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Water and nutrients distribution in sweet corn field under gravity drip irrigation and nitrogen management in eastern indo-gangetic plains

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Abstract
A field experiment was carried out during the winter season of 2015-16 to study the effects of four levels of irrigation (gravity drip at 1.0, 0.8 and 0.6 of crop evapotranspiration and surface irrigation) and four levels of nitrogen management (100% inorganic N, 75% inorganic N + 25% inorganic N as vermicompost, 75% inorganic N + 25% inorganic N as FYM and 75% inorganic N + 25% inorganic N as mustard oilcake) on the temporal distribution of water and macronutrients in sweet corn field grown in sandy loam soil. The results of the study showed that amounts of soil water consistently decreased with increase in soil depth; the more so in higher irrigation level than in lower irrigation level and that too under integrated nitrogen management schedule than in chemical nitrogen fertilization only. Higher soil moisture storage was observed in rooting zone depth under drip irrigation scheduling at 1.0 ETc followed by 0.8 ETc as compared with surface irrigation. Higher availability of N, P and K contents in soils at harvest was observed in deficit irrigation regimes than in higher irrigation regimes and that too with integrated N supply than with chemical N fertilization only. Maximum NPK uptake by plant was noticed with surface irrigation and drip irrigation at 1.0 ETc each provided with 75% N as fertilizer and 25% N as vermicompost. The deficit irrigation scheduling with different N management resulted in moderate to low uptake of macronutrients from soil by corn plant.

Keywords: Gravity drip irrigation, sweet corn, soil water, nutrients, sandy loam soil

1. Introduction

Sweet corn (*Zea mays* L var. *saccharata* Sturt) is one of the most versatile high value crops across the world grown almost throughout the year. In India, it is cultivated in 9.4 million hectares with total production of 22.3 million tonnes. However, the productivity is 2.5 tonnes per hectare which is much below the global average. Being an exhaustive deep rooted crop it absorbs more water and nutrients from soil. Since water and nutrients are the most critical inputs for agriculture, their better management and effective utilization is essential for optimizing crop production, food and nutritional security and environmental sustainability (Hanumanth *et al.*, 2016) [8]. The corn plant is very sensitive to soil moisture stress and excessive moisture as well as nitrogen constraint during any physiological stage of crop growth (Moser *et al*., 2006; Payero *et al*., 2009; Kuscu and Demir, 2013) [13, 17, 11]. The best solution for attaining maximum use of limited water and nutrient resources is to improve the existing water and nitrogen management techniques (Borin *et al*., 2010; Okumura *et al*., 2011) [3, 15]. Drip irrigation is a cutting edge water management technology because it maintains optimum soil water balance and imparts high water and nutrient use efficiencies due to the direct application of precise amounts of water and nutrients in the vicinity of crop root zone (Abd El-Wahed and Ali, 2013) [1]. It proves its superiority over other methods of irrigation owing to minimal evaporation and deep percolation loss (Vijayakumar *et al*., 2010; Feleafel and Mirdad, 2013; Deshmukh and Hardaha, 2014) [19, 7, 5]. High frequency water management by drip irrigation minimizes soil as a storage reservoir for water, provides at least daily requirements of water to a portion of root zone of each plant and maintains a high soil matric potential in the rhizosphere to reduce plant water stress (Mantell *et al*., 1985) [12]. In addition to irrigation, nitrogen is also the key nutrient element in production process and its plenty availability in soil throughout the growing stages is vital for optimal yield (Chauhan and Patel,

2011) [4]. The increase in mineral nitrogen application can improve yield, but concurrently reduces its use efficiency and can contribute to the groundwater pollution (Muhumed *et al*., 2014) [14]. The integrated use of nitrogen combining both fertilizer and manurial sources is an alternative viable option to sustain the crop and soil productivity and economic profitability (Pan *et al*., 2009; Wailare, 2014) [16, 20].

