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Gravity Drip Irrigation and Nitrogen Management on Yield and Water Productivity of Sweet Corn

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Abstract: ***A field experiment was conducted during winter season of 2015-16 on a sandy loam soil to assess four levels of irrigation (gravity drip irrigation at 1.0, 0.8 and 0.6 ETc and surface irrigation) and nitrogen management practices (100% N as fertilizer, 75% N as fertilizer + 25% N as vermicompost, 75% N as fertilizer + 25% N as FYM and 75% N as fertilizer + 25% N as mustard oil cake) on sweet corn. The results of the study showed that surface irrigation recorded the maximum plant growth, yield attributes, cob and fodder yields which were competitive with drip irrigation at 1.0 ETc. Higher plant variables, cob and fodder yields was noticed with 75% N as fertilizer plus 25% N as vermicompost. However, conventional surface irrigation with 75% N as fertilizer + 25% N as vermicompost showed maximum growth, yield attributes, cob and fodder yields which being identical with drip irrigation at 1.0 ETc with 75% N as fertilizer + 25% N as vermicompost. Maximum water productivity was obtained with drip irrigation at 0.6 ETc with 75% N as fertilizer + 25% N as vermicompost. The maximum cob yield was predicted as 7.35 t/ha with 200 mm water application.***

Keywords: Drip irrigation, sweet corn, cob yield, water productivity, crop evapotranspiration, sandy loam soil

1. Introduction

Sweet corn (*Zea mays* L var. *saccharata* Sturt) is one of the most versatile high value cereal crops across the world (Kannan *et al*. 2013). It has wider adaptability under diverse agro-climatic conditions (Chennankrishnan *et al*. 2012). In addition to staple food for human consumption as either a fresh or a processed product and quality feed for livestock, it serves as a basic raw material for industry and fuel (Khazaei *et al*. 2010). In India, it is cultivated in 9.4 million hectare with total production of 22.3 million tonnes with an average yield of 2.5 t/ha (Anon. 2016). It can be accommodated as a monocrop or intercrop system, and it is an alternative for resource poor small and medium farmers.

The most important limiting factors affecting the overall growth and production of sweet corn are inadequate supply of water and nitrogen fertilization (Moser *et al*. 2006). The plant is very sensitive to soil moisture stress during any stage of crop growth cycle. It has deleterious effect on corn production as a result of reduced growth, development and physiological processes of plants (Payero *et al*. 2009, Kuscu and Demir 2013). The supply of soil nutrients and its uptake by plant is directly related to the availability of optimum soil moisture regime in root zone. The limited water supply or drought condition results in reduced corn growth and smaller grains mainly by way of reducing the plant uptake of macronutrients (Gutierrez *et al*. 2008). The practice of irrigation scheduling such as deficit irrigation is now widely recognized as one of the solutions to save scarce water as well as to obtain maximum crop and water productivity (Geerts and Raes 2009). Drip irrigation is an important way in the management of water by maintaining the optimum soil moisture balance in root zone with increased yield. It provides the efficient use of limited water resources with higher water use efficiency because it allows precise amount, timing and uniform distribution of water in the vicinity of root zone (Abd El-Wahed and Ali 2013). It proves its superiority over surface and sprinkler methods of irrigation owing to negligible surface evaporation, less surface runoff as well as minimal deep percolation (Feleafel and Mirdad 2013, Deshmukh and Hardaha 2014).

In addition to irrigation, the nitrogen is the key nutrient element in yield determining factor and its availability in soil in sufficient quantity throughout the growing stages is vital for corn growth and yield (Chauhan and Patel 2011). The increase in chemical nitrogen application can increase in yield, but simultaneously it reduces the nitrogen use efficiency and contributes to the economic and environmental vulnerability (Muhumed *et al*. 2014). The judicious application of fertilizer nitrogen in conjunction with organic manures from different sources is the most feasible option to increase the crop and soil productivity, maintain the environment sustainability and improve the economic stability of farmers (Wailare 2014).

