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Research Article

Impact of drip irrigation and tailored fertigation levels at various stages of crop growth on the yield and nutrient uptake of high-density sweet corn (*Zeamays*var. Saccharata Sturt)

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Abstract
Sweet corn (*Zeamays*var. saccharatasturt) is a high-value crop with rising demand. Efficient irrigation and fertigation management play a vital role in improving crop yield and quality. A study was conducted during the summers of 2020 and 2021 to evaluate the effects of drip irrigation and fertigation levels on the nutrient uptake and yield of high-density sweet corn grown in sandy clay loam soil under semi-arid conditions. The experiment used a factorial randomized block design with three replications and twelve treatment combinations, varying drip irrigation across three levels (0.6, 0.8, and 1.0 Epan) and fertigation across four levels: 100% recommended dose of nitrogen and potassium (RDNK) applied based on differential dosage (F_1), 100% RDNK based on the crop coefficient curve (F_2), 125% RDNK with differential dosage (F_3), and 125% RDNK based on the crop coefficient curve (F_4).Results showed that irrigation at 1.0 Epan (I_3) achieved the highest cob yield (12,870 kg ha^{-1} in 2020 and 12,337 kg ha^{-1} in 2021), fodder yield (36,409 kg ha^{-1} in 2020 and 35,044 kg ha□¹ in 2021), nutrient uptake, and crude protein content. Among fertigation treatments, F_4 (125% RDNK based on crop coefficient curve) recorded the highest cob yield (12,349 kg ha^{-1} in 2020 and 11,769 kg ha^{-1} in 2021), nutrient uptake, and protein content.The study concluded that using 1.0 Epan irrigation combined with fertigation based on the crop coefficient curve (F_4) is the most effective strategy, promoting nutrient uptake and maximizing sweet corn yield.

Keywords: Crude protein,Drip irrigation, Fertigation, Nutrient uptake, Sweetcorn, Yield

INTRODUCTION

Sweet corn (*Zeamays*var. SaccharataSturt)is a maize variety characterized by its immature grains containing 13 to 15% sugar. During the summer, sweet corn is an excellent source of green feed, particularly beneficial for maintaining the cow herd. It can be effectively utilized as a subsequent crop following long-duration kharif crops like cotton and red gram, especially in regions with limited irrigation due to its short growth cycle. According to data compiled by the United States Department of Agriculture (USDA), corn cultivation covered approximately 201.29 million hectares worldwide, with a total production of 1147.52 million metric tonnes during the 2021-2022 period(USDA-FAS,2023)

Efficient utilization of growth characteristics through optimal plant stand has enhances sweet corn output (Sandhya *et al.,* 2016; Spandana, 2012). Adequate resources, including water and nutrients, are crucial for maintaining uniform growth, development, and crop yield, especially as the population density increases (Rao *et al.,* 2014). Prudent water management and appropriate nutrition are paramount for maximizing overall food grain production.Irrigation plays a pivotal role in maize cultivation, particularly in arid and semi-arid regions, where it is a critical factor affecting yield under conditions of limited or irregular rainfall (Jacek *and Renata,* 2023). Scientific research on corn irrigation focuses on economic management amid declining water resources, aiming to optimize water consumption. Innovative water and energy-saving technologies like drip irrigation are gaining prominence over conventional methods like surface and sprinkler irrigation systems (Sandeep Kumar *et al.,* 2023).

Drip irrigation facilitates fertigation, an advanced method of delivering water and nutrients (nitrogen and potassium) directly to the active root zone of plants, contributing to improved efficiency and reduced environmental pollutionCoyago-Cruz *et al.* (2019), and Vwiokoe*t al.* (2019).Tailoring fertigation to match plant nutritional requirements at different growth stages can prevent fertilizer leaching and optimize yield potential. Studies comparing uniform versus variable dosage fertigation have shown higher cob yield (Jha *et al.,* 2015) and cotton yield (Stesi*et al.,* 2023)with the latter approach.In light of increased planting density by 50%, from 83,333 to 160,000, the sweetcorn fertilization schedule requires revalidation to maximize yield potential. Despite numerous studies on the impact of drip irrigation and nitrogen fertigation levels on maize and sweetcorn, precise water and nutrient scheduling based on scientific evidence such as crop coefficient (Kc) values remains lacking for sweetcorn.Against this backdrop, a study was conducted to assess the response of high-density sweetcorn to drip irrigation as an innovative, water-saving, and energy-efficient irrigation technology.The present study aimed to evaluate the response of sweetcorn(*Zeamays*var. SaccharataSturt) to growth stage-based fertigation and examine the interaction between drip irrigation and fertigation in shaping crop yield.

MATERIALS AND METHODS

The study was conducted at the College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, in Hyderabad, Telangana State, India. It is situated at an altitude of 542.3 meters above mean sea level, the farm lies at 17°19’ N latitude and 78°23’ E longitude, falling within the Southern Telangana agro-climatic zone. It is categorized as semi-arid tropics (SAT) based on Troll's classificationClimatic classification-ICRISAT, 1980) (Fig. 1, 2).Throughout the cropping period, the mean weekly maximum temperature ranged from 31.00 to 39.00 ^oC, averaging 34.31 ^oC in 2019-20, and from 37.14 to 35.50 ^oC, averaging 30.63 ^oC in 2020-21 (Fig.3). Conversely, the weekly mean minimum temperature varied between 10.64 to 24.29 ^oC, with an average of 19.40 ^oC in 2019-20, and from 11.21 to 16.21 ^oC, averaging 14.90 ^oC during 2020-21 (Fig.4).During the crop growth stage, precipitation totaled 21.00 mm over five rainy days in 2019-20 (Fig.5) and 4.6 mm in one rainy day in 2020-21 (Fig.6). Mean weekly pan evaporation (PE) ranged from 3.74 to 7.90 mm in 2019-20 and 2.49 to 5.96 mm in 2020-21. The total evaporation during the crop study amounted to 366.8 mm in 2019-20 and 335.5 mm in 2020-21(Lavanya, 2022, https://krishikosh.egranth.ac.in/items/50946bed-298f-46fe-8c95-b9d53116275b).

