www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(6): 1525-1531

www.thepharmajournal.com
Received: xx-03-2022
Accepted: xx-04-2022

Prasang H Rank
Ph.D., Research Scholar, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering & Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

Dr. RM Satasiya
Principal, Department of Agricultural Engineering, Junagadh Agricultural University, Targhadia, Gujarat, India

Corresponding Author:
Prasang H Rank
Ph.D., Research Scholar, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering & Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

Sweet corn crop (*Zea mays* L.) performance under various irrigation water management strategies

Prasang H Rank and Dr. RM Satasiya

Abstract
An experiment was conducted for 2 years (Dec.2020 to March-2021 and Nov. 2021 to Feb. 2022) to assess sweet corn crop performance under various irrigation water management strategies. Sweet corn was grown in winter season at the research farm. JAU, Junagadh, Gujarat, India. Total 32 treatments comprising of aerated and non-aerated irrigation, deficit irrigation (0.7 ETc) and full irrigation (1.0 ETc), deficit fertigation (0.7 RDF) and full fertigation (1.0 RDF), Surface drip and subsurface drip and with/ without mulch. The yield of fresh green cob and fodder were observed from each of 2 replications of each of 32 treatment. The fresh cob yield was increased by 8.94% due to aerated irrigation as compared to non-aerated. The increase in irrigation applications from 70% of ET_c to 100% ET_c increased the fresh cob yield by 15.07%. The yield could be enhanced by the tune of 17.77% by increasing the fertigation level from 0.7 RDF to 1.0 RDF. The mulch adoption helped increase yield by 21.67% under surface drip irrigation while by 7.57% only under subsurface drip irrigation as compared to no mulch. The adoptions of subsurface drip irrigation could increase the cob yield by 22.69% under no mulch and 8.47% under mulch as compared to surface drip irrigation.

Keywords: Sweet corn, aerated irrigation, deficit irrigation, fertigation, surface drip, subsurface drip, mulch

1. Introduction

The water productivity in agriculture can be enhanced through adoption of MIS with its new dimensions of technologies. Out of a total 140.13 million hectares of sown area, India's net irrigated area is 68.38 million ha (48.7%) only while 71.74 million hectares are unirrigated. This requires to promote the water use efficient micro Irrigation Systems (MISs). The estimated potential of micro irrigation in India is 69.5 Mha, whereas the area covered so far is only about 15.011 Mha. The penetration of micro irrigation in India is 19%, which is much lesser than many countries. However, the MIS system saves lots of water by not allowing water to percolate but the farmers willing to see the soil wetted full after the irrigation causes enormous amount of water use. The wetting pattern around the plant root zone also gives better environment for root zone to grow (Rank, *et al.*, 2019) [28]. The new dimensions of irrigation water management like MIS, aerated irrigation, deficit irrigation, fertigation, subsurface irrigation and mulching can only help to boost water productivity along with nutritional security.

1.1 Sweet corn crop

Sweet corn is the crop which can be helpful for the nutritive supports to human body. The sweet corn is considered the most nutritive fruit as it contains starch (18.2%), carbohydrates (19%), fibre (2.4%) and protein (3.4%). Sweet corn is a variety of maize grown for human consumption with a high sugar content. Sweet corn is the result of a naturally occurring recessive mutation in the genes which control conversion of sugar to starch inside the endosperm of the corn kernel. One of the main nutritional benefits of sweet corn is its high fiber content. And as we know, dietary fiber is important for our health: it aids digestion, it can decrease the risk of heart disease, strokes, type 2 diabetes and bowel cancer. On top of that, fiber helps you stay fuller for longer.

The sweet corn crop is grown in few patched areas only even though it is highly profitable. The reason is the lack of recommended package of practices on irrigation and fertigation strategies. Also, there is a need to reduce the water footprints of its production because of increasing scarcity of water. The water footprints of sweet corn production can be shrunk by adoptions of MIS with its new dimensions of technologies.

Therefore, the present investigation was planned with the objectives to sweet cop performance under drip irrigation having different irrigation water management strategies like aerated irrigation, deficit irrigation and fertigation, subsurface drip, subsurface drip and mulching technology and cost economics.