In the eastern Indo-Gangetic plains, the sweet corn is an emerging crop and the farmers usually grow the crop with surface irrigation and conventional nitrogen fertilization resulting in low marketable yield and poor quality of produce. The probable reasons for low crop productivity were due to the low availability of water and nutrients in the rhizosphere soil and its corresponding low uptake by crop under unplanned supply of irrigation water and nitrogen fertilizer. In this backdrop, the present study was aimed at evaluating the distribution of water and nutrients in sandy loam soil under the influence of gravity drip irrigation and nitrogen management practices.

2. Materials and Methods
2.1 Study area
The field experiment was conducted on sweet corn during the winter season of 2015-16 at Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya lying in the eastern Indo-Gangetic plains of West Bengal, India. It is located at an altitude of 9.75 m above the mean sea level and is intersected by 22°58'31" N latitude and 88°26'20" E longitude. The area falls under sub-humid tropics with mean monthly temperature ranging between 37.6 to 25.4 ^{0}C in summer and 23.7 to 10.5 ^{0}C in winter. The mean annual rainfall is 1500 mm. The pan evaporation loss ranges between 1.1 and 4.9 mm day^{-1}. The soil is sandy loam texture classified as Typic Fluvaquept. The physical, hydro-physical and chemical characteristics of the experimental soil are displayed in Tables 1 and 2.

Table 1: Physical and hydro-physical characteristics of the experimental soil

Soil depth (cm)	Soil texture (%)			BD (Mg m^{-3})	Ks (cm hr^{-1})	Infiltration (cm hr^{-1})	FC (%)	PWP (%)
	Sand	Silt	Clay					
0-15	70.17	15.75	14.08	1.49	2.35	1.82	23.64	11.16
15-30	72.41	16.24	11.35	1.53	2.23	1.45	21.38	10.74
30-45	78.92	12.27	8.81	1.58	2.31	1.23	19.52	9.43
45-60	74.56	14.01	11.36	1.51	2.19	1.16	22.53	10.57

FC: field capacity, PWP: permanent wilting point, BD: bulk density, Ks: hydraulic conductivity

Table 2: Chemical characteristics of the experimental soils

Soil depth (cm)	p^H (1:2.5)	EC (dS m^{-1})	Organic C (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
0-15	6.87	0.25	5.21	178.1	31.9	151.5
15-30	6.53	0.21	4.56	160.3	29.3	137.3
30-45	6.34	0.14	4.13	151.2	25.7	108.7
45-60	6.32	0.12	3.82	141.7	22.2	96.2

2.2 Experimental treatments and design
The experiment consisted of four irrigation treatments (gravity drip irrigation at 1.0, 0.8 and 0.6 of crop evapotranspiration (ETc) and surface irrigation at 50 mm depth) allotted in the main plots and four nitrogen management (100% N as inorganic, 75% N as inorganic + 25% N as vermicompost, 75% N as inorganic + 25% N as FYM and 75% N as inorganic + 25% N as mustard oilcake) in sub-plots was laid out in split plot design with three replications.

2.3 Agronomic manipulations
The sweet corn variety 'Sugar 75' were sown with row to row and plant to plant spacing of 75 cm x 30 cm on 10 November 2015. A common basal dose of 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} was applied in all plots in the form of single superphosphate and muriate of potash, respectively. The recommended dose of N was 120 kg ha^{-1} applied as urea The prescribed schedules of inorganic N was applied in three equal splits; first at sowing, second at vegetative (30 days after sowing) and third at flowering (60 DAS) stage. The organic sources of N *viz*., vermicompost (1.44% N), farmyard manure (0.52% N) and mustard oilcake (5.21% N) were incorporated in the soil before sowing. The plants were finally harvested on 6 March 2016 after several pickings. The standard agronomic and plant protection measures were adopted uniformly in all plots.

