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Nitrogen fertigation schedule and irrigation effects on productivity and economics of spring sugarcane

Hari Singh*, R.K. Singh, R.N. Meena and Vikram Kumar[1]

Department of Agronomy, Institute of Agricultural Sciences,
Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India.
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ABSTRACT

The field experiment was conducted to find the appropriate irrigation method, fertilization schedule and its influence on growth, yield and quality of sugarcane. The soil of the experimental site was sandy clay loam, neutral in reaction (pH 7.7), low in organic carbon (0.41%) and available nitrogen (167.0 kg ha^{-1}), medium in available phosphorus (19.1 kg ha^{-1}) and potassium (208.0 kg ha^{-1}). Experiment was laid out in split plot design with four replications. The treatments consisted of three irrigation methods in main plot *viz.*, flood, furrow and drip; five nitrogen scheduling in sub plot *viz.*, farmers practice, 4 splits, 6 splits, 8 splits and 10 splits. In flood method of irrigation all growth and quality parameter were recorded lowest. Thus, it may be concluded that to achieve highest millable cane and quality parameters, drip irrigation is a better option. The number of tillers (177.2 thousand ha^{-1}), number of millable canes (123.3 thousand ha^{-1}), cane length (367.98 cm), cane yield (168.51 t ha^{-1}), commercial cane (CCS) yield (25.05 t ha^{-1}) and economic return were found significantly higher under drip irrigation during first year. Similar trends were recorded during second year of experimentation. The highest dry matter accumulation and crop growth rate were also recorded under drip irrigation during both the years. Similarly, water use efficiency and water productivity were found maximum under treatment of drip irrigation. Significantly highest number of tillers (165.6 thousand ha^{-1}), millable canes (116.3 thousand ha^{-1}), cane yield (154.72 t ha^{-1}), dry matter accumulation, crop growth rate, CCS yield (23.39 t ha^{-1}) and economic return were recorded with 6 splits of nitrogen application. The overall effect of nitrogen scheduling was in the order of 6 splits > 8 splits > 10 splits > 4 splits > farmer's practice.

Key words: Growth, Irrigation, Nitrogen scheduling, Quality, Sugarcane.

INTRODUCTION

Sugarcane has one of the imperative position in agricultural economy of India. Sugarcane crop can be grown under varied agro ecological conditions ranging from tropical to subtropical climate of India. Major sugarcane producing countries in the world are India, Brazil, Cuba, Mexico, Pakistan and China. In India, area and production of sugarcane has been fluctuating from year to year depending upon climatic conditions and price policy. It occupies an area of 5.07 million hectare and production of 362.33 million ton cane with 71.5 t ha^{-1} productivity. Uttar Pradesh has the largest state in area as well as production of sugarcane, it accounts for 2.14 million hectare area and 133.06 million ton production. Sugarcane productivity is highest in West Bengal followed by Tamil Nadu, Maharashtra and Karnataka (Anonymous, 2017). The water requirement of sugarcane is normally met through irrigation during pre-monsoon period and rain during monsoon. It has been reported that about 35.0% of the total area of sugarcane comes under optimum irrigation while remaining 65.0 % comes under sub-optimal and no irrigation category (Bhatnagar *et al.* 2007). On an average 20 megalitres of water ha^{-1} is required by the crop to fulfill its metabolic activities, evapotranspiration and losses during the course of irrigation and thereafter (Shrivastava *et al.* 2011). During the entire growth period sugarcane require a constant moisture supply in the soil for profuse growth. Moisture stress at any growth stage of crop growth has negatively affects productivity. Thus, the pre-monsoon irrigations have crucial significance in relation to tillering and lateral developmental stages. For better juice quality and higher production, assured moisture supply is necessary. Inadequate water supply acts as a hindering factor in nutrient uptake and decrease the yield proportionately. In addition to this maturity pattern, sugar accumulation levels as well as the chemical composition of juice is also altered to a considerable extent. Conventional method of irrigation (flood irrigation) in subtropical region adopted because of convenience; however, huge quantity of water goes unused in this practice owing to irregular distribution in the field and consequently, WUE is low (Singh *et al.* 2018). Substantial amounts of nitrogenous fertilizer are necessary for higher sugarcane production because of the large biomass produced by sugarcane crops. Since this fertilizer needs substantial input cost and its environment implications, there are pressing needs to optimize the supply of nitrogen with most critical crop requirement stages.

*Corresponding author's e-mail: hsagro666@gmail.com
[1]Central Silk Board, Bangalore.