1.2 Aerated Irrigation

The aerated irrigation is the enhancement of dissolved oxygen (DO) of irrigation water. Aerated irrigation improves soil aeration, increases oxygen concentration and air-filled porosity. Aerated irrigation enhanced soil, microbial, and root respiration and microbe abundance. A low DO concentration in the irrigation water may have critical consequences, as it causes root oxygen deficiency which in turn can lead to agronomic problems such as crop stress, slow plant growth, low microbial activities, or low yields. However, Pulse Irrigation was also found as an alternative for aerated irrigation by surging on/off irrigation cycles. Rank and Vishnu (2021a; 2021b) [30, 31] reviewed and gave designed concept of Pulse Irrigation. Also Rank and Vishnu (2019) [29] gave detailed automation procedure for pulse irrigation. Moreover, oxygen deficiency in the root zone of plants can lead to poor root and plant performance and an increase in disease (Bhattarai *et al*., 2013, Chen *et al*., 2011, Friedman and Naftaliev, 2012, Abuarab *et al*., 2013, Li *et al*., 2015, Ben-Noah and Friedman, 2016, Li *et al*., 2016, Yan *et al*., 2019, Panich *et al*., 2021, Wei *et al*., 2021, Yu *et al*, 2022) [5, 8, 12, 2, 19, 4, 20, 41, 25, 40, 42].

1.3 Irrigation and fertilizer stress

The water footprints of agricultural produce can be reduced by efficient use of water. This can be achieved with deficit irrigation under optimal drip fertigation. The deficit irrigation helps to reduce excess vegetative growth and increase the harvest index. The enough empirical evidences on crop performance under varying degree of water and fertigation inputs for most of the crops are assessed in the world. In fact, in India also, such researches are done for few crops under varying soils and climates. The maximum water productivity can be achieved under optimal levels of water and fertilizer inputs. The excess of either irrigation water or fertilizer results to percolation below rootzone which pollute the soil as well as the groundwater. The heavy vegetative growth due to more irrigation water and fertilizer over optimal level reduces the harvestable yield. The optimal levels of irrigation and fertilizer depended on soil characteristics, crop and its variety, local climate and method of applications (Erdem *et al*. (2010, Abbas, 2012, Ertek and Kara, 2013, Bibe *et al*., 2017 [6], Nilahyane *et al*., 2018, Mubarak, 2020, Zou *et al*., 2021, Flynn *et al*., 2022) [9, 1, 10, 24, 23, 44, 11].

1.4 Subsurface drip irrigation

Subsurface drip irrigation is a high efficiency irrigation system that uses buried drip tubes or drip tape which supply water directly in the root zone bulb. Subsurface irrigation saves water and improves yields by eliminating surface water evaporation and reducing the incidence of weeds and disease. The subsurface irrigation is adopted widely in advanced countries and also in India to a little extent. The enough evidences of its success to reduce the irrigation water requirements are available (Kandelous *et al*., 2011, Tripathi *et al*., 2016, Hashem *et al*., 2018, Pendergast *et al*., 2019, Mansour *et al*., 2019, Valentín *et al*.,2020, Thamer *et al*. 2021a, Mohammed and Irmak, 2022) [16, 36, 13, 26, 21, 37, 34].

1.5 Mulching

Mulching can potentially serve the purpose of reducing soil evaporation, conserving moisture, controlling soil temperature, reducing weed growth, and improving microbial activities and improve the economic value of crops. The improved performance of crops through mulch adoptions under varying soils and climates are well documented (Igbaduna *et al*., 2012, Vial *et al*., 201, Helaly *et al*., 2017, Teame *et al*., 2017, Kumar and Sharma, 2018, Rahma *et al*., 2019, Wang *et al*., 2021, Zang *et al*., 2022) [15, 38, 14, 33, 18, 27, 39].
In the present study, the field experiment for assessing the sweet corn crop response to non-aerated/ aerated drip irrigation, deficit irrigation/fertigation, surface/ subsurface drip irrigation and no mulch / mulch was undertaken.

2. Study area

The site of the field experiment is located at 21.5º N latitude and 70.1º E longitude with an altitude of 82 m above mean sea level. The climate of the study area is 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 last 35 years. The area is characterized by climatic condition of fairly cold and dry winter, hot and dry summer and warm and moderately humid during monsoon. Winter sets in the month of November and continues till the end of February. Summer commences in the second fortnight of February and ends in the middle of June. April and May are the hottest month of summer. According to weather data recorded for 365 days of last 35 years at the JAU observatory located near to 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. The soil type of the experimental field is clay loam.