2.4 Irrigation schedules and crop evapotranspiration
Irrigation treatments were given based on surface irrigation at 50 mm depth at 12-15 day interval whereas gravity drip irrigation was scheduled at 1.0, 0.8 and 0.6 of ETc at 3-day interval, respectively (Table 3). The number of irrigation applied for surface and drip system was 5 and 21, respectively. A common irrigation at 20 mm depth was given in all plots just after sowing for proper seed germination and uniform plant establishment. The irrigation water requirement by drip system for the sweet corn was computed on the basis of CPE, pan factor, crop coefficient, canopy area factor and wetted area factor. Crop coefficient values adopted for early growth, crop development, mid season and late season for sweet corn were 1.05, 1.1, 1.15 and 1.2, respectively (Allen *et al*., 1998) [1]. Irrigations were given as per treatment schedules when ETc reached at respective level. Crop evapotranspiration was computed using the field water balance equation as $ETc = I + Re \pm \Delta S$; where, ETc is the crop evapotranspiration (mm), I is the irrigation water (mm), Re is the effective rainfall and $\pm\Delta S$ the change in soil water storage within rooting zone.

Table 3: Irrigation scheduling in gravity drip and surface irrigation system for sweet corn

Irrigation schedule	Number of irrigation	Irrigation water (mm)	Irrigation interval (days)
I_1 : Drip @ 1.0 ETc	21	142.0	3
I_2 : Drip @ 0.8 ETc	21	113.6	3

I_3 : Drip @ 0.6 ETc	21	85.2	3
I_4: Surface irrigation	5	250.0	12-15

2.5 Soil moisture, nutrients and plant sample analysis

The variation in soil water content was determined at 0-15 cm, 15-30 cm, 30-45, 45-60 and 60-90 cm layer just before and 24 hours after each irrigation /rainfall event until harvest of crop by the soil moisture probe. The obtained data on moisture percentage for each soil depth of respective treatment were converted into depth (mm) for estimating the soil moisture storage in rooting depth. The soil samples of the respective treatment plots were also collected from 0-15 cm, 15-30 cm and 30-45 cm depth at harvest and analyzed for available N (Subbiah and Asijia, 1956) [18], available P (Hesse, 1971) [9] and available K (Jackson, 1973) [10]. The initial physical, hydro-physical and chemical properties of the soil were estimated by the standard methods (Jackson, 1973) [10]

2.6 Statistical analysis

The data obtained were subjected to statistical analysis such as analysis of variance using MS Excel and SPSS 12.0 software. Statistical significance between means of individual treatments was assessed using Fisher's least significant difference at p <0.05 level.