Keeping in view that the scarcity of good quality irrigation water for agriculture in days to come, there is urgent need to manage water by adopting apposite practices to maximize the water use efficiency (WUE) and minimize losses of irrigation water. Drip method of irrigation is key practices to minimize water uses as compared to others. Drip irrigation with fertilizer application (drip fertigation) in sugarcane is a relatively novel technology that can conserve water, increase WUE, assists to increase nutrient use efficiency and partial factor productivity of nutrient. The present study was carried out in this context to optimize water and nitrogen application schedule to improve the efficiency and factor productivity.

MATERIALS AND METHODS

Field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during two consecutive years (2016-17 and 2017-18). It was located on $25^0 18'$ N latitude, $83^0 3'$ E longitude and at an altitude of 76.60 meters above mean sea level in the Northern Gangetic alluvial plains. The geographical area falls under subtropical sugarcane belt. The soil of the experimental site is categorized as sandy clay loam, neutral in reaction (pH 7.7) with a bulk density (BD) of 1.35 Mg m^3, an infiltration rate of 20.46 mm h^{-1}, low in organic carbon (0.40 %) and available nitrogen (167.0 kg ha^{-1}), medium in available phosphorus (19.1 kg ha^{-1}) and potassium (208.0 kg ha^{-1}). Soil texture of the experimental field was sandy clay loam (18.65 % clay, 22.45% silt and 58.90% sand), of Gangetic alluvial origin. The soil was medium deep, well drained and well levelled. The climate of Varanasi is semi-arid subtropical with dry hot summer (April to June) and cold winter (November to January). The annual rainfall received during first crop season was 1239.2 mm and 649 mm rainfall occurred in second year. Most of rainfall received through north-west monsoon from June to September. The average monthly maximum and minimum temperatures fluctuate from 20 to 41^{o}C and 8.2 to 30^{o}C in, respectively.

The experiment was laid out in split plot design replicated four times. The treatments consisted irrigation in main plot and nitrogen scheduling in sub plot. In main plot three method of irrigation *viz.* I_1 (flood irrigation) I_2 (furrow irrigation) I_3 (drip irrigation) and in sub plot five nitrogen scheduling *viz.* N_1 (50 % basal + 50 % on commencement of monsoon), N_2 (4 splits at 30 days interval), N_3 (6 splits at 20 days interval), N_4 (8 splits at 15 days interval) and N_5 (10 splits at 10 days interval) were kept. Split application started after 30 days of planting (except in N_1). The field was well prepared with one ploughing followed by one harrowing. The existing crop variety of sugarcane Co 0238 (Karan 4) was planted on 1st march 2016 and 3rd March 2017 during first and second year, respectively. Planting was done with treated two budded setts. The recommended fertilizer dose of N (180 kg ha^{-1}), P_2O_5 (80 kg ha^{-1}) and K_2O (60 kg ha^{-1}) were applied in the field. Urea, single super phosphate and murate of potash were used as source of fertilizer for nitrogen, phosphorus and potassium, respectively. Full amount of P and K fertilizers was applied as basal and N application was done as per treatment schedule.

The irrigation application was started at 30 days after planting. Thereafter, irrigations were applied five days interval up to last nitrogen fertilization schedule and after that ten days interval under furrow and flood method of irrigation. In case of drip method, irrigations were scheduled once in two days. The harvesting of the crop was done manually during the last week of January in each year followed by de-trashing and de-topping. Sampling was done by randomly selected ten canes from each plot of four replications. The plants were tagged for recording growth and development of sugarcane. Destructive sampling was done for dry matter accumulation studies. The data of two crop seasons were analyzed separately and to determine the significance of differences between the treatments obtained data's were subjected to statistical analysis by 'Analysis of Variance' for split plot design (Gomez and Gomez, 1984). Crop growth rate (CGR) was worked out by adopting the formula of Watson (1947) and expressed as g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 = Total dry weight per plant (g) at time t_1 and t_2, respectively.

Brix per cent measured directly by using brix hydrometer. Temperature corrections were made to correct observed brix reading by using temperature correction table as described by Spencer and Meade (1955). Juice sucrose per cent obtained by using Horne's Dry Lead Acetate method as described by Spencer and Meade (1955). The purity of cane juice was judged by calculating purity coefficient (%) by suing following formula:

$$\text{Purity coefficient (\%)} = \frac{\text{Sucrose per cent in juice}}{\text{Corrected brix value of juice}} \times 100$$

The commercial cane sugar (CCS) yield in tonnes per hectare was calculated by using the following formula:

$$CCS\ (t\ ha^{-1}) = \frac{\text{Cane yield } (t\ ha^{-1}) \text{ x CCS (\%)}}{100}$$

The net return in terms of rupees per hectare was worked out on the basis of subtracting total cost of production from gross return and expressed in rupees per hectare.