3. Materials and Methods

3.1 Experimental details

During the first year (2020-21) and second year (2021-22) of experimentation, sweet corn crop was sown on December 8, 2020 and November 19, 2021. The experimental details were as below. Total 32 treatments were comprised of 2 aeration levels, 2 irrigation levels, 2 fertigation levels and four irrigation types (surface drip with and without mulch and subsurface drip with and without mulch). These treatments were A1E1F1S, A1E1F1Sm, A1E1F1SS, A1E1F1SSm, A1E1F2S, A1E1F2Sm, A1E1F2SS, A1E1F2SSm, A1E2F1S, A1E2F1Sm, A1E2F1SS, A1E2F1SSm, A1E2F2S, A1E2F2Sm, A1E2F2SS, A1E2F2SSm, A2E1F1S, A2E1F1Sm, A2E1F1SS, A2E1F1SSm, A2E1F2S, A2E1F2Sm, A2E1F2SS, A2E1F2SSm, A2E2F1S, A2E2F1Sm, A2E2F1SS, A2E2F1SSm, A2E2F2S, A2E2F2Sm, A2E2F2SS and A2E2F2SSm.

Crop details	Treatment details
1. Crop: Sweet Corn (*Zea mays* L.) 2. Variety: Sugar-75 3. Crop growing season: Rabi season (Dec., 20 to Mar., 21) & (Nov.,21 to Feb., 22). 4. Plant Spacing: a. Pair/Bed spacing = 110 cm b. Plant Spacing = 25 cm × 40 cm c. No of row per bed = 2 5. Plot Size: a. Gross plot size of each replication of each treatment: 6 m × 3 m b. Net plot size of each replication of each treatment: 5 m × 3 m c. Experimental area: 96 m × 12 m 6. Recommended dose of fertilizer (kg/ha): 120: 60: 60:: N: P_2O_5: K_2O 7. Seed Rate: 7.5 kg/ha	**Treatments** Factor - I: Irrigation techniques A1 – Non-Aerated Irrigation A2 – Aerated Irrigation Factor - II: Water stress level E1 – 30% water stress (0.7 ETc) E2 – 0% water stress (1.0 ETc) Factor-III: Fertigation reduction level F1 – 30% fertilizer stress (0.7 RDF) F2 – 0% fertilizer stress (1.0 RDF) Factor – IV: Irrigation type S – Surface Drip + No Mulch SS – Subsurface Drip + No Mulch Sm – Surface Drip + Mulch SSm – Subsurface Drip + Mulch Total Treatments: 32 Treatment Combinations No. of Replications: 2 **Statistical Design:** Large Plot Technique

3.2 Drip irrigation system
The venturi with dust filter with air rotameter was connected with the sub main to supply oxygen enriched irrigation water to all treatments of aerated irrigation. The air flow was regulated as 12% of irrigation water flow though valve between venturi and rotameter. The PVC pipes of 75 mm Ø/63 mm Ø was used as main and submains for the irrigation purpose. The LLDPE inline lateral of 16 mm Ø x 0.4 m x 2 lph was used. The battery-operated fertilizer pump was used to inject the fertilizer in the drip line. The 16 mm water meter was fitted at inlet of 16 mm lateral to meter the irrigation water supply to the crop under treatments. Silver-Black plastic mulch having 25-micron thickness and 1.2 m width was used as a mulch treatment.
Total 2 levels *viz.* aerated irrigation water applications and without aerated irrigation water applications were studied. The irrigation water was made aerated by venturi injector before it gets emitted through drippers. The surface and subsurface drip irrigation system was installed before sowing. It was fitted and laid as per the experimental layout design using the materials/equipment/instruments. The subsurface drip was installed at 15 cm below the ground surface. The paired row plant geometry was adopted to reduce the cost of lateral. After the installation of subsurface irrigation system, the beds of 15 cm were prepared for each treatment. The beds were levelled properly before sowing and mulch installation. The drip lateral for the surface irrigation treatments was laid on the middle of the bed. Silver/Black plastic mulch was laid on the bed and anchored it's both edges in the ground for surface drip as well as subsurface drip irrigation. The width of mulch was 1.2 m, in which 10 cm was buried on both sides with soil. The mulch had 2 rows of holes in zig-zag pattern at 0.4 m x 0.25 m for sowing the seed at 25mm below the bed surface. Four treatments were applied i.e. surface drip irrigation without mulch (SDI), surface drip irrigation with silver/black plastic mulch (SDIM), sub surface drip irrigation without mulch (SSDI) and subsurface drip irrigation with silver/black plastic mulch (SSDIM).