The experimental soil was sandy clay loam, with a texture consisting of 75.24% sand, 10.4% silt, and 14.06% clay. The average bulk density for the 0-60 cm depth was 1.59 Mg m^3. The soil exhibited a slightly alkaline reaction, with pH ranging from 7.4 to 7.5 and electrical conductivity (EC) ranging from 0.26 to 0.28 dS m^-1. Available nutrient levels were measured at 182.4 kg ha^-1 for nitrogen (N), 63.8 kg ha^-1 for phosphorus (P), and 329.9 kg ha^-1 for potassium (K) (Lavanya, 2022, https://krishikosh.egranth.ac.in/items/50946bed-298f-46fe-8c95-b9d53116275b).

The experiment comprised twelve treatments arranged in a Factorial Randomized Block Design (FRBD) and replicated thrice. Three irrigation levels were implemented: irrigation scheduled at 0.6 (I1), 0.8 (I2), and 1.0 Epan (I3) throughout the crop growth period. Four fertigation levels were also employed: 100% recommended dose of nitrogen and potassium (RDNK) in differential dosage as per recommendation (F1), 100% RDNK in differential dosage as per crop coefficient curve (F2), 125% RDNK in differential dosage as per recommendation (F3), and 125% RDNK in differential dosage as per crop coefficient curve (F4).The sweet corn variety Madhuri was sown during the 1st season on (February 5th, 2020) and (December 11th, 2020) during the 2nd season, with a spacing of 30x20 cm. The recommended dose of fertilizer (RDF) consisting of 180 kg N, 60 kg P2O5, and 50 kg K2O ha^-1 was applied in the form of urea, single super phosphate, and sulphate of potash. Phosphorus was uniformly applied to all treatments as a basal dose, while nitrogen and potassium were applied in splits through fertigation according to the treatment specifications.

Irrigation was scheduled every three days. The irrigation water was applied based on data collected from a USWB open pan evaporimeter located at the Agrocli-

Fig. 1. *Geographical location of the experimental plot of the site (Google map)*

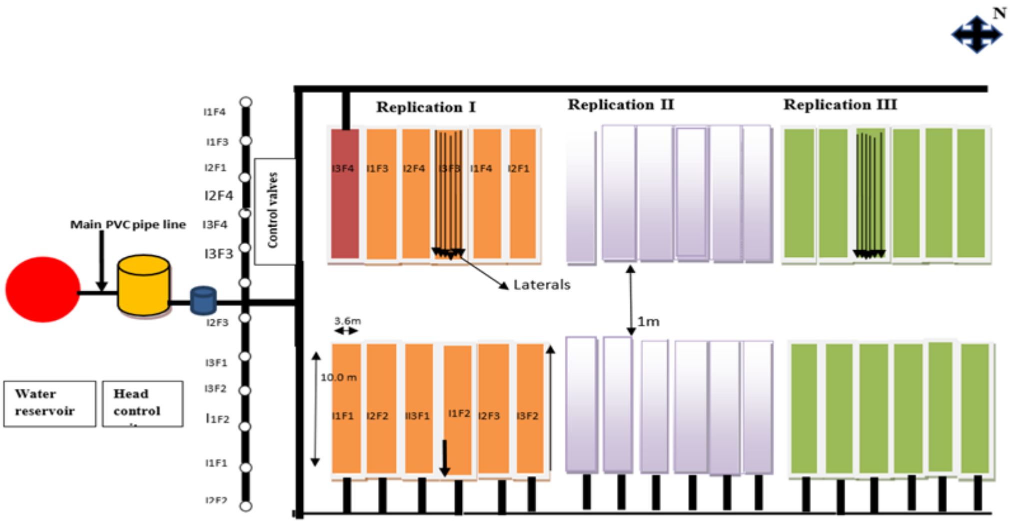

Fig. 2. *Layout of the experimental site*

matic Research Centre, ARI, Rajendranagar, Hyderabad. The 16 mm diameter laterals were spaced 0.6 m apart, with a 0.2 m interval between two inline emitters. The discharge rate of the emitter was 2.0 liters per hour. The following formula was used to compute the application rate in drip irrigation treatments.

Application rate (mm hr^{-1}) = Q ÷ D_L x DE (Eq. 1)

Whereas

Q = Dripper discharge (liters h^{-1}),D_L = Distance between lateral spacing (m)

D_E = Distance between dripper (emitters) spacing (m)

Irrigation time for each treatment was calculated using following formulae.

Irrigation time (minutes) =E_{pan} (mm) × 60 /Application rate (mm hr^{-1}) (Eq.2)

Fertigation was administered in 10 splits at 6-day intervals, tailored to the crop's growth stage, from 10 days after sowing (DAS) to 70 DAS. For treatments F1 and F3, fertigation was applied in differential dosages corresponding to 100% and 125% of the recommended dose of fertilizer (RDF), as detailed in Table 1. This fertigation schedule, established by PJTSAU, is based on crop growth stages and their respective nutrient uptake patterns. Nutrient doses vary throughout the crop's growth period, with lower dosages during the initial stages, increasing as the crop advances, and decreasing again as it reaches maturity.On the other hand, treatments F2 and F4 received fertigation in differential dosages based on the crop coefficient curve, corresponding to 100% and 125% of RDF, respectively, as outlined in Table 2. Reference crop coefficient (Kc) values from the FAO manual were used to plot Kc values on a graph sheet for every six days. Average Kc values were derived from these plots, and the average nutrient dose requirement per day during the crop growth period was calculated. Utilizing these average