3. Results and Discussion

3.1 Soil moisture distribution

The average temporal soil moisture distribution along the vertical distance (0-15, 15-30, 30-60 and 60-90 cm) under different levels of gravity drip irrigation vis-à-vis conventional surface irrigation just before and after the irrigation event under various nitrogen management are presented in Table 4. During the experimental period there was no water stagnation in the field as no heavy spell of rains occurred. The results showed that in the drip system under N_1 source of nitrogen fertilization, the soil moisture contents at 0-15, 15-30, 30-45 and 60-90 cm vertical distances before irrigation and 24 hours after the irrigation were found to be 22.3, 25.6, 26.8, 19.4% and 37.3, 38.6, 39.1, 23.9% for $I_{1;}$ 18.8, 22.2, 23.6, 16.3% and 32.6, 33.8, 34.3, 20.7% for I_2; 16.2, 19.5, 21.7, 15.9% and 27.2, 28.5, 29.3, 20.3% for I_3, respectively. This indicated that under N_1 source of nitrogen application there was an average increase in soil moisture contents at 0-15, 15-30, 30-45 and 60-90 cm depth by 15.0, 13.0, 12.3, 4.5% for $I_{1;}$ 13.8, 11.6, 10.7, 4.4% for I_2; 11.0, 9.0, 7.6, 4.4% for I_3, respectively over their status recorded before irrigation. The more or less same pattern of distribution, but of different magnitudes was also observed for N_2 and N_3 sources of nitrogen fertilization under I_2 and I_3 level, respectively. In the surface irrigation, the increase in soil moisture contents at 0-15, 15-30, 30-45 and 60-90 cm depth was 9.1, 8.9, 8.2 and 5.6% for $N_{1;}$ 9.4, 8.9, 9.4 and 5.8% for N_2; 8.9, 8.4, 7.8 and 5.5% for N_3 and 8.6, 8.5, 7.4 and 5.3% for N_4, respectively. The results demonstrated that the increase in soil moisture content progressively increased with increasing soil depth and the magnitude of variation was relatively more when higher water supply by drip irrigation system at 1.0 ETc was applied under N_1 and N_2 level of nitrogen management. However, in case of surface irrigation, the consistent increase in soil moisture contents varied little up to 30-45 cm soil depth. But in deeper soil layer (60-90 cm) the increase was relatively higher than in drip system at each N management level. Application of high volume of water at a time in surface irrigation could result in the increase of the transmission zone due to increased hydraulic head above the soil leading to high water accumulation at lower depth (60-90 cm). This eventually might accelerate the movement of water under gravitational pull out of the root zone depth. The data further indicates that under N_2 management (75% N as inorganic + 25% N as vermicompost) the imposition of drip irrigation scheduling at optimum (1.0 ETc) or moderately deficit (0.8 ETc) resulted in higher water availability along the soil layers of rooting depth, which lastly caused the higher water utilization. On the other hand, higher level of deficit drip irrigation scheduling at 0.6 ETC at each N management practices was not conducive to meet the daily crop evapotranspiration demand, and the plants might suffer soil moisture stress during some parts of their life cycles. Frequent and lower quantity of water applied through drip irrigation could result in minimum fluctuations in matric suction and lesser movement of water down the lower soil depth might be the reasons for better soil moisture distribution and availability to plants. The maintenance of soil moisture at field capacity under drip system throughout the growing season might have favored in the proliferation and growth of roots in the soil layers.

Based on the periodic soil moisture data, the average soil moisture storage down the soil layers was computed to determine the efficiency of drip and surface irrigation system (Table 5, Figure 1). The overall results show that soil moisture storage marginally decreased first at 15-30 cm layer, substantially increased at 30-60 cm layer and finally decreased abruptly in 60-90 cm soil layer under both drip and surface irrigation system. Relatively higher soil moisture storage was observed in drip than in surface irrigation system in 0-15, 15-30 and 30-60 cm depth, the effect was more pronounced in higher level of drip irrigation schedule than in lower drip irrigation schedule. At 60-90 cm depth the soil moisture storage was more in surface irrigation than in drip irrigation system. The results indicated that there were 13.6, 8.3 and 2.4% more moisture storage in active rooting zone depth (0-90 cm) under drip irrigation scheduling at 1.0, 0.8 and 0.6 ETc as compared with the surface irrigation system. This indicates that optimum to moderate water supply by drip irrigation scheduling at 1.0-0.8 ETc maintained an adequate soil moisture regime in rooting zone, which could mitigate the crop evapotranspiration demand. On the other hand, low water supply by higher level of deficit drip irrigation at 0.6 ETc failed to meet the crop water demand, and thus the plants might expose to soil moisture stress signature frequently. The performance of surface irrigation was quite moderate in relation to various water losses through seepage, evaporation and runoff mechanisms.