In the Indo-Gangetic alluvial plains, the sweet corn is an emerging crop which has a high market demand all through the year, but its supply chain is inadequate to meet the consumers' requirements. The farmers usually grow the crop during the winter season with improper use of irrigation and nitrogen fertilization resulting in low yield and poor quality of produce. Sweet corn being deep rooted exhaustive crop requires liberal amounts of water and nutrients especially nitrogen for growth and yield. Hence, there is necessity for planned use of irrigation and nitrogen fertilization in such a manner to obtain higher yield. With this background, the present study was conducted with the objectives of finding the optimal water and nitrogen requirements for higher yield and water productivity of sweet corn plant in a sandy loam soil.

2. Materials and Methods

Experimental site, soil and climatic condition

The field experiment was carried out on sweet corn during winter season (*rabi*) of 2015-16 at Central Research Farm, Gayeshpur, Nadia, Bidhan Chandra Krishi Viswavidyalaya, under jurisdiction of the Indo-Gangetic plains of West Bengal, India. The site is located at 22°58'31" N latitude and

88°26'20" E longitude with an altitude of 9.75 m above the mean sea level. The study area falls under sub-humid tropics marked by hot dry summer months (May-June) and cold winter (December-January). The monthly mean temperature ranges between 37.6 ^{O}C to 25.4 ^{O}C in summer and 23.7 ^{O}C to 10.5 ^{O}C in winter. The annual mean rainfall is about 1500 mm with more than 75% of it being received during June through September. The mean relative humidity varies from 71 to 95%. The wind speed velocity varies from 0.2 to 2.3 kmph. The pan evaporation loss ranges from 0.9 to1.4 mm/day in the month of January which reaches 3.8 to 4.9 mm/day during May. The depth of groundwater table ranges from 3.8 to 5.2 m bgl. Soil is sandy loam classified as Typic Fluvaquept with good drainage and water transmission characteristics. The relevant physical, hydro-physical and chemical characteristics of the soil determined by the methods of Jackson (1973) are listed in Tables 1 and 2.

Experimental treatments and design

There were four irrigation treatments comprised of three levels of gravity drip irrigation (1.0, 0.8 and 0.6 of crop evapotranspiration (ETc) and one conventional surface irrigation at 50 mm depth) as the main plots and four nitrogen combinations using inorganic and organic sources in the recommended nitrogen level (100% N as inorganic fertilizer, 75% N as inorganic fertilizer + 25% N as vermicompost, 75% N as inorganic fertilizer + 25% N as FYM and 75% N as inorganic fertilizer + 25% N as mustard oil cake) as sub-plots. The experiment was arranged in split plot design with three replications.

Agronomic manipulations

The land was prepared by several cross-ploughing followed by laddering to obtain a good tilth. The experimental field was partitioned into the 48 unit plots in accordance with the experimental design. The uniform sized seeds of sweet corn variety 'Sugar 75' were sown at 5-6 cm depths with crop geometry of 75 cm row to row and 30 cm plant to plant distance on 10 November 2015. All treatments received a common basal dose of 60 kg P_2O_5/ha and 40 kg K_2O/ha applied in the form of single superphosphate and muriate of potash, respectively. The recommended fertilizer nitrogen was 120 kg N/ha applied in the form of urea The prescribed schedules of inorganic nitrogen was applied in three equal splits; first one at the time of sowing, second at the vegetative (30 days after sowing) and the third at the flowering stage (60 DAS). All organic sources of nitrogen viz., vermicompost (1.44% N), farmyard manure (0.52% N) and mustard oil cake (5.21% N) were incorporated in the soil before sowing. The corn plants were harvested on maturity on 6 March 2016. The crop growing period was lasted for 88 days. Necessary cultural operations like row gap filling, weeding, earthing-up and plant protection measures were equally performed in all the treatments. Six plants were randomly selected from the centre of each unit plot for collection of data on growth and yield components.