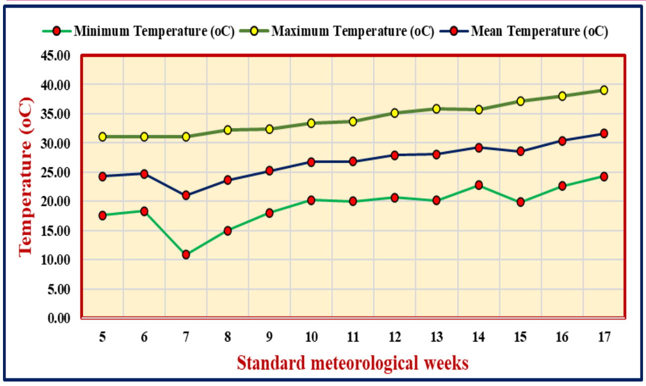

Fig. 3. *Weekly maximum, minimum and mean temperatures (°C) during sweetcorn crop growth period (2019-20)*

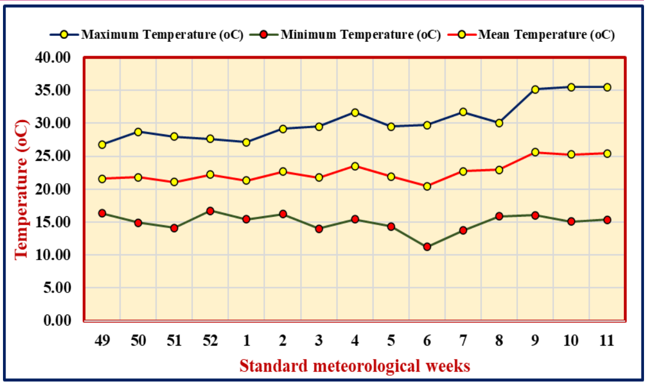

Fig. 4. *Weekly maximum, minimum and mean temperatures (°C) during sweetcorn crop growth period (2020-21)*

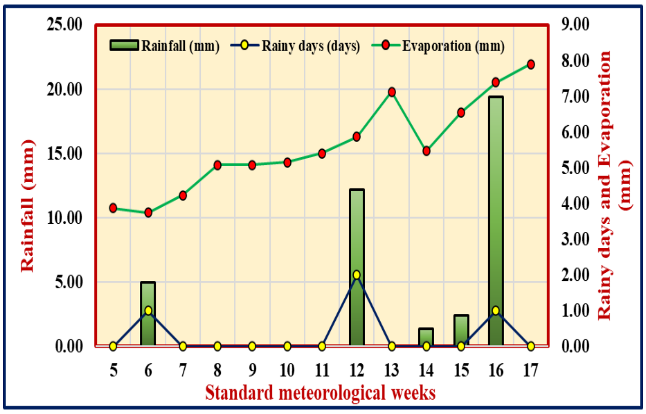

Fig. 5. *Weekly rainfall, rainy days and evaporation during sweetcorn crop growth period (2019-20)*

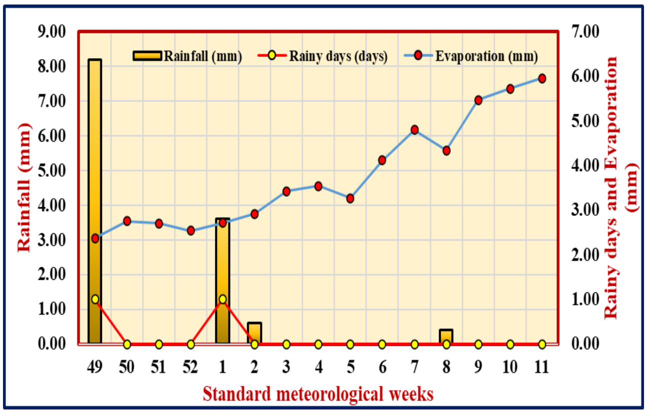

Fig. 6. *Weekly rainfall, rainy days and evaporation during sweetcorn crop growth period (2020-21)*

Table 1. Differential dosage of fertilizer application based on the growth stage of sweet corn crop as per recommendation by PJTSAU(Professor Jayashankar Telangana State Agricultural University) (Vyavasaayadiksoochi-PJTSAU, 2018-19, https://www.pjtsau.edu.in/pjtsau-vyavasaayadiksoochi.html#:~:text=PJTSAU%20publishes%20agriculture%20almanac%20popularly,crops%20in%20the%20vernacular%20language)

Crop stage	Nutrient dose (kg ha^{-1} day^{-1})	
	N	K_2O
After sowing 20 days (10-30 DAS)	1.31	0.56
Grand growth period 20 days (30-50 DAS)	4.39	1.18
Reproductive stage 20 days (50-70 DAS)	3.30	0.75

values, nutrient doses for each Kc value were determined and multiplied for six days, and fertigation scheduling was conducted every six days according to the developed pattern. The fertigation pattern devised for the sweet corn crop is provided below.

Crude protein (%)

The crude protein of the kernel was calculated by analyzing the nitrogen % of the kernels in the laboratory as per the standard procedure i.e. Modified kjeldhal digestion method and crude protein % was worked out.