3.3 Irrigation water applications
The irrigation application was made based on the crop evapotranspiration (ET_c). It was taken as product of reference evapotranspiration (ET_o) and crop coefficient (Kc). Reference evapotranspiration (ET0) was calculated using the FAO Penman-Monteith (PM) method (Allen *et al.*, 1998). The daily ET_o was computed using the data of daily maximum and minimum temperature, maximum and minimum relative humidity, wind speed, and bright sun shine hours using the FAO Penman-Monteith (PM) method.
ET_c was determined by the crop coefficient approach where the effects of various weather conditions are incorporated into ET_o and the crop characteristics into the crop coefficient:

$$\sum_{i=1}^{3} ET_{ci} = \sum_{i=1}^{3} K_{ci}\, ET_{0i} \quad (1)$$

Where
ET_{ci} = Crop evapotranspiration of i^{th} day,
K_{ci} = Crop coefficient of i^{th} day,
ET_{0i} = Reference evapotranspiration of i^{th} day

The irrigation interval was fixed at 3 days interval for the crop so that irrigation operation time can be enough to wet the entire width strip between paired rows. The daily ET_o was multiplied with corresponding K_c value of DAS (days after sowing). That gave the ET_c for the crop, thus it was the water requirement of the crop. The irrigation water applications for 30% deficit treatment was 70% of ET_c. The treatment of 100% of ET_c, was no stress treatment. So total of 2 irigation levels as 0.7 ET_c and 1.0 ET_c were applied.

3.4 Drip Fertigation
The 100% Phosphorous of RDF through SSP (16% P), 20% of Nitrogen of RDF though Urea (46% N) and 20% of potash through Murate of Potash (60% K) was applied as basal dose before sowing. The 80% of N and K was applied through equal 8 splits though soluble urea and MOP respectively. The fertigation was made in total 8 splits at 9 days interval, starting from 21^{st} days after sowing. So total of 2 fertigation level as 0.7 RDF and 1.0 RDF were applied.

4. Results and Discussion
The crop period of sweet corn is about 100 days. The cobs were harvested manually for each treatment and weighted separately. The fresh green cobs from the plants in each replication plots of all treatments were harvested and recorded separately. 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 Fig. 1. It can be seen in Fig. 1 that the lowest of 15201 kg/ha and highest of 27607 kg/ha fresh green cobs were observed under treatment having non aerated surface drip irrigation following irrigation and fertigation schedules at 0.7 ET_c and 0.7 RDF under no mulch (A1E1F1S) and treatment having aerated sub surface drip irrigation following irrigation and fertigation schedules at 1.0 ET_c and 1.0 RDF under mulch ($A2E2F2SS_m$) respectively. The fresh green cobs were affected by different treatments of aeration level, irrigation level, and fertigation level, surface drip and subsurface drip with and without mulch. The fresh green cobs under all the treatment was found increased by treatment effects of irrigation/fertigation level under various irrigation practices.

It can be seen in the Table 1 that the fresh green cobs were increased by 8.94% due to aerated irrigation as compared to non-aerated irrigation. When the irrigation to sweet corn crop was increased from 70% of ET_c to 100% of ET_c., the sweet corn fresh green cobs was increased by 15.07%. Similarly, it was increased by 17.77% under fertigation level of 100% RDF as compared to 70% RDF. The fresh green cobs of sweet corn crop were increased by 21.67% and 7.57% due to mulch adoption in surface and subsurface drip irrigation respectively. Similarly, it was found increased by the tune of 22.69% and 8.47% due to subsurface drip adoption under no mulch and mulch respectively as compared to surface drip irrigation.

The similar results were also observed by Abuarab *et al*. (2013) [2]. They evaluated the effect of air-injection into the irrigation stream in SDI on the performance of corn. They found that the effects of aerated irrigation were more in subsurface irrigation as compare 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 compared to the DI and SDI treatments, respectively. Data from this study indicate that corn yield can be improved under SDI if the drip water is aerated.

The results on sweet corn crop response to irrigation level shows that the fresh green cob yield increases with increase irrigation level from 0.7ETc to 1.0 ETc. Bibe *et al* (2017) [6] also found that irrigation levels significantly influenced the grain yield of maize. Drip irrigation at 1.0 PE registered significantly higher grain yield of maize than 0.6 PE and was at par with 0.8 PE. The increased in irrigation level from 0.4 ET_c to 1.0 ET_c had increased the sweet corn yield as per results reported by Ertek and Kara (2013) [10]. They also reported that the water deficit irrigation had affected on sweet corn fresh ear yields, yield components, quality and water use efficiencies.