Irrigation schedules

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. Five (5) number of irrigation was applied in surface irrigation, while 21 number of irrigation was required for drip irrigation. A separate lateral line of 12 mm diameter was laid for each treatment. Two drippers per plant were provided on either side of plant at a distance of 30 cm. The discharge rate of emitter was 1.8 lph at a pressure of 0.32 kg/cm^2. A common irrigation at 20 mm depth was given in all plots just after sowing for proper seed germination, uniform plant establishment and maintaining identical irrigation regime.

Estimation of irrigation water requirement

The amount of irrigation water applied by drip system was calculated using the following equation:

$I = Ep \times Kp \times Kc \times P - Re$

Where, I is the irrigation water (mm), Ep is the pan evaporation (mm), Kp is the pan coefficient, Kc is the crop coefficient, P is the percentage of wetted area and Re is the effective rainfall. The wetted area was taken as 100% assuming that lateral interval is equal to the spaces between drippers (Karmeli and Keller 1975). The evaporation data was obtained from a USDA Weather Bureau Class A Pan located inside the experimental site on a wooden support at a height of 15 cm above the soil surface. The pan coefficient value was taken as 0.7. Crop coefficient values adopted for early growth, crop development, mid season and late season for crop were 1.05, 1.1, 1.15 and 1.2, respectively (Allen *et al*., 1998). Irrigations were given as per treatment schedules when ETc reached at respective level. The quantity of surface water applied was measured with the help of Parshall flume commissioned at the head of each plot.

Estimation of crop evapotranspiration

Crop evapotranspiration (ETc) during the growing period (sowing to harvest) for sweet corn field was computed using the following field water balance equation:

$ETc = I + Re + Cp - Rf \pm \Delta S$

Where, ETc is the crop evapotranspiration (mm), I is the irrigation water (mm), Re is the effective rainfall, Cp is the contribution through capillary rise from groundwater (mm), Rf the surface runoff (mm) and ±ΔS the change in soil water storage in the profile between planting and harvest time (mm) in the 0-90 cm active rooting depth. The monthly effective rainfall was calculated by the method of Sharma *et al*. (2010). The capillary rise from groundwater (Cp) was assumed to be negligible as depth of groundwater was more than 25 m below the local ground level. The surface runoff (Rf) was considered negligible as the field plots were bunded at 50 cm height and no bund overflow occurred. Thus, $ETc = I + Re \pm \Delta S$.

Water productivity

It is the ratio of cob yield to the amount of water depleted by sweet corn in the process of evapotranspiration. The water productivity was calculated based on the relation (Kang *et al*. 2000) as below,

Water productivity (WP) = Y/ETc (kg/ha/mm), where, Y = Marketable cob yield (kg/ha) and ETc = Crop evapotranspiration (mm)

Soil moisture measurement

The soil moisture percentage determined by using soil moisture probe was initiated on 10 December 2015 and ended on 15 February 2016. The transparent polythene tubes were commissioned at a depth of 15, 30, 45, 60 and 90 cm in soil in different unit irrigated plot area. Soil water percentage was directly measured from 0-15 cm, 15-30 cm, 30-45, 45-60 and 60-90 cm layer just before and 48 hours after irrigation and also before sowing and final harvest of the plant. The obtained data on moisture percentage for each soil depth of respective treatment were converted into depth (mm) for estimating the soil moisture storage.

Statistical analysis

The data obtained in relation to the different plant parameters were subject to analysis of variance (ANOVA) techniques using software packages of MS Excel and SPSS 12.0 version. Statistical significance between means of individual treatments was assessed using Fisher's Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez 1984).

