Pak. J. Agri. Sci., Vol. 57(3), 829-835; 2020
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/20.8833
http://www.pakjas.com.pk

IMPACT OF DIFFERENT LEVELS OF NITROGEN BY SOIL APPLICATION AND FERTIGATION THROUGH DRIP IRRIGATION ON GROWTH, YIELD AND QUALITY OF SUGARCANE

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The present study was conducted at Water Management Research Farm, Renala Khurd, Okara, Punjab, Pakistan during 2015 and 2016 to determine the effect of different levels of nitrogen applied through soil and fertigation on sugarcane crop. The nitrogen levels were 0, 168, 210, 126 and 84 kg ha^{-1} whereas P and K were constant. There were seven treatments i.e. T_1 (0-112-112 NPK kg ha^{-1}) through soil application, T_2 (168-112-112 NPK kg ha^{-1}) through soil application and flood irrigation, T_3 (168-112-112 NPK kg ha^{-1}) through soil application and drip irrigation, T_4 (125% N of recommended dose of 168 N kg ha^{-1}) i.e. 210 kg N ha^{-1} through fertigation in 12 equal splits , T_5 (100% N of recommended dose of 168 kg N ha^{-1}) i.e. 168 kg N ha^{-1} through fertigation in 12 equal splits, T_6 (75% N of recommended dose of 168 kg N ha^{-1}) i.e. 126 kg N ha^{-1} through fertigation in 12 equal splits and T_7 (50% N of recommended dose of 168 kg N ha^{-1}) i.e. 84 kg N ha^{-1} through fertigation in 12 equal splits. The experimental results indicated that T_5:100% N (168 kg N ha^{-1} through fertigation) produced taller plants, more millable canes, cane length, stripped cane weight, stripped cane yield and total sugar yield than all other treatments however, it remained statistically at par with T_6: (75% N of 168 kg recommended applied nitrogen through fertigation). Moreover, the lowest plant height, tillers, millabe canes, stripped cane yield, stripped cane weight and total sugar yield was recorded in control. In conclusion, 25% Nwas saved owing to the fertigation with similar cane yield as that of recommended dose of soil applied nitrogen.
Keywords: Nitrogen, sugarcane, fertigation, sugar yield, drip irrigation**.**

INTRODUCTION

Sugarcane is an important crop of tropical to warm temperate parts of the world (Carry and Knox, 2001). Pakistan ranks 5th in sugarcane production and 11th in cane yield among top 10 cane producing countries (Govt. of Pakistan, 2018). In Pakistan, sugarcane is an important cash crop and it is grown to produce sugar. It is integral income source for farming community and provides raw material for making chip board and paper. Sugarcane yield may be increased by improved planting method with optimum fertilization under optimum irrigation regimes (Raza *et al*., 2019a,b). Among different nutrients, nitrogen (N) is essential element because sugarcane requires optimum doses of N at critical phenological stages (Dinh *et al.,* 2017). Nitrogen involves in numerous critical aspects including plant vegetative growth, green leaf expansion and production of suckers or tillers in sugarcane. Moreover, it is also important for bio-synthesis of plant proteins which are essential for photosynthesis, and photosynthetic enzymes particularly rubisco and PEPCase (Dinh *et al.,* 2017; Yang *et al.,* 2019).

It is a well-known that N deficiency leads to lower vegetative growth and cane yield, however, its excessive application can result in increased growth of vegetative parts and decreased cane yield and overall quality (Dinh *et al.,* 2017; Yang *et al.,*2019). Moreover, N deficiency also decrease photosynthesis owing to reduction in leaf area, chlorophyll biosynthesis and overall production of biomass. It is important to mention that sugarcane biomass yield increased with optimum rate of N fertilizer (Thorburn *et al.,* 2005; Van Heer-den *et al.,* 2010). Nevertheless, N fertilizer should be utilized wisely to minimize the environmental impacts and to enhance the agronomic yield. This could be achieved by the application of optimum and recommended N doses at critical time period in sugarcane crop (Van Heer-den *et al.,* 2010). The increase in nitrogen use efficiency (NUE) appreciably increased the sugarcane growth and cane yield. The optimum N application improves the N uptake and NUE with additional benefits of improvement in cane production (Dinh *et al.,* 2017). Similarly, significant increase was observed between N application and cane yield and quality (Acreche, 2017). In the same way, substantial improvement was observed in vegetative growth and biomass production in response to the N application (Calif and Edgecombe, 2015).

