxia to crop roots near the drip head; on the other hand, the higher frequency of subsurface drip irrigation [27] will intermittently lead to an increase in soil water content, which increases the degree of tortuosity of soil oxygen transport paths [28] and reduces the availability and diffusivity of soil oxygen [29].

Aerated irrigation (AI) has emerged as a method to mitigate hypoxic conditions; it is defined as the delivery of aerated water directly to the root zone by subsurface drip irrigation (SDI) [30-31]. With the use of AI, substantial quantities of oxygen both in the gaseous phase and dissolved in water can be delivered via subsurface pipes and emitters to the root zone. Many studies have shown the advantages of AI for crop growth and yield potentials [32-33]. Furthermore, based on SSDI, AI further improves water use efficiency [34]. At the macro-level, sustainable irrigation developed from AI and SSDI to balance the supply of soil water, oxygen, nutrients, and agrochemicals may provide a future direction for irrigation [35]. Yu et al., [29] also found that as compared to non-aerated irrigation, the aerated irrigation treatment significantly increased the soil respiration rate and soil oxygen content (15.38-17.87 % and 18.94-25.17 % respectively), as well as the root biomass and soil bacterial biomass (14.99~19.09 % and 35.10~45.59 %, respectively), and reduced the soil water content by 5.33~12.71 %. The mean corn yield with aerated irrigation was also 7.16~20.51 % higher than that with non-aerated irrigation, and the stem thickness and leaf area of maize plants were significantly increased (9.31~17.06 % and 8.68~15.20 %, respectively). Bhattarai et al., [13] demonstrated that aerated irrigation technology can drive soil respiration rate by changing soil oxygen content and root biomass. Furthermore, the improvements in soil aeration conditions and respiration with aerated irrigation appeared to facilitate the improvement in yields, which also suggests the economic benefits of AI.

Conclusion

The effects of aerated irrigation on the yield of fresh cob yield depends on the adoption of various options for irrigation water management. The aerated irrigation can help to increase the fresh cob yield of sweet corn respectively as 8.2 % and 9.62 % under no mulch and mulch, 6.25 % and 12.02 % under surface and sub-surface drip irrigation, 8.19 % and 9.58 % under deficit and full fertigation and 7.95% and 9.81 % under deficit and full irrigation. The average yield of fresh cob yield of sweet corn crops under various adopted strategies could be increased by 8.94% due to aerated irrigation as compared to non-aerated.

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