3. Results and Discussion

Growth and yield parameters

A perusal of data on growth and yield attributes of sweet corn showed that the tallest plant height (173.64 cm), highest number of leaves/plant (11.93), number of cobs/plant (2.07), cob length (22.09 cm), cob girth (20.99 cm), green cob weight (358.12 g) and number of grains/cob (194.92) were obtained from conventional surface irrigation (Table 3). These values were found to be statistically comparative with higher drip irrigation schedule at 1.0 ETc with the corresponding values of 172.88 cm, 11.86, 2.04, 21.34 cm, 20.74 cm, 352.72 g and 191.46, respectively. The observed growth and yield components were intermediate in moderate deficit drip irrigation schedule at 0.8 ETc, but significantly the lowest in higher deficit drip irrigation schedule at 0.6 ETc. These indicate that maintenance of higher availability of soil moisture either through surface or drip irrigation at 1.0 ETc resulted in vigorous growth of plant by increasing the height and number functional leaves with corresponding increase in yield attributes a result of higher photosynthetic activity and accumulation of more assimilates due to more exposure to sunlight. Maximum plant height and number of leaves with conventional irrigation as well as irrigation at 1.0 IW/CPE or 100% Epan were reported earlier (Patil and Mahadkar 2011, Mohamed *et al*. 2014, Dutta *et al*. 2015). The observed reduction in plant height, number of leaves and yield components due to soil moisture stress condition have been corroborated with the previous studies (Moser *et al*. 2006, Payero *et al*. 2006).

As regards to the nitrogen management, the conjunctive use of 75% N as inorganic fertilizer and 25% N as vermicompost recorded the tallest plant height (174.1 cm), maximum number of leaves (11.98), number of cobs/plant (2.07), cob length (22.50 cm), cob girth (21.08 cm), green cob weight (362.11 g) and number of grains/cob (195.72). These were statistically at par with 100% N as inorganic fertilizer application exhibiting the corresponding values of 171.1 cm, 11.77, 1.95, 21.14 cm, 21.47 cm, 350.06 g and 189.28, respectively. The least growth and yield attributes were displayed with application of 75% N as inorganic fertilizer and 25% N as mustard oil cake (MOC). The effect of integrated use of 75% N as inorganic fertilizer and 25% N as FYM in increasing the growth and yield attributes was moderate. This indicated that the release of N from organic inputs like FYM and MOC was not in synchrony with the demand of plant N requirement. However, the integrated application of inorganic fertilizer N and organic N source through vermicompost increased more readily available N in soil due to addition of adequate soluble fertilizer N and quickly release of N on mineralization of vermicompost which helped increase in plant N uptake leading to higher growth and yield attributes (Muhumed *et al*. 2014). These results are in agreement with those of Dass *et al*. (2008), Uwah *et al*. (2014) and Rashedi and Ghosh (2016).

The interaction effects between irrigation and nitrogen management (Table 4) showed that the tallest plant (179.43 cm), number of leaves (12.45), number of cobs/plant (2.32), cob length (23.98 cm), cob girth (22.22 cm), green cob weight (379.22 g) and number of grains/cob (208.74) were obtained with surface irrigation complemented with 75% N as fertilizer and 25% N as vermicompost (I_4N_2). These parametric values were almost identical with treatment combination of drip irrigation at 1.0 ETc supplemented with 75% N as fertilizer and 25% N as vermicompost (I_1N_2) displaying corresponding figures of 178.62 cm, 12.32, 2.21, 23.65 cm, 21.81 cm, 372.68 g and 204.31, respectively. All growth and yield attributes were found to be the least with drip irrigation at 0.6 ETc provided with 75% N as fertilizer N and 25% N as MOC (I_3N_3). These conformed to the observations of Muhumed *et al*. (2014) who reported that higher irrigation regime coupled with higher nutrition had significant effect on the yield components of sweet corn.