Sugarcane has long growing season and it is generally grown as a frequently irrigated crop. The crop normally needs around 1700-1900 mm water to complete its growth cycle (Chattha, 2007). The water application timing and total requirement are critical factors affecting sugarcane production. The suitable irrigation method effectively enhanced per unit production of sugarcane (Gulati and Nayak, 2002). Therefore, an improved and effective water management is direly needed, particularly, during the hot dry period to increase the water use efficiency with significantly higher cane yield. This is perhaps only plausible with the drip irrigation method (Uribe *et al.,* 2013). This micro irrigation technique has a possibility to play effective role in managing the scarcity of water by the judicious water application directly in root zone of sugarcane plant (Kaushal *et al.,* 2102). The drip system uses water in highly précised way and irrigation water can be directly applied in root zone of the crop. Moreover, this précised water application can also be used to apply fertilizer (fertigation) to sugarcane plant and it may ultimately help to enhance crop productivity. Furthermore, the NUE substantially increase in fertigation owing to the regular and controlled fertilizers application. So, it is need of the time to increase quality and per unit production of sugarcane. In this context, irrigation or water application has now become a critical cultural practice to guarantee higher sugarcane yield. It was hypothesized that N application by different methods may increase cane and sugar yield of sugarcane. Therefore, the present study was conducted to determine the most effective method of N application for increasing the growth, cane yield and sugar yield of sugarcane.

MATERIALS AND METHODS

***Study site and plant material*:** The trial was conducted at Water Management Research Farm, Renala Khurd, Okara. The study site falls in semi-arid region; moreover, the weather conditions during the crop growing periods are given in the Table 1. The sugarcane variety CPF-246 was used as an experimental material. The size of the plot was 6.0 m × 10 m and sets were planted at 1.20 m apart trenches by placing two sets in one trench at a distance of 37.5 cm apart. The seed rate was used at the rate of 75000 double budded sets ha^{-1}.

***Treatments*:** The experiment was comprised of different treatments i.e., T_1= 0-112-112 NPK kg ha^{-1} and application of P and K through soil in two splits i.e. at planting and 45 days after planting, T_2= 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and flood irrigation, T_3= 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and drip irrigation, T_4= 125% N of 168 kg recommended nitrogen (210 kg N ha^{-1} through fertigation in 12 equal splits) and 112 kg P and 112 kg K application in two equal splits i.e. at planting and 45 days after planting, T_5=100% N of 168 kg recommended nitrogen (168 kg N ha^{-1} through fertigation in 12 equal splits) and 112 kg P and 112 kg K soil application in two equal splits i.e. at planting and 45 days after planting, T_6= 75% N of 168 kg recommended nitrogen (126 kg N ha^{-1} through fertigation in 12 equal splits) and 112 kg P and 112 kg K soil application in two equal splits i.e. at planting and 45 days after planting, T_7= 50% N of 168 kg recommended nitrogen (84 kg N ha^{-1} through fertigation in 12 equal splits) and 112 kg P and 112 kg K soil application in two equal splits i.e. at planting and 45 days after planting.