Net Return (` ha^{-1}) =
Gross Return (` $ha^{-1}$) – Cost of cultivation (` ha^{-1})

The treatment wise B: C ratio was calculated by dividing the net return with respective cost of cultivation.

$$\text{B: C ratio} = \frac{\text{Net Return (` ha}^{-1}\text{)}}{\text{Cost of cultivation (` ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

The data revealed that number of tillers, number of millable cane (NMC), cane length, cane yield, dry matter accumulation, crop growth rate and economic return were significantly affected by irrigation methods (Table 1). Irrigation methods did not exert any significant influence on the germination of sugarcane at 30 days after planting and cane girth at harvest during both the years of investigation.

Drip irrigation recorded highest number of tillers (177.20 and 176.86 thousand ha^{-1} during first and second year, respectively) at 120 DAP which was significantly superior over flood and furrow method of irrigation. However, furrow and flood methods of irrigation were at par among each other. Highest numbers of millable cane (123.28 and 122.39 thousand ha^{-1} during two consecutive years) were registered under drip irrigation which was significantly superior over furrow and flood irrigation. Similar results were obtained by Sarala *et al.*, (2014) (significantly highest number of millable canes was recorded with both the irrigation method surface and subsurface drip, than the conventional furrow irrigation).

Irrigation water affects the entire plant from root hair to stomata. Irrigation application through drip increases water potential in soil and its uptake by roots. Drip irrigation recorded significantly maximum cane length (367.98 and 364.68 cm during first and second year, respectively) as compared to flood irrigation and furrow irrigation at harvest during both the year of study. Moreover, furrow and flood methods of irrigation were at par with each other. Chen *et al.* (2012) reported that the treatments of drip irrigation promoted faster and earlier growth of sugarcane and increased number of tillers compared to the conventional practice.

It is evident from the analyzed result that drip irrigation exhibited their superiority over other irrigation methods; increase the cane yield in the tune of 21.27 per cent in first and 23.48 per cent in second year as compared to flood irrigation. This might be due to prosperous growth, higher biomass accumulation and favorable yield attributing parameters. Narayanamoorthy (2010) also resulted that the cane yield of sugarcane cultivated under drip method of irrigation is much higher than the crops which are cultivated under the method of surface irrigation. Dry matter accumulation (Table 2) and crop growth rate (Table 3) under drip irrigation were recorded significantly higher over flood and furrow irrigation. Increase in dry matter due to increased plant height and higher number of millable cane. Mahendran and Dhanalakshmi (2003) and Farooq *et al.* (2015) also reported similar results.

Table 1: Effect of irrigation methods and nitrogen scheduling on germination, tillers, millable cane, cane length, cane girth and cane yield.

Treatment	Germination (%)		Number of tillers (000 ha^{-1})		NMC (000 ha^{-1})		Cane length (cm)		Cane girth (mm)		Cane yield (t ha^{-1})	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
I_1 : Flood irrigation	42.22	43.79	148.67	146.53	105.06	103.92	303.93	297.63	23.95	23.17	138.95	135.37
I_2 : Furrow irrigation	43.31	45.02	154.04	153.51	108.10	107.08	316.66	313.36	23.99	23.47	144.41	142.63
I_3 : Drip irrigation	42.92	44.89	177.20	176.86	123.28	122.39	367.98	364.68	24.57	24.16	168.51	167.15
S.Em.±	0.80	0.87	4.209	3.791	2.79	2.65	8.17	7.46	0.57	0.54	3.22	3.32
CD (P=0.05)	NS	NS	14.57	13.12	9.64	9.16	28.29	25.83	NS	NS	11.16	11.48
N_1 : Farmers practice	43.16	44.91	148.38	147.81	103.77	102.47	299.28	291.78	23.63	23.08	141.06	138.27
N_2 : 4 split	42.86	44.51	159.30	157.99	111.23	110.21	325.31	321.81	24.00	23.50	150.09	148.05
N_3 : 6 split	42.59	44.34	165.57	164.42	116.28	115.26	346.46	342.96	24.65	24.22	154.72	152.88
N_4 : 8 split	42.91	44.76	164.37	163.18	115.16	114.11	342.62	338.12	24.31	23.62	154.04	151.51
N_5 : 10 split	42.55	44.30	162.24	161.44	114.29	113.60	333.95	331.45	24.27	23.57	153.20	151.22
S.Em.±	0.75	0.73	3.546	3.518	2.40	2.39	7.05	7.07	0.50	0.51	2.61	2.78
CD (P=0.05)	NS	NS	10.17	10.09	6.88	6.85	20.21	20.28	NS	NS	7.50	7.98

Table 2: Effect of irrigation methods and nitrogen scheduling on dry matter accumulation (kg m^{-1} row length) by sugarcane at different growth stages.