Cob and fodder yields

Surface irrigation resulted in maximum cob (7.20 t/ha) and fodder (32.0 t/ha) yields of corn plant which was statistically at par with higher drip irrigation schedule at 1.0 ETc with the analogous values of 7.11 and 31.5 t/ha, respectively (Table 4). The observed yield data under moderate deficit drip irrigation at 0.8 ETc were intermediate. On the contrary, significantly the lowest yield of cob (6.41 t/ha) and fodder (26.6 t/ha) were obtained from higher deficit drip irrigation at 0.6 ETc. The marked reduction in cob and fodder yield with higher deficit drip irrigation schedule at 0.6 ETc might be due to higher soil water stress which restricts the transpiration, stomatal opening and reduced $^{14}CO2$ fixation resulting into low photosynthetic activity, retarded growth and leaf area expansion and the depressed yield (Karam *et al*. 2002). Conversely, the higher availability of soil moisture either through surface irrigation or drip irrigation at 1.0 ETc at critical physiological stages helps for keeping the plant photosynthetically active which might have resulted in proper growth and development and ultimately maximum yields (Rathore and Singh 2009, Acharya *et al*. 2013). The highest corn grain yield from full irrigation with 6-day interval using drip system was obtained by Yazar *et al*. (2002). The improvement in yield and yield components of corn with adequate or excess irrigation level were demonstrated by Dutta *et al*. (2015). Marked reduction in yield due to soil water deficit condition during any physiological stage of plant was recorded earlier workers (Moser *et al*. 2006, Payero *et al*. 2006).

The integrated use of 75% N as inorganic fertilizer and 25% N as vermicompost recorded maximum cob (7.29 t/ha) and fodder (30.8 t/ha) yield. These were comparative with application of 100% N as fertilizer with the corresponding values of 7.06 and 30.5 t/ha, respectively. Minimum yield of cob (6.16 t/ha) and fodder (25.5 t/ha) was obtained with 75% N as inorganic fertilizer and 25% N as MOC. The combined application of 75% N as fertilizer and 25% N through FYM in increasing the cob and fodder yield was moderate. This amply suggests that the slow release of N from organic inputs like FYM and MOC on mineralization is not adequate to meet the plant N demand in different physiological stages. However, organic manuring with vermicompost along with chemical N fertilization rendered higher cob and biomass yields due to steady promotion of growth stature and yield enhancing characters as a result of higher N release (Rashedi and Ghosh, 2016).

The interaction effect between irrigation and nitrogen management (Table 5) showed that the highest cob (7.66 t/ha) and fodder (41.5 t/ha) yield was observed with surface irrigation coupled with 75% N as fertilizer N and 25% N as vermicompost (I_4N_2). The obtained data were at par with drip irrigation at 1.0 ETc with 75% N as fertilizer and 25% N as vermicompost (I_1N_2) which showed the corresponding values of 7.53 and 40.3 t/ha, respectively. The cob and fodder yields were found to be the lowest with deficit drip irrigation schedule at 0.6 ETc complemented with 75% N as fertilizer and 25% N as MOC (I_3N_3). The maintenance of high availability of water and nitrogen in root zone under higher water regime and integrated N supply condition might have facilitated the better water usage and higher N uptake which promoted the root growth and proliferation, thereby higher yield production (Bozkurt *et al.*, 2009).