Kernel crude protein content (%) = Per cent nitrogen (N) of kernel x 6.25 (factor)   (Eq.3)

Chemical analysis of plants

Sweetcorn plant samples were collected at 30, and 60 days after sowing (DAS), and at harvest. These samples were shade-dried and placed in labeled brown paper bags. Subsequently, they were oven-dried for 36-48 hours at temperatures ranging from 60 to 65°C until a constant weight was achieved. The oven-dried plant samples were then ground and finely ground samples were stored in labeled butter paper bags.The samples were analyzed for nitrogen (N), phosphorus (P), and potassium (K) content using adapted standard procedures: Modified Kjeldhal method (Jackson, 1967) for total nitrogen, Di-acid digestion method followed by

Table. 2. Differential dosage of fertilizer application based on the growth stage of sweet corn as per crop coefficient curve

Crop stage (Days)	Kc values	Nutrient dose (kg ha^{-1} day^{-1})	
		N	K_2O
10-20	0.4	1.54	0.42
21-26	0.51	2	0.53
27-31	0.62	2.4	0.65
32-37	0.74	2.8	0.77
38-43	0.84	3.2	0.88
44-49	0.90	3.5	0.95
50-55	0.98	3.8	1.03
56-61	1.05	4.03	1.10
62-67	1.13	4.3	1.18
68-70	1.15	4.4	1.20
Average = 0.83			

colorimetric estimation (Piper, 1966) for total phosphorus, and Di-acid digestion method followed by Flame photometer method (Jackson, 1967) for total potassium.The N, P, and K content values for plant samples were recorded for each treatment, and subsequently, N, P, and K uptakes were determined for plant samples of each treatment.

Nutrient uptake =Percentage of nutrient x Total dry matter production (kg ha^{-1})/104 (Eq. 2)

Soil analysis

Soil samples were collected from each plot down to a depth of 15 cm after the crop harvest. These samples were shade-dried, pounded, and passed through a 2 mm mesh sieve. A representative sample was prepared for each treatment using the quadrant method and stored in polythene bags for preservation.The soil samples were then analyzed for physico-chemical, physical, and chemical properties according to standard procedures.

Soil reaction (pH) was assessed by creating a suspension of soil and water in a ratio of 1:2.5. This mixture was prepared by shaking the soil sample intermittently for 20-30 minutes. The pH of the soil suspension was then measured using a Blackman's glass electrode pH meter (Elico CM 180), following the method outlined by Jackson (1973).Total soluble salts (EC)(dS m^{-1})were measured in a 1:2.5 soil water suspension using the conductometric method with an Elico CM 180 conductivity meter. This procedure involved creating the soil water suspension and then measuring the electrical conductivity (EC) of the solution using a "Solubridge conductivity meter." The EC values were expressed in deciSiemens per meter (dS m^-1), following the method outlined by Jackson (1967).Organic carbon (%) in soil sample was estimated by wet chromic acid digestion method as outlined by Walkley and Black (1934). Available N (kg ha^{-1}) content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956). Soil Available P (kg ha^{-1}) was extracted from soil by Olsen"s extractant (0.5 N NaHCO3 with pH 8.5). The phosphorous content in the extract was determined by L-ascorbic acid method (Olsen*et al.,* 1954). The intensity of color was measured with spectrophotometer at 420 nm and available 'P' was expressed in kg ha^{-1}. Available K (kg ha^{-1}) was extracted from the soil using neutral normal ammonium acetate in 1:5 ratio and the readings were measured using a flame photometer (Muhr*et al.,* 1963). The quantity was calculated and expressed as kg ha^{-1}.The crop was harvested on 24th April 2020 and 12th March 2021 during the 1st and 2nd seasons respectively.

Statistical analysis

The experimental data recorded on different parameters were analyzed statistically by applying the Duncan's Multiple Range test (DMRT) technique using Genstat software.

RESULTS AND DISCUSSION

Crude protein

Maximum protein content was observed under irrigation scheduling at 1.0 Epan (I3) during study period (Table 8), possibly due to increased production and translocation of assimilates to the sink. Conversely, lower irrigation levels (0.6 Epan) may have led to insufficient plant requirements, affecting nutrient transport and delaying the development of stem and leaf cells. This could result in shorter plants, reduced leaf area, decreased dry matter accumulation, and lower kernel protein content. Jacek and Renata (2023) from Poland reported higher protein content in maize under W1-under optimal drip irrigation compared to no irrigation, that variation in protein content was the result of variation in grain dry matter yield (10.0–10.1%) of dry matter among the treatments. Therefore higher irrigation and fertigation levels lead to higher dry matter production, which ultimately leads to higher protein content This observation is consistent with the findings of Ertek and Karato (2013) at I100: full irrigation; I85: 15% deficit, I70: 30% deficit; I55: 45% deficit and I40: 60% deficit in sweetcorn, Sharanabasava (2012) at 100 % Epan over 80, 60 Epanand surface irrigation at 1.0 IW/CPE in sweetcorn and Shiva Kumar *et al.* (2011) at IW/CPE ratio 1.0 over IW/CPE 0.6 in baby corn

Among the fertigation levels, F4 recorded significantly higher protein content compared to F2 and F1, and was comparable to F3 during both years. The increase in protein content under higher fertigation levels (F3 and F4) may be attributed to better utilization and translocation of nitrogen (N) from leaves to kernels. This finding aligns with research by Abdullah Oktemet *al.* (2010), who found that protein content in sweet corn kernels increased with higher N rates, ranging from 9.6% (control) to 18.7% (360 kg N ha^-1). Similar results were reported by Sharanabasava (2012) at 200 kgs N ha^{-1}through fertigation over 120, 160 kg and was on par with 240 kg in sweetcorn, and Shiva Kumar (2010) at 125% RDF through fertigation over 75 and 100 % RDF in maize.