The present results on crop performance to different levels of drip fertigation are comparable to most of the research reported in the world and contradictory to a few only. In fact, drip fertigation not only increase the yield but also saves the fertilizer, reduces the soil, water and environment pollutions. Sandal and Kapoor (2015) [32] reviewed the crop performance to fertigation for many crops. They found that the fertigation is an excellent technique of application of fertilizers along with irrigation water which provides an excellent opportunity to maximize yield and minimize environmental pollution. Fertigation ensures availability of fertilizer nutrients in the root zone in readily available form and therefore, minimize fertilizer application rate and increases fertilizer use efficiency. Fertigation ensures saving in fertilizer (40-60%), due to “better fertilizer use efficiency” and “reduction in leaching” (Kumar and Singh 2002) [17]. The associated increase in yield with minimum fertilizer application rate, increases return on the fertilizer invested. Based on experimentation, it has been observed that fertigation leads to saving of fertilizer by 25-40%, increased returns and reduced leaching of the nutrients.

Valentín *et al*. (2020) [37] concluded that subsurface irrigation was a water savings strategy for irrigation of sweet corn reducing the consumptive water use and increasing IWP. The results of field experiment over two years (2016 & 2017) by Thamer *et al*. (2021b) [35] for sweet corn crop was supportive to present outcomes. Their results indicated that the consumptive water use of sweet corn crop under surface drip were 558.65 and 529.66 mm and under subsurface drip with emitter deep at 20 cm were 313.93 and 293.50 mm for 2016 and 2017 respectively. Subsurface drip irrigation increased sweet corn crop yield. The greatest crop performance was found under the treatment of subsurface drip irrigation with 20 cm emitter depth and the lowest under surface drip irrigation. Ayars *et al*. (1999) [3] summarized SSDI research results for row crops from 15 years of studies conducted in California by the USDA-ARS. Camp (1998) [7] published an extensive review of SSDI research covering both agronomic and horticultural crops as well as design and management considerations.