Table 4: Distribution of soil profile moisture (%) as influenced by drip and surface methods of irrigation under different nitrogen management on sweet corn field

Irrigation regime	Nitrogen source	Before irrigation				24 hours after irrigation			
		Soil depth (cm)				Soil depth (cm)			
		0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
I_1	N_1	22.3	25.6	26.8	19.4	37.3	38.6	39.1	23.9

	N_2	22.9	26.1	27.6	19.6	37.9	39.3	39.5	24.3
	N_3	21.7	24.9	26.1	19.3	35.7	36.1	37.4	22.4
	N_4	21.2	24.3	25.6	19.2	33.5	34.6	35.2	22.2
I_2	N_1	18.8	22.2	23.6	16.3	32.6	33.8	34.3	20.7
	N_2	19.3	23.1	24.2	16.6	33.4	34.7	35.9	21.3
	N_3	18.2	21.7	22.8	16.1	30.8	31.5	32.6	20.4
	N_4	17.7	21.2	22.3	15.9	26.8	27.9	28.6	20.1
I_3	N_1	16.2	19.5	21.7	15.9	27.2	28.5	29.3	20.3
	N_2	16.6	20.6	22.3	16.2	27.7	29.3	30.2	20.5
	N_3	15.9	19.3	21.2	15.7	26.8	27.4	28.6	20.1
	N_4	15.5	18.9	20.8	15.4	26.4	27.1	28.2	19.9
I_4	N_1	15.6	19.3	20.7	15.7	24.7	28.2	28.9	21.3
	N_2	15.8	20.2	21.5	15.9	25.2	29.1	30.9	21.7
	N_3	15.4	19.1	20.4	15.5	24.3	27.5	28.2	21.0
	N_4	15.3	18.7	20.3	15.3	23.9	27.2	27.7	20.6

I_1: drip @ 1.0 ETc, I_2: drip @ 0.8 ETc, I_3: drip @ 0.6 ETc, I_4: surface irrigation @ 50 mm depth; N_1: 100% inorganic N, N_2: 75% inorganic N + 25% vermicompost N, N_3: 75% inorganic N + 25% FYM N, N_4: 75% inorganic N + 25% mustard oil cake N

Table 5: Average soil moisture storage (cm) prior to the next irrigation under drip and surface irrigation methods in crop root zone depth

Irrigation regime	Soil moisture storage (cm)				Soil moisture storage (cm) in rooting depth (0-90 cm)
	Soil depth (cm)				
	0-15	15-30	30-60	60-90	
Drip @ 1.0 ETc (I_1)	3.15	2.74	5.21	1.79	12.89 (13.6)
Drip @ 0.8 ETc (I_2)	2.98	2.53	4.87	1.91	12.29 (8.3)
Drip @ 0.6 ETc (I_3)	2.83	2.36	4.48	1.95	11.62 (2.4)
Surface irrigation (I_4)	2.66	2.29	4.30	2.10	11.35

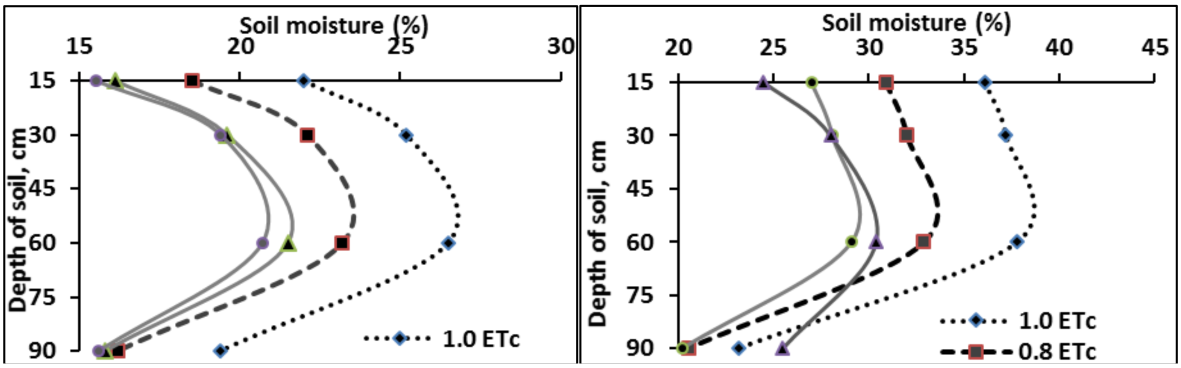

Fig 1: Vertical distribution of soil water (a) before and (b) 24 hours after irrigation under drip and surface methods of irrigation at varied moisture regime.