Treatment	at 90 DAP		at 180 DAP		at 270 DAP		at harvest	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Irrigation Methods								
I_1 : Flood irrigation	0.163	0.160	1.74	1.70	3.84	3.77	4.95	4.87
I_2 : Furrow irrigation	0.171	0.170	1.82	1.80	4.03	3.99	5.18	5.13
I_3 : Drip irrigation	0.185	0.182	2.01	1.99	4.58	4.54	5.91	5.88
S.Em.±	0.003	0.003	0.04	0.04	0.08	0.08	0.09	0.08
CD (P=0.05)	0.010	0.009	0.13	0.12	0.27	0.26	0.30	0.29
Nitrogen Scheduling								
N_1 : Farmers practice	0.160	0.159	1.73	1.71	3.88	3.82	5.00	4.95
N_2 : 4 split	0.171	0.168	1.85	1.82	4.09	4.07	5.32	5.26
N_3 : 6 split	0.179	0.176	1.93	1.91	4.31	4.24	5.55	5.50
N_4 : 8 split	0.178	0.176	1.89	1.87	4.25	4.20	5.47	5.41
N_5 : 10 split	0.177	0.174	1.87	1.85	4.21	4.16	5.41	5.36
S.Em.±	0.002	0.002	0.03	0.03	0.06	0.06	0.06	0.06
CD (P=0.05)	0.007	0.006	0.08	0.07	0.16	0.16	0.18	0.19

Table 3: Effect of irrigation methods and nitrogen scheduling on crop growth rate (g m^{-2} day^{-1}) of sugarcane.

Treatment	90 - 180 DAP		180 - 270 DAP		270 - harvest	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Irrigation Methods						
I_1 : Flood irrigation	19.23	18.88	25.70	25.19	18.54	18.49
I_2 : Furrow irrigation	20.13	19.92	27.03	26.76	19.24	19.09
I_3 : Drip irrigation	22.26	22.13	31.41	31.17	22.29	22.33
S.Em.±	0.43	0.41	0.69	0.74	0.63	0.47
CD (P=0.05)	1.48	1.42	2.39	2.57	2.19	1.62
Nitrogen Scheduling						
N_1 : Farmers practice	19.22	18.99	26.23	25.81	18.75	18.80
N_2 : 4 split	20.46	20.22	27.49	27.49	20.35	19.83
N_3 : 6 split	21.39	21.15	29.15	28.52	20.54	20.98
N_4 : 8 split	20.90	20.68	28.85	28.44	20.37	20.29
N_5 : 10 split	20.74	20.51	28.52	28.26	20.10	19.96
S.Em.±	0.33	0.31	0.67	0.66	0.77	0.73
CD (P=0.05)	0.95	0.88	1.92	1.88	2.21	2.10

Table 4: Effect of irrigation methods and nitrogen scheduling on brix, sucrose, purity and commercial cane sugar (CCS) yield.

Treatment	Brix (%)		Juice sucrose (%)		Purity coefficient (%)		CCS (t ha^{-1})	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Irrigation Methods								
I_1 : Flood irrigation	19.99	19.94	17.52	17.55	87.73	88.09	21.28	20.65
I_2 : Furrow irrigation	19.93	19.91	17.42	17.45	87.46	87.70	22.08	21.77
I_3 : Drip irrigation	19.51	19.38	17.31	17.34	88.82	89.56	25.05	24.62
S.Em.±	0.17	0.16	0.13	0.12	1.12	1.14	0.46	0.50
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.61	1.74
Nitrogen Scheduling								
N_1 : Farmers practice	19.96	19.93	17.52	17.57	87.84	88.22	21.56	21.05
N_2 : 4 split	19.77	19.72	17.36	17.46	87.89	88.62	22.73	22.31
N_3 : 6 split	19.72	19.57	17.20	17.27	87.28	88.34	23.39	22.85
N_4 : 8 split	19.78	19.76	17.43	17.43	88.21	88.29	23.26	22.83
N_5 : 10 split	19.81	19.75	17.57	17.52	88.79	88.78	23.08	22.71
S.Em.±	0.15	0.14	0.12	0.12	0.92	0.88	0.47	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.34	1.33

Table 5: Economics of irrigation methods and nitrogen scheduling in sugarcane.