Crop water use and water productivity

The components of water balance, crop water use and water productivity by sweet corn plant are furnished in Table 5. The depth of irrigation water applied in conventional surface irrigation and gravity drip irrigation at 1.0, 0.8 and 0.6 of ETc was 250, 142, 113.6 and 85.2 mm, respectively. The effective rainfall calculated during the experimental period was 26.5 mm for surface irrigation and 19.4 mm for drip irrigation. The soil profile moisture storage ranged between 14.02 mm and 19.37 mm. The profile moisture storage was relatively higher in lower moisture regime and *vice versa*. Thus the seasonal crop evapotranspiration under drip irrigation at 1.0, 0.8 and 0.6 of ETc was 198.28, 171.17 and 143.69 mm, respectively. The corresponding figure for surface irrigation was 311.94 mm. The water use and water productivity (WP) by sweet corn plant were influenced by the amounts of irrigation water applied, contribution from soil water storage and the sources of nitrogen ingredient incorporation. The highest water use (311.94 mm) was found in surface irrigation and the lowest (143.69 mm) in drip irrigation at 0.6 ETc. On the other hand, the highest water productivity (44.63 kg/ha-mm) was obtained with drip irrigation at 0.6 ETc, whereas the lowest WP (23.1 kg/ha-mm) was observed with the surface irrigation. This implies that the water productivity of plant decreased progressively with increment in water supply. Likewise, the integration of 75% N as fertilizer with 25% N as vermicompost recorded the highest water productivity (37.97 kg/ha-mm). The corresponding data for the treatment of 100% N as fertilizer, 75% N as fertilizer + 25% N as FYM and 75% N as fertilizer + 25% N as MOC were 36.69, 36.53 and 32.13 kg/ha-mm, respectively. The interaction effects between irrigation schedule and nitrogen management demonstrated that maximum water productivity of 47.35 kg/ha-mm was obtained with drip irrigation at 0.6 ETc supplemented with 75% N as fertilizer plus 25% N as vermicompost (I_3N_2) and minimum of 20.61 kg/ha-mm was recorded with surface irrigation provided with 75% N as fertilizer + 25% N as MOC (I_4N_4). The reduced water productivity in surface irrigation complemented with chemical N fertilization or integration of inorganic and organic sources of N supply could be ascribed to the losses of water and N as a result of evaporation and deep percolation. However, in terms of increased cob yield, better water productivity (38.0 kg/ha-mm) and substantial water savings, drip irrigation schedule at 1.0 ETc accompanying with 75% N as fertilizer and 25% N as vermicompost (I_1N_2) emerged as the suitable strategy to counteract the adverse effects of excess irrigation application and chemical N fertilization to the ecology. This treatment combination was also advantageous to the sweet corn growers from economic point of view.

Water-yield relation

The relationship between fresh cob yields with respect to the amount of irrigation water application is displayed in Fig. 1. A second degree polynomial equation was best fitted to the data of fresh cob yield and amount of irrigation water applied. Coefficient of determination (R^2) value was found to be 0.999 for the entire irrigation treatments including surface and drip irrigation system. Predicted cob yield was observed maximum as 7.35 t/ha with 200 mm of irrigation water application. Thereafter, the cob yield was declined with increasing amount of water application. This result revealed an interesting point from groundwater management point of view. The higher amount of water application by conventional surface irrigation at 12-15 days interval was not conducive to increase the marketable yield; rather it allowed the wastage of water. On the other hand, irrigation based on 100% crop evapotranspiration by gravity drip system at 3-day interval throughout the crop stages is imperative for promoting higher sweet corn yield with higher water productivity in sandy loam soil.

4. Conclusion

The results of the study showed that gravity drip irrigation at 1.0 ETc along with 75% N as fertilizer and 25% N as vermicompost in the recommended N fertilizer dose was found to be best treatment option in deriving higher yield and water productivity of sweet corn. The predicted maximum cob yield was estimated as 7.35 t/ha with 200 mm water application. The findings will augur the precise planning and efficient management of irrigation water and nitrogen fertilizer for the crop in this region.

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

Soil depth (cm)	Soil texture (%)			BD (Mg/m)	Ks (cm/hr)	Infiltration (cm/hr)	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

Table 2: Chemical characteristics of the experimental soil

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

Table 3: Effect of different irrigation and nitrogen management on growth, yield components and yield of sweet corn