3.2 Available nutrients in post-harvest soil

The depth-wise distribution of available N, P and K contents of soils at harvest at 0-15, 15-30 and 30-45 cm soil layers were significantly influenced by various irrigation regimes and nitrogen management (Table 6). Before the experimentation, the initial available N, P and K contents in soil at 0-15, 15-30 and 30-45 cm depths were 178.3, 160.3 and 151.2; 31.9, 29.3 and 25.7 and 151.5, 137.3 and 108.7 kg ha^{-1}, respectively indicating a consistent decrease in amounts with increase in soil depth. The main effect of irrigation revealed that available N, P and K contents in all the soil layers was relatively low in the treatments of higher soil moisture regimes under surface and drip irrigation at 1.0 ETc as compared with the treatments of deficit drip irrigation at 0.8 and 0.6 ETC. Likewise, in the nitrogen management schedule, the treatments provided with fertilizer N in conjunction with farmyard manure (N_3) or mustard oilcake (N_4) resulted in higher availability of N, P and K in soils in comparison with the treatment of fertilizer N supplemented with vermicompost (N_2) or sole N fertilization (N_1). The interaction effects between irrigation and N management showed that the contents available N, P and K along 0-15, 15-30 and 30-45 cm soil layers were within the range of 119.2-149.8, 109.5-137.2 and 98.7-125.0 kg ha^{-1}; 33.4-39.8, 29.6-37.4 and 26.6-33.3 kg ha^{-1}; 109.4-135.7, 106.7-128.5 and 85.7-99.2 kg ha^{-1}, respectively. The overall results showed that the availability of N, P and K contents of soils after harvest was generally low in higher irrigation than in deficit irrigation regimes and that too with chemical N fertilization than with combined organic N and chemical N fertilizer application. Comparing with the initial soil available N status, there was depletion of available N in soil in varying magnitudes depending on the nature of organic manure incorporated into soil. This reduction in available N was attributed to the combined effects of crop removal and deep percolation losses as nitrogen element is more mobile in nature. The similar pattern of depletion was also observed in available K in soil. The reasons for the decrease in the availability of soil K was perhaps due to the combined effects of crop removal, soil colloidal adsorption and downward leaching loss below the root zone as the soil is sandy loam in texture and porous. However, there was considerable build-up of soil available P in all the layers. The first reason for such increase in the availability of soil P was ascribed to the low mobility of P in soil since P-fertilizers are prone to fixation by the soil colloids. Secondly, there was low absorption of P by plants, the maximum of which being utilized from the added water soluble P-fertilizer. Thirdly, there was significant addition of P in soil through organic manures such as vermicompost, farmyard manure and mustard oilcake.

Table 6: Available N, P and K contents in post-harvest soils of sweet corn plant under drip and surface methods of irrigation and nitrogen management