The present work was done under high-density conditions and summer sweetcorn. Many irrigation and fertigation studies were conducted under normal plant density conditions of 60x20 cm in maize and sweetcorn. Some studies compared different irrigation methods (surface and drip), and some are among different drip irrigation levels and with different levels. The present study designed fertigation treatments based on crop uptake patterns and growth stages. For optimization in the future,the study can also be conducted for the experiments under higher irrigation beyond 1.0 Epan and 150 % RDNK levels

N, P and K uptake

N, P, and K uptake by sweetcorn at 30, 60 DAS, and at harvest were notably higher under irrigation scheduling at 1.0 Epan (I3) compared to 0.8 and 0.6 Epan (I2 and I1) (Table 3, 4, and 5). Specifically, 0.6 Epan (I1) had the lowest nitrogen uptake during both 2020 and 2021. The significantly higher nitrogen and potassium uptake in above-ground biomass under higher irrigation regimes (I3) may be attributed to optimal soil moisture content throughout the crop growth period, facilitating nutrient availability to the plant roots. This and higher dry matter accumulation likely contributed to the increased N and K uptake.The favorable soil moisture availability provided by continuous irrigation at 1.0 Epan led to enhanced mineralization from native and applied sources of phosphorus, resulting in increased phosphorus uptake by the crop. Similar findings were reported by Kumari *et al.* (2017)at 25% DASM than 75% DASM and rainfed crop in maize, Kadasiddappa (2015) at 100 % drip Epan over 40 and 60 Epan in maize, and Sharanabasava (2012)at 100 % drip Epan over 80, 60 Epan and surface irrigation at 1.0 IW/CPE in sweetcorn.

Among fertigation levels, at 30 DAS, higher N, P, and K uptake was recorded under F4, which was comparable to F3. Conversely, F1 recorded lower N, P, and K uptake, which was on par with F2 during 2020 and 2021. At 60 DAS, higher N, P, and K uptake was observed under the F3 treatment, comparable to F4. However, F2 registered lower nitrogen uptake, which was on par with F1 during both years.The study utilised two fertigation patterns: one based on fertilizer application recommendations and the other based on the crop coefficient curve. While the number of fertigation splits was equal in both patterns, the nutrient dose varied for each fertigation event. Higher doses were applied between 30-60 DAS under F3 and F1 treatments compared to F4 and F2, resulting in increased dry matter production

Table 3. N uptake (kg ha^{-1}) by sweet corn as influenced by drip irrigation and fertigation levels

Treatments	Days after sowing					
	30		**60**		**At harvest**	
	2020	**2021**	**2020**	**2021**	**2020**	**2021**
Irrigation levels (I)						
I_1	8.6^a	8.7^a	252.3^a	245.8^a	321.4^a	300.9^a
I_2	10.2^b	10.2^b	270.2^a	272.7^b	414.6^b	399.2^b
I_3	11.6^c	11.3^c	303.5^b	299.7^c	525.6^c	481.0^c
SE±	0.3	0.3	7.4	7.9	19.3	16.5
LSD(P=0.05%)	0.9	0.8	21.8	23.3	56.7	48.3
Fertigation levels (F)						
F_1	9.2^a	9.3^a	264.3^{ab}	238.2^a	364.5^a	339.8^a
F_2	9.9^{ab}	9.7^{ab}	259.3^a	251.6^{ab}	385.7^{ab}	368.3^{ab}
F_3	10.3^{bc}	10.4^{bc}	292.1^c	291.9^c	450.5^{bc}	433.3^{bc}
F_4	11.0^c	10.9^c	285.7^{bc}	283.2^{bc}	481.3^c	433.4^c
SE±	0.3	0.3	8.6	9.2	22.3	19.0
LSD(P=0.05%)	0.97	0.98	25.2	26.9	65.4	55.8
Interaction (IXF)						
SE±	0.6	0.6	14.9	15.9	38.6	32.9
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS

*Means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; Irrigation levels:0.6 Epan (I_1); 0.8 Epan (I_2);1.0 Epan (I_3); Fertigation levels: 100% recommended dose of nitrogen and potassium (RDNK) (F_1); 100% RDNK dosage as per crop coefficient curve (F_2); 125% RDNK (F_3); 125% RDNK as per crop coefficient curve (F_4).

Table 4. P uptake (kg ha^{-1}) by sweet corn as influenced by drip irrigation and fertigation levels

Treatments	Days after sowing					
	30		60		At harvest	
	2020	2021	2020	2021	2020	2021
Irrigation levels (I)						
I_1	1.46^a	1.42^a	98.5^a	115.3^a	123.9^a	115.3^a
I_2	1.69^b	1.66^b	105.5^b	156.3^b	160.2^b	156.3^b
I_3	1.84^c	1.79^c	111.7^b	182.6^c	189.8^c	182.6^c
SE±	0.05	0.04	2.25	5.67	5.7	5.7
LSD(P=0.05%)	0.14	0.11	6.61	16.62	16.71	16.6
Fertigation levels (F)						
F_1	1.52^a	1.48^a	100.8^{ab}	132.1^{ab}	137.6^a	132.1^a
F_2	1.57^{ab}	1.57^{ab}	99.9^a	142.4^a	146.9^{ab}	142.4^{ab}
F_3	1.71^{bc}	1.69^{bc}	111.5^c	162.6^c	168.1^{bc}	162.2^{bc}
F_4	1.87^c	1.74^c	108.7^{bc}	169.0^{bc}	179.3^c	169.0^c
SE±	0.05	0.04	2.6	6.5	6.6	6.5
LSD(P=0.05%)	0.16	0.13	7.63	19.2	19.3	19.2
Interaction (IXF)						
SE±	0.09	0.08	4.5	11.3	11.4	11.3
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS

*Means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; Irrigation levels: 0.6 Epan (I_1); 0.8 Epan (I_2);1.0 Epan (I_3); Fertigation levels: 100% recommended dose of nitrogen and potassium (RDNK) (F_1); 100% RDNK dosage as per crop coefficient curve (F_2); 125% RDNK (F_3); 125% RDNK as per crop coefficient curve (F_4).