***Crop Husbandry*:** The field was irrigated before sowing to create the favorable conditions for cultivation. The soil was cultivated twice and followed by sub soiler and planked twice to prepare the final seed bed. The trenches for sowing of sugarcane were made by the ridger. The crop was sown in 120 cm apart trenches. The recommended P (112 kg ha^{-1}) and K fertilizers (112 kg ha^{-1}) was applied at sowing and N was applied according to the treatments. Insecticide, chlorpyrifos (Larsban) was used at the rate of 5 Lha^{-1} to control the termites and carbofuran (Furadon)was applied at 35 kg ha^{-1} to control borer attack. The other production and management practices were kept constant to maintain the healthy crop stand.

Observations

***Growth attributes*:** Leaf areawas measured at a regular interval of 30 days by a leaf area meter.Leaf area index (LAI) was calculated using leaf area divided by land area (Watson, 1947). Moreover, leaf area duration (LAD) as calculated by

Table 1. Climatic conditions during the two growing years.

Months	Mean maximum Temp.		Mean Minimum Temp.		Rain fall(mm)	
	2015	2016	2015	2016	2015	2016
January	16.6	17.3	6.9	7.7	12.2	13.1
February	22.0	23.3	11.1	9.3	20.5	7.8
March	24.5	26.8	13.6	15.6	67.0	66.7
April	33.2	34.3	20.7	20.2	32.8	5.6
May	38.7	39.8	24.9	25.6	17.0	25.0
June	25.6	40.2	31.8	28.5	11.6	39.9
July	34.9	36.6	27.0	27.4	128.0	193.5
August	35.9	35.7	26.7	26.5	48.4	48.1
September	35.4	36.5	24.4	25.5	75.2	12.0
October	32.2	33.9	19.1	19.6	14.5	22.2
November	27.1	27.6	12.1	12.6	8.8	0.0
December	21.8	23.6	7.20	9.2	0.0	0.0

method of Watson (1947) and net assimilation rates (NAR) was determined by method of Hunt (1978).

***Yield attributes*:** A unit area (1 m^2) was selected and number of sprouts and number of tillers were counted. At final harvesting; ten plants were randomly selected and plant height, cane length and diameter was measured and averaged. Moreover, these ten plants were weighed to determine the stripped cane weight. Moreover, all the millable stripped canes from each plot were weighed to determine stripped cane yield and later on converted into t ha^{-1} basis.

***Quality characteristics*:** Ten plants were selected and crushed to collect the juice in the glass jars. The brix percentage in juice was determined by hydrometer and corrected by methods ofSpancer and Meade (1963). Moreover, the pol percentage in juice was recorded with Polarimeter. The cane juice sucrose content (%) was calculated using the Schmitz, table as described by Spancer and Meade (1963). Commercial cane sugar (CCS) in percent was determined by using the formula ofSpancer and Meade (1963). Cane sugar recovery percent (CSR %) was calculated by the formula as follows: C.S.R. (%) = CCS (%) × 0.94, where CCS = Commercial cane sugar and 0.94 is net titer.

***Experimental design and statistical analysis*:** The experiment was conducted in randomized complete block design. The effect of different treatments on growth, yield and quality attributes of sugarcane was analyzed through analysis of variance technique and differences among treatments were compared using LSD at $p \leq 0.05$.

RESULTS

***Growth attributes*:** The N applied through soil and fertigation significantly improved the growth attributes i.e., LAI, LAD and CGR. All the treatments significantly influenced the LAI; initially there was no obvious difference among the treatments for the LAI, however, significant difference was observed with the passage of time and LAI reached to plateau at 180 days of sowing (DAS). At 180 DAS highest LAI was recorded in 100% N (168 kg recommended nitrogen applied through fertigation) that was similar with 75% N (75% N of 168 kg applied through fertigation) and lowest LAI was recorded in control (Fig 1). LAD and CGR also showed the same trend and LAD and CGR reached to maximum value at 210 DAS; whereas, maximum LAD and CGR was recorded for the 100% N (168 kg recommended nitrogen applied through fertigation), and minimum was recorded for control. Afterward, LAD and CGR both started to decline, and minimum reduction was recorded with 100% N (168 kg recommended nitrogen applied through fertigation), and 75% N (75% N of 168 kg applied through fertigation) and maximum reduction both in LAD and CGR was recorded in control (Fig. 3).