Treatment	Available N (kg ha^{-1})			Available P (kg ha^{-1})		Available K (kg ha^{-1})			
	Depth of soil (D) in cm								
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
I_1	133.10	122.63	110.96	36.23	32.69	28.55	119.06	117.02	92.79
I_2	142.30	127.66	115.63	36.97	34.77	31.23	127.33	120.17	96.51
I_3	144.62	133.05	119.30	38.78	35.89	32.32	131.46	123.69	97.19
I_4	127.75	117.86	103.67	35.27	31.80	27.85	88.47	114.24	90.02
	I	D	I x D	I	D	I x D	I	D	I x D
SEm ±	0.76	1.26	1.15	0.63	0.73	1.27	0.71	0.84	1.37
CD (p=0.05)	2.19	3.64	4.21	1.83	2.12	3.67	2.05	2.42	3.96
N_1	130.39	118.39	106.56	35.11	31.67	28.57	117.52	112.29	90.36
N_2	135.73	122.80	111.34	36.46	33.66	29.67	121.32	117.56	93.53
N_3	139.49	127.90	115.09	37.27	34.61	30.52	125.67	120.69	95.54
N_4	142.17	132.12	116.56	38.40	35.21	31.19	101.82	124.58	97.08
	N	D	N x D	N	D	N x D	N	D	N x D
SEm ±	0.76	1.26	1.15	0.63	0.73	1.27	0.71	0.84	1.37
CD (p=0.05)	2.19	3.64	4.21	1.83	2.12	3.67	2.05	2.42	3.96
I_1N_1	127.93	115.38	105.75	34.12	30.78	27.15	112.52	110.45	89.27
I_1N_2	131.18	119.42	109.46	35.42	32.64	28.35	117.36	115.62	91.43
I_1N_3	135.22	125.61	113.08	37.25	33.27	28.98	121.25	118.44	94.09
I_1N_4	138.07	130.12	115.53	38.12	34.08	29.72	125.12	123.57	96.36
I_2N_1	135.54	121.37	109.51	35.57	32.62	29.35	121.34	114.15	92.65
I_2N_2	141.87	125.18	114.76	36.92	34.91	30.85	124.76	119.37	96.23
I_2N_3	144.46	130.85	119.94	37.25	35.47	31.98	129.31	122.12	98.05
I_2N_4	147.33	133.22	118.31	38.12	36.08	32.72	133.92	125.05	99.12
I_3N_1	138.84	127.33	112.23	37.32	33.63	31.12	126.84	117.83	93.85
I_3N_2	142.62	132.08	117.86	38.83	35.57	32.08	129.55	122.32	97.22
I_3N_3	147.17	135.61	122.13	39.15	36.93	32.87	133.78	126.08	98.48
I_3N_4	149.83	137.18	124.98	39.82	37.42	33.22	135.67	128.54	99.22
I_4N_1	119.23	109.47	98.75	33.42	29.65	26.65	109.37	106.74	85.68
I_4N_2	127.25	114.51	103.28	34.67	31.52	27.41	113.62	112.92	89.23
I_4N_3	131.09	119.53	105.22	35.44	32.78	28.26	118.33	116.13	91.54
I_4N_4	133.44	127.94	107.41	37.53	33.25	29.08	12.56	121.17	93.62
	N	D	N x D	N	D	N x D	N	D	N x D
SEm ±	1.20	1.39	1.71	0.38	0.62	0.93	1.10	1.35	1.61
CD (p=0.05)	3.41	3.93	4.87	1.09	1.77	2.63	3.12	3.81	4.56

I_1: 1.0 ETc, I_2: 0.8 ETc, I_3: 6 ETc, I_4: surface irrigation @ 50 mm depth; N_1: 100% inorganic N, N_2: 75% inorganic N + 25% organic N as vermicompost, N_3: 75% inorganic N + 25% organic N as FYM, N_4: 75% inorganic N + 25% organic N as mustard oilcake