Table 5. K uptake (kg ha^{-1}) by sweet corn as influenced by drip irrigation and fertigation levels

Treatments	Days after sowing					
	30		60		At harvest	
	2020	2021	2020	2021	2020	2021
Irrigation levels (I)						
I_1	11.3^a	10.2^a	357.0^a	333.6^a	449.7^a	401.1^a
I_2	13.4^b	11.9^b	389.2^b	364.2^b	585.7^b	537.3^b
I_3	14.9^c	13.3^c	427.0^c	397.9^c	691.6^c	662.5^c
SE±	0.42	0.34	10.08	10.07	22.7	25.1
LSD(P=0.05%)	1.23	1.00	29.6	29.5	66.5	73.5
Fertigation levels (F)						
F_1	12.2^a	10.9^a	377.5^{ab}	351.1^{ab}	494.9^a	464.8^a
F_2	12.5^{ab}	11.5^{ab}	364.0^a	341.2^a	536.1^{ab}	494.3^{ab}
F_3	13.8^{bc}	12.1^{bc}	418.3^c	389.2^c	614.4^{bc}	574.6^{bc}
F_4	14.3^c	12.8^c	404.2^{bc}	379.5^{bc}	657.8^c	600.9^c
SE±	0.48	0.39	11.6	11.6	26.2	28.9
LSD(P=0.05%)	1.42	1.16	34.14	34.1	76.8	84.8
Interaction (IXF)						
SE±	0.84	0.69	20.16	20.1	45.4	50.1
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS

***** means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; *Means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; Irrigation levels: 0.6 Epan (I_1); 0.8 Epan (I_2);1.0 Epan (I_3); Fertigation levels: 100% recommended dose of nitrogen and potassium (RDNK) (F_1); 100% RDNK dosage as per crop coefficient curve (F_2) ; 125% RDNK (F_3); 125% RDNK as per crop coefficient curve (F_4)

and higher nutrient uptake.At harvest, the highest N, P, and K uptake was observed with F4, significantly superior to F2 and F1 and comparable to F3 during both seasons. Lower nitrogen uptake was recorded with F1, which was comparable to F2. Additionally, F3 was comparable to F2 but significantly superior to F1.

Overall, the increased N and K uptake under F3 and F4 treatments may be attributed to the higher dose of N and K supplied through fertigation in a more readily available form at more frequent intervals. This likely resulted in higher availability of nitrogen and potassium in the soil solution, consequently promoting greater growth and uptake. The phenomenon of higher accumulation of N and K in above-ground biomass with increasing nitrogen and potassium doses has been documented by several researchers, including Kumari *et al.* (2017)at 160 kg N ha^{-1} over 120 and 80 kg in maize, Shiva Kumar (2010) at 125% RDF through fertigationover 75 and 100 % RDF in maize, Anitta Fanish and Muthukrishnan (2011) at 150 % RDF through fertigation over 100, 125 % RDF through fertigation and 100 % RDF through soil application, Hassan *et al.* (2010) at 140 kg N ha^{-1} through fertigation over 100 and 60 kg in maize and Hassanein *et al.* (2007)who achieved higher uptake at 300 kg Nitrogen per hectare over 225,150, 75 kg N ha^{-1} and control in hybrid maize.Moreover, the higher phosphorus uptake with F3 and F4 may be attributed to the synergy between nitrogen and phosphorus. In this scenario, the supply of nitrogen in higher doses may enhance the production of small roots and root hairs, thereby facilitating a higher absorbing capacity per unit of dry weight. These findings are consistent with the results reported by Hassanein (2007)in maize at 300 kg Nitrogen per hectare over 225,150, 75 kg N ha^{-1} and control.

Physico-chemical properties of the soil

An overview of the data indicated that, soil pH, EC and organic carbon did not differ significantly by different irrigation, fertigation levels and their interaction effect during 2020 and 2021 (Table 6).

Nutrient status of the soil after harvest of sweet corn

The soil available nitrogen, phosphorus, and potassium after the harvest of the sweetcorn crop did not significantly differ among varying irrigation, fertigation levels, and their interaction during both years of the study (Table 7). However , in contrast to the present findings, Sharana Basava, 2012 noticed maximum availability of N in drip irrigation schedule at 100% Epan over 60 and 80 % Epan.This observation could be attributed to the mobile nature of nitrogen in the soil and its uptake by plants, as well as the various losses affecting nitrogen, resulting in less accumulation of residual nitrogen. Similar findings were reported by Divya *et al.* (2018) in marigold among treatments varying from 50 to 125 % RDF supplied through water soluble fertilisers and straight fertilisers (only fertigation study).Regarding available phosphorus, the lack of significant differences may be due to its uptake by plants and phosphorus fixation in the soil. Since 100% of the recommended dose of phosphorus was applied as a basal dose in all treatments, any remaining phosphorus after plant uptake may have become fixed in the soil. Similar observations were reported earlier by Prabhu *et al.* (2016) in chilli crops among 75 to 125% RDF treatments (only fertigation study).Similarly, the minimal variation in residual potassium levels may be attributed to crop uptake, leading to less residual potassium buildup. This finding aligns with previous reports by Hanuman Naik *et al.* (2016)on bananas among treatments with 50, 75, and 100% RDF through fertigation.