Treatment	Plant height (cm)	No. of leaves /plant	No. of cobs /plant	Cob length (cm)	Cob girth (cm)	Green cob weight (g/cob)	No. of grains/cob	Cob yield (t/ha)	Fodder yield (t/ha)
Irrigation (I)									
I_1 (Drip 1.0 ETc)	172.88	11.86	2.04	21.34	20.74	352.72	191.46	7.11	31.5
I_2 (Drip 0.8 ETc)	167.21	11.39	1.81	20.25	19.79	345.69	179.83	6.80	29.0
I_3 (Drip 0.6 ETc)	163.86	11.13	1.67	20.08	19.18	318.33	172.99	6.41	26.6
I_4 (Surface irrigation)	173.64	11.93	2.07	22.09	20.99	358.12	194.92	7.20	32.0
SEm±	1.03	0.06	0.03	0.29	0.12	2.41	2.03	0.08	0.56
CD (0.05)	2.92	0.17	0.09	0.81	0.34	6.83	5.76	0.23	1.58
Nitrogen (N)									
N_1 (100% N as inorganic)	171.11	11.77	1.95	21.14	20.47	350.06	189.28	7.06	30.8
N_2 (75% N as inorganic + 25% N as vermicompost)	174.10	11.98	2.07	22.50	21.08	362.11	195.72	7.29	32.3
N_3 (75% N as inorganic + 25% N as FYM)	170.06	11.65	1.94	20.74	20.31	341.55	186.45	7.01	30.5
N_4 (75% N as inorganic + 25% N as mustard cake)	162.32	10.91	1.63	19.38	18.83	321.14	167.75	6.16	25.5
SEm±	1.31	0.09	0.04	0.48	0.16	3.33	2.54	0.09	0.58
CD (0.05)	3.72	0.24	0.11	1.35	0.46	9.42	7.19	0.25	1.64

Table 4: Interaction effects between irrigation and nitrogen management on growth, yield components and yield of sweet corn

Treatment (I × N)	Plant height (cm)	No. of leaves /plant	No. of cobs/plant	Cob length (cm)	Cob girth (cm)	Green cob weight (g/cob)	No. of grains/cob	Cob yield (t/ha)	Fodder yield (t/ha)
I_1N_1	174.32	12.06	2.11	21.87	21.10	363.35	196.32	7.31	39.1
I_1N_2	178.62	12.32	2.21	23.65	21.81	372.68	204.31	7.53	40.3
I_1N_3	171.34	11.84	2.05	20.33	20.68	351.64	192.57	7.22	38.6
I_1N_4	167.23	11.21	1.77	19.51	19.36	323.22	172.65	6.39	32.4
I_2N_1	168.54	11.61	1.85	20.24	19.89	346.57	183.44	6.97	37.3
I_2N_2	170.43	11.72	1.97	21.46	20.62	353.91	188.76	7.17	38.3
I_2N_3	168.15	11.47	1.81	20.13	20.18	345.56	180.98	6.92	37.5
I_2N_4	161.72	10.75	1.61	19.15	18.45	336.72	166.13	6.14	32.8
I_3N_1	165.33	11.28	1.69	19.92	19.45	321.45	177.82	6.54	35.6
I_3N_2	167.92	11.42	1.77	20.89	19.67	342.64	181.08	6.81	36.5
I_3N_3	165.64	11.31	1.72	20.36	19.52	311.68	175.41	6.58	35.2
I_3N_4	156.56	10.49	1.49	19.15	18.07	297.54	157.63	5.7	30.6
I_4N_1	176.25	12.12	2.16	22.54	21.43	368.86	199.55	7.41	39.7
I_4N_2	179.43	12.45	2.32	23.98	22.22	379.22	208.74	7.66	41.5
I_4N_3	175.09	11.97	2.17	22.13	20.87	357.31	196.82	7.34	39.4
I_4N_4	163.78	11.19	1.63	19.72	19.42	327.08	174.58	6.41	34.3
SEm±	1.95	0.16	0.09	0.82	0.23	5.75	4.63	0.14	0.92
CD (0.05)	5.54	0.45	0.25	2.33	0.65	16.32	13.16	0.39	2.60

Table 5: Water balance components, crop evapotranspiration (ETc) and water productivity (WP) of sweet corn under different irrigations and nitrogen management