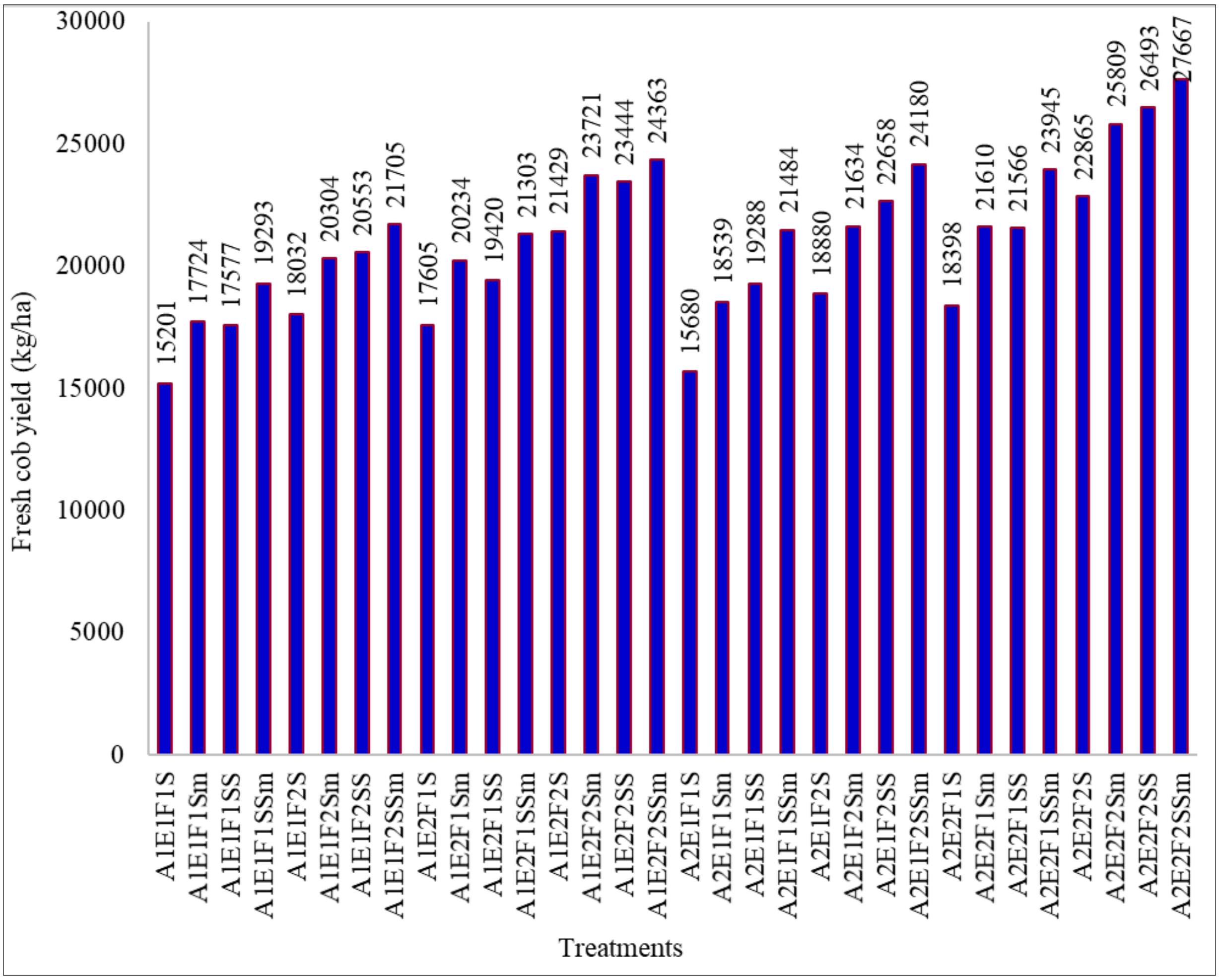

Fig 1: Effects of various treatments on fresh cob yield of sweet corn crop

The mulching adoption in the present research of sweet corn response showed that mulch to increase the crop yield and water productivity. Vial *et al.* (2015) [38] also reported similar results stating that mulch increased fresh ear yield and water productivity by 42% with low water input but had no effect with high water input under drip irrigation. The combination of mulch and reducing water input from high to low water inputs increased gross margin (GM) per hectare by 20% and GM per m^3 water input by 66% due to increased yield and reduced water and labour costs. Gill *et al.* (1996) increased maize yield by only 0–5% with mulch with shorter irrigation intervals but by 19–35% with longer irrigation intervals. They also reported that maize water productivity due to mulch under deficit irrigation increased by 46%.

Table 1: Effect of different treatments on fresh cob yield of sweet corn crop

Treatment	Fresh cob yield (kg/ha) during year			Increase
	2020-21	2021-22	Pooled	
Factor-I: Aeration				
A1 No aeration	19731.83	20506.81	20119.32 [a]	8.94%
A2 Aeration	21457.64	22379.5	21918.57 [b]	
S.Em.±			281.48	
C.D. at 5%			795.24	
C.V.%			10.71	
Factor-II: Irrigation level				
I1 (0.7ETc)	19198.81	19892.72	19545.76 [a]	15.07%
I2 (1 ETc)	21990.66	22993.6	22492.13 [b]	
S.Em.±			281.48	
C.D. at 5%			795.2382	
C.V.%			10.71	
Factor-III: Fertigation level				
F1 (0.7 RDF)	18984.03	19624.35	19304.19 [a]	17.77%
F2 (1 RDF)	22205.44	23261.96	22733.7 [b]	
S.Em.±			281.48	
C.D. at 5%			795.2382	
C.V.%			10.71	

Factor-IV: Irrigation practices				
SDIo	17133.35	17711.29	17422.32 ^{a}	21.67% due to mulch in SDI 7.57% due to mulch in SSDI 22.69% due to SSDI under no mulch 8.47% due to SSDI under mulch
SDIm	20784.37	21609.67	21197.02 ^{b}	
SSDIo	20931.15	21818.86	21375.01 ^{b}	
SSDIm	22459.23	23525.85	22992.54 ^{c}	
S.Em.±			398.071	
C.D. at 5%			1124.6366	
C.V.%			10.71	

5. Conclusions

The results obtained through 2 years field experiment on sweet corn crop performance under various irrigation water management strategies was analyzed. The aerated drip irrigation could increase the fresh cob yield of sweet corn crop by the tune of 8.94% over the non-aerated drip irrigation. The increase in irrigation applications from 70% of ET_c to 100% ET_c could help to get increased the fresh cob yield by 15.07%. When the irrigation to sweet corn crop was increased from 70% of ET_c to 100% of ET_c., the sweet corn fresh green cobs was increased by 15.07%. Similarly, it was increased by 17.77% under fertigation level of 100% RDF as compared to 70% RDF. The fresh green cobs of sweet corn crop were increased by 21.67% and 7.57% due to mulch adoption in surface and subsurface drip irrigation respectively. Similarly, it was found increased by the tune of 22.69% and 8.47% due to subsurface drip adoption under no mulch and mulch respectively as compared to surface drip irrigation.

6. Acknowledgements

This work was supported by Junagadh Agricultural University and was gratefully acknowledged. The author is also grateful to Dr. R. M. Satasiya on guiding for the research.