3.3 Plant nutrients uptake

A perusal of data showed that N, P and K uptake by plant was significantly influenced by different irrigation regimes and nitrogen management (Table 7). Highest crop uptake of N, P and K was found with conventional surface irrigation (91.75, 22.06 and 63.62 kg ha^{-1}, respectively) which was statistically at par with drip irrigation at 1.0 ETc (89.48, 21.54 and 60.41 kg ha^{-1}, respectively). This might be due to the higher availability of soil water which had synergistic effect on the uptake of nutrients by plants. Increased biomass yield and higher uptake of N, P and K uptake by baby corn as a result of higher soil moisture regime was reported by Dutta *et al*. (2015) [6]. On the other hand, uptake of N, P and K by plant was significantly lower under deficit irrigation scheduling of 0.8 and 0.6 ETc under drip system. Similarly, nitrogen management had also significant influence on N, P and K uptake of corn plant. Removal of N, P and K by plant was found highest with N_2 treatment (91.90, 22.22 and 63.42 kg ha^{-1}, respectively) which was on par with N_1 treatment (89.06, 21.17 and 59.85 kg ha^{-1}, respectively). The other nitrogen management on N, P and K uptake by plant was significantly low. The interaction effect between irrigation and nitrogen management on N, P and K uptake was also significant. Maximum accumulation of N, P and K (98.15, 24.47 and 69.47 kg ha^{-1}, respectively) in plant tissues was obtained with the treatment combination of surface irrigation with 75% N as fertilizer and 25% N as vermicompost (I_4N_2) which was statistically comparative with the treatment combination of drip irrigation at 1.0 ETc with 100% fertilizer N (I_1N_2) giving the corresponding values of 95.33, 23.47 and 64.86 kg ha^{-1}, respectively. The deficit irrigation scheduling at 0.8 or 0.6 ETc with 100% N as fertilizer N or 75% N as fertilizer N plus 25% N as vermicompost, FYM or mustard oil cake resulted in moderate to low uptake of N, P and K by plant. The variable plant biomass yield as stimulated by different irrigation schedules coupled with various N supplies from inorganic or both inorganic and organic sources were probably responsible for the differential uptake of N, P and K from soils.

Table 7: Plant nutrients uptake at harvest of sweet corn plant under drip and surface methods of irrigation and different nitrogen management

Treatment	Nutrient uptake (kg ha^{-1})		
	N	P	K
I_1	89.48	21.54	60.41
I_2	85.67	19.80	57.43
I_3	80.24	18.36	53.92
I_4	91.75	22.06	63.62
SEm ±	0.96	0.46	0.84
CD (p=0.05)	2.77	1.32	2.42
N_1	89.06	21.17	59.85
N_2	91.90	22.22	63.42
N_3	85.02	19.65	57.42
N_4	81.17	18.72	54.69
SEm ±	0.96	0.46	0.84
CD (p=0.05)	2.77	1.32	2.42
I_1N_1	93.14	22.78	61.25
I_1N_2	95.33	23.47	64.86
I_1N_3	87.27	20.13	59.41
I_1N_4	82.19	19.78	56.13
I_2N_1	86.35	20.42	58.37
I_2N_2	89.21	21.97	61.48
I_2N_3	85.65	18.65	56.76
I_2N_4	81.48	18.14	53.12
I_3N_1	82.24	18.36	54.21
I_3N_2	84.92	18.95	57.87
I_3N_3	77.67	18.36	52.16
I_3N_4	76.14	17.76	51.43
I_4N_1	94.52	23.12	65.58
I_4N_2	98.15	24.47	69.47
I_4N_3	89.47	21.46	61.33
I_4N_4	84.86	19.19	58.09
SEm ±	1.47	0.63	1.39
CD (p=0.05)	4.16	1.78	3.94

I_1: 1.0 ETc, I_2: 0.8 ETc, I_3: 6 ETc, I_4: surface irrigation @ 50 mm depth; N_1: 100% inorganic N, N_2: 75% inorganic N + 25% organic N as vermicompost, N_3: 75% inorganic N + 25% organic N as FYM, N_4: 75% inorganic N + 25% organic N as mustard oilcake

4. Conclusion

Drip irrigation at 1.0 or 0.8 ETc with chemical N fertilizer or 75% N as fertilizer + 25% N as vermicompost maintained higher water availability and soil water storage in rooting depth. Higher availability of NPK contents in soils at harvest was observed in deficit irrigation than in higher irrigation schedules and that too with integrated N supply than with chemical N fertilization only. Maximum NPK uptake by plant was noticed with surface irrigation and drip irrigation at 1.0 ETc each accommodated with 75% N as fertilizer and 25% N as vermicomposting.

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