Treatment	Cost of cultivation (` ha^{-1})		Gross return (` ha^{-1})		Net return (` ha^{-1})		B:C Ratio	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Irrigation Methods								
I_1 : Flood irrigation	109055	114275	354325	345186	245270	230911	2.25	2.02
I_2 : Furrow irrigation	110655	115875	368235	363712	257580	247837	2.33	2.14
I_3 : Drip irrigation	120245	119009	429690	426238	309445	307229	2.57	2.58
Nitrogen Scheduling								
N_1 : Farmers practice	110998	114066	359695	352580	248696	238514	2.24	2.09
N_2 : 4 split	112158	115226	382738	377528	270580	262301	2.41	2.27
N_3 : 6 split	113318	116386	394532	389831	281213	273445	2.48	2.35
N_4 : 8 split	114478	117546	392802	386351	278324	268804	2.42	2.28
N_5 : 10 split	115638	118706	390652	385603	275013	266896	2.37	2.24

The results regarding quality (Table 4) in terms of brix, juice sucrose, purity did not influenced by the different irrigation methods. However, commercial cane sugar (CCS) yield significantly increased with drip irrigation. It might be due to increased cane yield in drip irrigation. Singandhupe *et al.* (2008) observed that total sugar yield in drip irrigation was increased by 26.7%, 21.3% and 17.3% in 2, 3 and 4 day intervals, respectively, compared to furrow irrigation.

The economic return was calculated in terms of cost of cultivation, gross return, net return and benefit: cost ratio (Table 5). The higher cost of cultivation was registered under drip irrigation during both the years. This might be due to higher system cost, depreciation cost and interest on drip system. These findings are also supported by Hussain *et al.* (2010). Gross return, net return and benefit: cost ratio were recorded maximum in drip irrigation as compared to flood and furrow irrigation. This might be due to increased cane production. Hirwe and Jadhav (2010) reported that adoption of drip irrigation method produced significantly additional gross and net monetary returns than surface and sub-surface methods of irrigation. Punetha and Reddy (2006) also revealed similar record.

Nitrogen scheduling significantly affected the tiller population, number of millable cane (NMC), cane length, cane yield, dry matter accumulation, crop growth rate and CCS yield.

The data (Table 1) showed that significantly highest number of tillers (165.57 and 164.42 thousand per hectare in first and second year, respectively) and number of millable cane (116.28 and 115.26 thousand per hectare in first and second year, respectively) were recorded by application of nitrogen in 6 splits over farmers practice but it was statistically at par with 8 splits, 10 splits and 4 splits during both the year of experimentation. This might be due to better nutrition effect on crop. These findings are also supported with observation recorded by Padmanabhan *et al.* (2017). Increment in NMC was due to increased number of tillers and ultimately it converts into maximum number of millable cane. Significantly increased cane length (21.07 per cent in first and 22.53 per cent in second year) was found under 6 splits application as compared to farmers practice. This might be due to enhanced supply of nitrogen according to crop need (Kumar *et al.* 2014). Among nitrogen scheduling treatments application of nitrogen through 6 splits registered significantly increased cane yield. The cane yield was observed 9.69 and 10.57 % higher in 6 split application of nitrogen during two consecutive years, respectively, over farmers practice. This might be due to prosperous growth, favorable yield attributing character. Sreewarome *et al.* (2007) also advocated increased growth.

Nitrogen scheduling in 6 split registered significantly higher dry matter accumulation and crop growth rate when compared with farmers practice (Table 2 and 3). This might be due to maximum plant height, more number of tillers and availability of nutrient. Sreewarome *et al.* (2007) and Saleem *et al.* (2012) also reported similar results.

The data (Table 4) revealed that various nitrogen scheduling treatments did not differ significantly in regard to brix, juice sucrose and purity during any of the year. In case of nitrogen scheduling 6 splits application recorded significantly higher commercial cane sugar yield (23.39 and 22.85 t ha^{-1} during first and second year, respectively) as compared to farmers practice but statistically at par with 8 splits, 10 splits, and 4 splits during both the years. Hussain *et al.* (2017) also observed that different timing schedule of nutrient significantly affect the sugar yield.

The data regarding cost of cultivation indicated that cost of cultivation increased with increase in nitrogen splits and registered highest with 10 splits of nitrogen application. This might be due to higher labourer cost, required for split application of nitrogen fertilizer. However, lowest cost of cultivation recorded in farmers practice. Gross return, net return and benefit: cost ratio were recorded maximum with 6 splits as compared to others. This might be due to increased cane yield generate maximum return. Similar finding was reported by Hussain *et al.* (2017).

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