Green cob yield and fodder yield (kg ha^{-1})

Drip irrigation scheduled at 1.0 Epan (I3) consistently resulted in significantly higher cob yield and fodder yield compared to the other two irrigation levels (I2 and I1) during both seasons (Table 8 and Fig. 7). This can be attributed to the favorable soil moisture conditions maintained throughout the crop growth period, which enhanced photosynthetic rate, biomass accumulation, and partitioning into economic plant parts. Conversely, the lowest yield under I1 (0.6 Epan) may be due to insufficient moisture for nutrient absorption by the crop, as optimal water availability is crucial for nutrient absorption, leading to reduced leaf area, photosynthesis, biomass production, and ultimately cob yield. Dharaiya*et al.* (2022) also recorded higher cob yield in rabi sweetcorn under drip irrigation scheduling at 1 Epan over 0.6 and 0.8 Epan. Similarly Brar *et al.* (2018) recorded cob yield under drip irrigation at 100 % CPE over 80 and 60 CPE in maize, Bibe *et al*. (2017) recorded

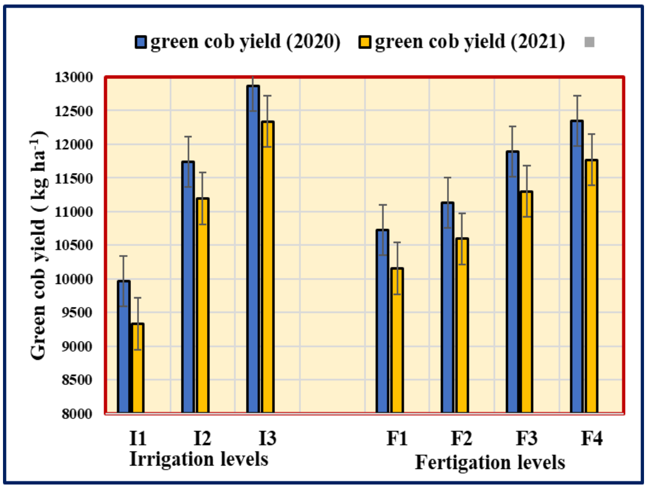

Fig. 7. *Green cob yield (kg ha^{-1}) of summer sweetcorn as influenced by irrigation and fertigation levels*

Table 7. Available nutrient status of the soil (kg ha^{-1}) after harvest of sweet corn as influenced by drip irrigation and fertigation levels

Treatments	Days after sowing					
	Available Nitrogen		Available Phosphorous		Available Potassium	
	2020	2021	2020	2021	2020	2021
Irrigation levels (I)						
I_1	185.7^a	181.2^a	63.5^a	65.3^a	326.2^a	337.3^a
I_2	187.4^a	183.8^a	65.0^a	65.3^a	329.4^a	338.9^a
I_3	191.5^a	188.3^a	65.0^a	66.5^a	332.6^a	340.7^a
SE±	4.38	5.2	2.0	1.7	8.6	8.2
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS
Fertigation levels (F)						
F_1	182.7^a	175.1^a	62.2^a	65.0^a	321.3^a	333.7^a
F_2	185.0^a	179.5^a	63.2^a	65.7^a	323.9^a	336.1^a
F_3	190.2^a	189.7^a	65.4^a	65.7^a	331.8^a	340.7^a
F_4	194.9^a	193.4^a	67.2^a	66.5^a	340.5^a	345.5^a
SE±	5.06	6.0	2.3	1.9	9.9	9.5
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS
Interaction (IXF)						
SE±	8.8	10.5	3.4	3.4	17.2	16.4
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS

*Means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; Irrigation levels: 0.6 Epan (I_1); 0.8 Epan (I_2);1.0 Epan (I_3); Fertigation levels: 100% recommended dose of nitrogen and potassium (RDNK) (F_1); 100% RDNK dosage as per crop coefficient curve (F_2); 125% RDNK (F_3); 125% RDNK as per crop coefficient curve (F_4).

higher cob yield under drip irrigation at 15% of available soil water consumed in the root zone over 30%, 50 % available soil water consumed and no irrigation treatments in corn, Kadasiddappa*et al*. (2013) at 100 % Epan over 40 and 60 Epan in maize, and Salah *et al.* (2008) also reported higher cob yields in maize crop under drip irrigation rate I1: 1.00 over I2: 0.80 and I3: 0.60 of the estimated evapotranspiration.

Among the four fertigation levels, F4 consistently resulted in significantly higher cob yield and green fodder yield than F1 and F2 during both years. However, it was statistically on par with F3 in 2020 and 2021. Conversely, lower fresh cob yield and fodder yield were recorded for F1 during both years. Specifically, cob yield and fodder yield obtained through F1 and F2 were comparable, and cob yield obtained with F3 was also comparable with F2 but significantly higher than F1. A recommendation-based sustainable approach, such as the crop coefficient curve, could save up to 25% of nutrients.

The higher yield recorded with F4 may be attributed to the application of lower fertilizer rates during the initial stages and higher rates during the grand growth period and reproductive stage, meeting the crop's growth needs and promoting increased nutrient uptake, resulting in higher cob and fodder yield. This precise and scientific nutrient application under F4 and F2 treatments likely contributed to their higher yields compared to F1 and F3 treatments. Additionally, the higher cob yield under F3 and F4 fertigation levels can be attributed to the increase in fertilizer levels (N and K), which improved all growth and yield attributes, especially under higher density planting. Similar findings of increased yield with increased fertilizer rates have been reported by Richa Khanna (2013) noticed higher yield under drip fertigation with 125% RDF over 50, 75 and 100 % RDF in maize , Shiva Kumar (2010) at 125% RDF over 75 and 100 % RDF in maize through fertigation, Sharanabasava (2012) at 200 kgs N ha^{-1} over 120, 160 kg and was on par with 240 kg in sweetcorn through fertigation, and Hassanein *et al.* (2007) recorded higher yield 300 kg Nitrogen per hectare over 225,150, 75 kg N ha^{-1} and control in hybrid maize

However, there was no significant interaction effect of drip irrigation and fertigation levels on nutrient uptake, quality, and yield of sweetcorn during both years.

Economics

Among the three irrigation levels, irrigation scheduled at 1.0 Epan consistently resulted in significantly higher net returns and benefit-cost ratio (B:C ratio) than 0.8 and 0.6 Epan during both years (Table 9). The lowest net returns and B:C ratio were observed under 0.6 Epan. The increased net returns and B:C ratio with 1.0 Epan were mainly attributed to the higher cob and fodder yield obtained compared to the other irrigation levels (0.8 and 0.6 Epan). These findings are consistent with those of Brar *et al.* (2018),who reported higher

Table 8. Green cob yield, green fodder yield (kg ha^{-1}) and Crude protein (%) of sweet corn as influenced by drip irrigation and fertigation levels.