7. Reference

1. Abbas M. Effect of Different Levels of Irrigation on Maize Yield, Water Use Efficiency and Soil Properties under Different Sowing Methods. Lambert Academic Publishing, 2012, 48.
2. Abuarab M, Mostafa E Ibrahim M. Effect of air injection under subsurface drip irrigation on yield and water use efficiency of corn in a sandy clay loam soil. J Adv. Res. 2013;4(6):493-499.
3. Avars JE, Phene CJ, Hutmacher RB, Davis KR, Shoneman RA, Vail SS, *et al*. Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. Agric Water Manage. 1999;42:1-27.
4. Ben-Noah, Friedman SP. Oxygation of clayey soils by adding hydrogen peroxide to the irrigation solution: Lysimetric experiments. Rhizosphere. 2016;2:51-61.
5. Bhattarai SP, Balsys RJ, Wassink D, Midmore DJ, Torabi M. The total air budget in oxygenated water flowing in a drip tape irrigation pipe. Int. J Multiph. Flow 2013;52:121-130.
6. Bibe SM., Jadhav KT, Chavan AS. Response of irrigation and fertigation management on growth and yield of maize. Int. J Curr. Microb. and App. Sci. 2017;6(11):4054-4060.
7. Camp CR. Subsurface drip irrigation: a review. Trans ASAE. 1998;41(5):1353-1367.
8. Chen X, Dhungel J, Bhattarai SP, Torabi M, Pendergast L, Midmore DJ. Impact of oxygation on soil respiration, yield and water use efficiency of three crop species. J Plant Ecol. 2011;4(4):236-248.
9. Erdem Y, Arin L, Erdem T, Polat S, Deveci M, Okursoy H, *et al*. Crop water stress index for assessing irrigation scheduling of drip irrigated broccoli (*Brassica oleracea* L.). Agric. Water Manage. 2010;98(1):148-156.
10. Ertek A, Kara B. Yield and quality of sweet corn under deficit irrigation. Agric. Water Manage. 2013;129:138-144.
11. Flynn NE, Stewart CE, Comas LH, Del Grosso SJ, Schnarr C, Schipanski M, *et al*. Deficit irrigation impacts on greenhouse gas emissions under drip- fertigated maize in the Great Plains of Colorado, 2022.
12. Friedman SP, Naftaliev B. A survey of the aeration status of drip-irrigated orchards. Agric. Water Manage. 2012;115:132-147.
13. Hashem MS, El-Abedin TZ, Al-Ghobari HM. Assessing effects of deficit irrigation techniques on water productivity of tomato for subsurface drip irrigation system. Int. J Agric. Biol. Eng. 2018;11(4):156-167.
14. Helaly AA, Goda Y, El-Rehim AAS, Mohamed AA, El-Zeiny OAH. Effect of polyethylene mulching type on the growth, yield and fruits quality of Physalis pubescens. Adv. in Plants and Agric. Res. 2017;6(5):1-7.
15. Igbaduna HE, Ramalan AA, Oiganji E. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. Agric. Water Manage. 2012;109:162-169.
16. Kandelous MM, Simunek J, Van Genuchten MT, Malek K. Soil Water content distributions between two emitters of a subsurface drip irrigation system. Soil science society of Am. J. 2012;75(2):488-497.
17. Kumar A, Singh AK. Improving nutrient and water use efficiency through fertigation. J Water Manage. 2002;10:42-48.
18. Kumar D, Sharma R. Effect of mulching on growth, yield and quality in different varieties of summer squash (*Cucurbita pepo* L.). Int. J Curr. Microb. App. Sci. 2018;7(6):2113-2119.
19. Li Y, Jia Z, Niu W, Wang J, Zhang M. Effect of post-infiltration soil aeration at different growth stages on growth and fruit quality of drip-irrigated potted tomato plants (*Solanum lycopersicum*). PLoS One. 2015;10(12):0143322.
20. Li Y, Niu W, Xu J, Wang J, Zhang M. Root morphology of greenhouse produced muskmelon under sub-surface drip irrigation with supplemental soil aeration. Sci. Horti. 2016;201:287-294.
21. Mansour HA, Hu J, Pibars S, Bao HF, Liang C. Effect of pipes installation by modified machine for subsurface drip irrigation system on maize crop yield costs. CIGR Journal, 2019, 21(2).
22. Mohammed AT, Irmak S. Maize response to coupled irrigation and nitrogen fertilization under center pivot, subsurface drip and surface (furrow) irrigation: Soil-water dynamics and crop evapotranspiration. Agric. Water Manage. 2022;267:107634.