Treatment	Profile water storage (mm)	Effective rainfall (mm)	Irrigation water (mm)	ETc (mm)	Cob yield (kg/ha)	WP (kg/ha-mm)
Irrigation (I)						
I_1 (Drip 1.0 ETc)	16.88	19.40	142.00	198.28	7112.50	35.87
I_2 (Drip 0.8 ETc)	18.17	19.40	113.60	171.17	6798.75	39.72
I_3 (Drip 0.6 ETc)	19.09	19.40	85.20	143.69	6412.00	44.63
I_4 (Surface irrigation)	15.44	26.50	250.00	311.94	7203.50	23.10
Nitrogen (N)						
N_1 (100% N as inorganic)	18.24	21.18	147.70	207.11	7059.25	36.69
N_2 (75% N as inorganic + 25% N as vermicompost)	17.11	21.18	147.70	205.98	7292.75	37.97
N_3 (75% N as inorganic + 25% N as FYM)	17.14	21.18	147.70	206.01	7011.50	36.53
N_4 (75% N as inorganic + 25% N as mustard cake)	17.10	21.18	147.70	205.98	6163.25	32.13
Irrigation × Nitrogen (I x N)						
I_1N_1	16.98	19.4	142	198.38	7308	36.84
I_1N_2	16.86	19.4	142	198.26	7531	37.99
I_1N_3	16.82	19.4	142	198.22	7216	36.40
I_1N_4	16.87	19.4	142	198.27	6395	32.25
I_2N_1	18.12	19.4	113.6	171.12	6974	40.76
I_2N_2	18.26	19.4	113.6	171.26	7168	41.85
I_2N_3	18.18	19.4	113.6	171.18	6917	40.41
I_2N_4	18.12	19.4	113.6	171.12	6136	35.86
I_3N_1	18.58	19.4	85.2	143.18	6542	45.69
I_3N_2	19.28	19.4	85.2	143.88	6813	47.35
I_3N_3	19.37	19.4	85.2	143.97	6576	45.68
I_3N_4	19.13	19.4	85.2	143.73	5717	39.78
I_4N_1	19.26	26.5	250	315.76	7413	23.48
I_4N_2	14.02	26.5	250	310.52	7659	24.67
I_4N_3	14.18	26.5	250	310.68	7337	23.62
I_4N_4	14.28	26.5	250	310.78	6405	20.61

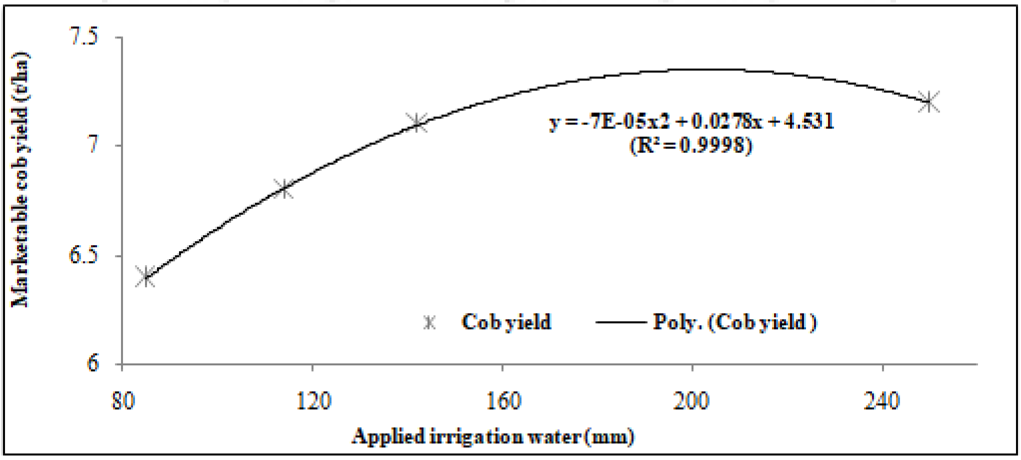

Figure 1: Relationship between seasonal water applied (x) and marketable cob yield (y) of sweet corn