Treatments	Days after sowing					
	Green cob yield (kg ha^{-1})		Green fodder yield (kg ha^{-1})		Crude protein (%)	
	2020	2021	2020	2021	2020	2021
Irrigation levels (I)						
I_1	9967^a	9332^a	27878^a	26551^a	12.4^a	12.9^a
I_2	11734^b	11195^b	33149^b	31559^b	13.7^b	13.8^b
I_3	12870^c	12337^c	36409^c	35044^c	14.9^c	14.7^c
SE±	321	307	839	847	0.2	0.2
LSD(P=0.05%)	941	899	2461	2485	0.7	0.7
Fertigation levels (F)						
F_1	10724^a	10156^a	30117^a	28879^a	13.2^a	13.3^a
F_2	11131^{ab}	10593^{ab}	31423^{ab}	29937^{ab}	13.3^{ab}	13.4^{ab}
F_3	11891^{bc}	11300^{bc}	33600^{bc}	32294^{bc}	14.1^{bc}	14.2^{bc}
F_4	12349^c	11769^c	34776^c	33096^c	14.2^c	14.3^c
SE±	371	354	969	978	0.3	0.3
LSD(P=0.05%)	1087	1039	2842	2870	0.8	0.8
Interaction (IXF)						
SE±	642	613	1678	1695	0.5	0.5
LSD(P=0.05%)	NS	NS	NS	NS	NS	NS

*Means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; Irrigation levels: 0.6 Epan (I_1); 0.8 Epan (I_2);1.0 Epan (I_3); Fertigation levels: 100% recommended dose of nitrogen and potassium (RDNK) (F_1); 100% RDNK dosage as per crop coefficient curve (F_2); 125% RDNK (F_3); 125% RDNK as per crop coefficient curve (F_4).

Table 9. Economics of sweet corn as influenced by different drip irrigation and fertigation levels

Treatments	Net Returns (Rs ha^{-1})		Benefit Cost Ratio	
	2020	2021	2020	2021
Irrigation levels (I)				
I_1	82803^a	71745^a	2.9^a	2.5^a
I_2	104721^b	94733^b	3.3^b	2.9^b
I_3	118327^c	108829^c	3.5^c	3.2c
SE±	3319	3316	0.04	0.03
LSD (P=0.05%)	9736	9725	0.12	0.10
Fertigation levels (F)				
F_1:	93262^a	83505^a	3.1^a	2.8^a
F_2:	98638^{ab}	88925^{ab}	3.2^{ab}	2.9^{ab}
F_3	105072^{bc}	94580^{bc}	3.2^{ab}	2.9^{ab}
F_4	110830^c	100066^c	3.3^b	3.0^b
SE±	3833	3829	0.05	0.04
LSD (P=0.05%)	11242	11230	0.14	0.12
Interaction (IXF)				
SE±	6639	6632	0.08	0.07
LSD (P=0.05%)	NS	NS	NS	NS

*Means with at least one letter common are at par using Fisher's LSD @ 5% level of significance; Irrigation levels: 0.6 Epan (I_1); 0.8 Epan (I_2);1.0 Epan (I_3); Fertigation levels: 100% recommended dose of nitrogen and potassium (RDNK) (F_1); 100% RDNK dosage as per crop coefficient curve (F_2); 125% RDNK (F_3); 125% RDNK as per crop coefficient curve (F_4).

returns with drip irrigation at 100 % CPE over 80 and 60 CPE in maize.

Among the four fertigation levels, the application of 125% recommended dose of nitrogen and potassium (RDNK) in differential dosage as per crop coefficient curve (F4) resulted in significantly higher net returns and B:C ratio, on par with the application of 125% RDNK in differential dosage as per recommendation (F3). Conversely, lower net returns and B:C ratio were obtained with the application of 100% RDNK in differential dosage per recommendation (F1), which were comparable to 100% RDNK in differential dosage as per crop coefficient curve (F2) during both years (Table 10). The higher net returns and B:C ratio under F3 and F4 were due to the higher fresh cob and green fodder yield obtained compared to the other fertigation levels. Similar findings were reported by Shruthi *et al.* (2018) recorded higher returns with drip fertigation at 125 % RDF over 100 and 75 % RDF in maize, Richa Khanna (2013) also recorded higher net returns and B:C ratio under drip fertigation with 125% RDF over 50, 75 and 100 % RDF in maize.

Conclusion

Th present study observed that drip irrigation scheduled at 1.0 Epan throughout the crop growth period led to a significant increase in nutrient uptake, crude protein content, and yield of sweetcorn compared to 0.6 and 0.8 Epan. The increase in green cob yield at 1.0 Epan over 0.8 and 0.6 Epan ranged from 9.94 to 30.56 percent on average.Among fertigation levels, application of 125% recommended dose of nitrogen and potassium (RDNK) in differential dosage as per crop coefficient curve, as well as application of 125% RDNK in differential dosage as per recommendation, resulted in higher crude protein content, nutrient uptake, and yield. Additionally, growth and yield obtained with the application of 100% RDNK in differential dosage as per crop coefficient curve were comparable to those with the application of 125% RDNK in differential dosage as per recommendation. Utilizing fertigation based on the crop coefficient curve could potentially save up to 25% of nutrients.Therefore, it can be concluded that irrigation at 1.0 Epan and fertigation with 100% and 125% RDNK in differential dosage as per crop coefficient curve are recommended for sweetcorn crops under high-density and limited water conditions to achieve higher yield and minimize fertilizer and water wastage.

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Conflict of interest

The authors declare that they have no conflict of interest.

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