23. Mubarak I. The Response of Two Drip-Irrigated Sweet Corn Varieties to the Twin-Row Production System in the Dry Mediterranean Region. The Open Agric. J. 2020;14(1):9-15.
24. Nilahyane A, Islam MA, Mesbah AO, Garcia A. Effect of irrigation and nitrogen fertilization strategies on silage corn grown in semi-arid conditions. Agron. 2018;8(10):208.
25. Panich P, Tawonsri P, Nuntadusit C. Effect of Using Venturi-type Bubble Generator with Pressure Tank on Micro Bubble Generation for Aeration. Princess of Naradhiwas University Journal. 2021;13(3):245-261.
26. Pendergast L, Bhattarai SP, Midmore DJ. Evaluation of aerated subsurface drip irrigation on yield, dry weight partitioning and water use efficiency of a broad-acre chickpea (*Cicer arietinum*, L.) in a vertosol. Agric. Water Manage. 2019;217:38-46.
27. Rahma AE, Warrington DN, Lei T. Efficiency of wheat straw mulching in reducing soil and water losses from three typical soils of the Losses Plateau, China. Int. Soil and Water Conserv. Res. 2019;7:335-345.
28. Rank PH, Unjia YB, Kunapara AN. Soil Wetting Pattern under Point and Line Source of Trickle Irrigation. Int. J Curr Microbiol App Sci. 2019;8(07):785-792.
29. Rank PH, Vishnu B. Automation of Pulsed Drip Irrigation. Int J Engg Sci Comp. 2019;9(7):23265-23276.
30. Rank PH, Vishnu B. Pulse drip irrigation: A review. J Pharmacognosy and Phytochemistry. 2021a;10(1):125-130.
31. Rank PH, Vishnu B. Design Concepts of Pulse Drip Irrigation. Int Res J Modern Engg Tech Sci. 2021b;3(12):414-420.
32. Sandal SK, Kapoor R. Fertigation technology for enhancing nutrient use and crop productivity: An overview. Himachal J Agric Res. 2015;41(2):114-121.
33. Teame G, Tsegay A, Abrha B. Effect of organic mulching on soil moisture, yield, and yield contributing components of sesame (*Sesamum indicum* L.). Int. J Agron, 2017, 1-6.
34. Thamer TY, Nassif N, Almaeini AH. The productivity of Maize (*Zea mays* L.) Water using efficacy and Consumptive use under different Irrigation systems. Period Eng. Nat. Sci. 2021;9(1):90-103.
35. Thamer TY, Nassif N, Almaeini A, Al-Ansari N, Hassan D. Modeling of Different Irrigation Methods for Maize Using AquaCrop Model: Case Study. Engineering. 2021;13(8):472-492.
36. Tripathi VK, Rajput TBS, Patel N. Biometric properties and selected chemical concentration of cauliflower influenced by wastewater applied through surface and subsurface drip irrigation system. J of Cleaner Prod. 2016;139:396-406.
37. Valentín F, Nortes PA, Domínguez A, Sánchez JM, Intrigliolo DS, Alarcón JJ, ry al. Comparing evapotranspiration and yield performance of maize under sprinkler, superficial and subsurface drip irrigation in a semi-arid environment. Irri. Sci. 2020;38(1):105-115.
38. Vial LK, Lefroy RDB, Fukai S. Application of mulch under reduced water input to increase yield and water productivity of sweet corn in a lowland rice system. Field Crops Res. 2015;171:120-129.
39. Wang Z, Li M, Flury M, Schaeffer SM, Chang Y, Tao Z, *et al*. Agronomic performance of polyethylene and biodegradable plastic film mulches in a maize cropping system in a humid continental climate. Sci. Total Environ. 2021;786:147460.
40. Wei C, Zhu Y, Zhang J, Wang Z. Evaluation of suitable mixture of water and air for processing tomato in drip irrigation in Xinjiang Oasis. Sustain. 2021;13(14):7845.
41. Yan ZHU, Dyck M, Cai HJ, Song LB, Hui CHEN. The effects of aerated irrigation on soil respiration, oxygen, and porosity. J Integr. Agric. 2019;18(12):2854-2868.
42. Yu Z, Wang H, Zou H, Sun H, Wang H, Wang C, *et al*. Changes in respiration rate of red loam soil under aerated irrigation and its relationship with soil water oxygen. J Trop. Crops. 2022;43:110-118.
43. Zhang Z, Yang H, Shi M. Analyses of water footprint of Beijing in an interregional input–output framework. Ecol. Econ. 2011;70(12):2494-2502.
44. Zou Y, Saddique Q, Ali A, Xu J, Khan MI, Qing M, *et al*. Deficit irrigation improves maize yield and water use efficiency in a semi-arid environment. Agric. Water Manage. 2021;243:106483.