***Yield attributes*:** The results indicated that effect of different N rates on sugarcane sprouting percentage was non-significant during both the years 2015-16 (Table 1), however, the different rates of N application through soil and fertigation significantly affected the plant height and number of tillers (Table 2). 100% N (168 kg recommended nitrogen applied through fertigation) remained at top; and produced taller plants (218.70 cm, 215.75 cm) with highest tillers (23, 24), that was similar with that of 75% N (75% N of 168 kg applied through fertigation) with plant height (214.72 cm, 214.75 cm) and tillers (22, 23) whilst least plant height (190.50 cm, 182.75 cm) and tillers (14, 13) was recorded in control during both years of study (Table 2).

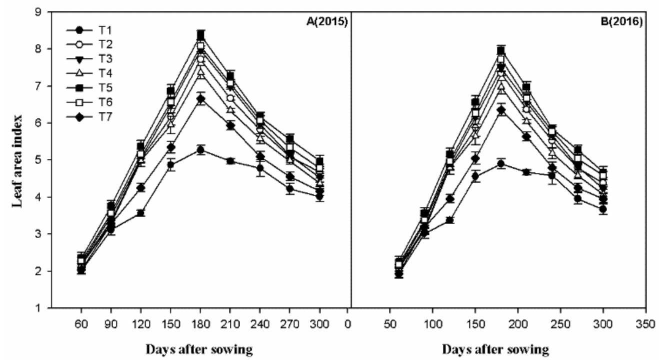

Figure 1. Effect of different N levels on leaf area index of sugarcane crop under drip irrigation system.

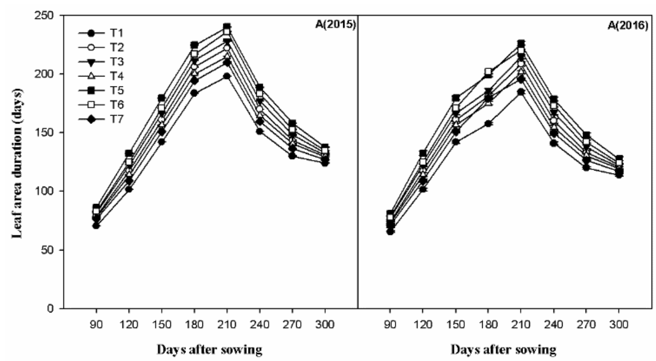

Figure 2. Effect of different N levels on leaf area duration (days) of sugarcane crop under drip irrigation system.

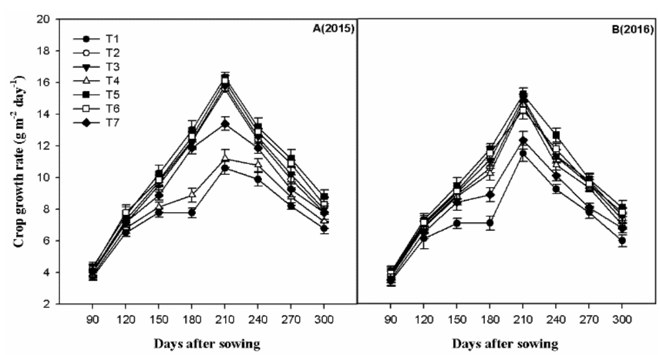

Figure 3. Effect of different N levels on crop growth rate (g m^{-2} day^{-1}) of sugarcane crop under drip irrigation system.

Table 2. Effect of different N levels on sprouting percentage, plant height and number of tillers of sugarcane crop under drip irrigation system.

Treatments	Sprouting %age		Plant height (cm)		No. of Tillers m^{-2}		No. of millable canes ha^{-1}	
	2015	2016	2015	2016	2015	2016	2015	2016
T_1	56.49	56.59	190.50 D	182.75 D	14 D	13 D	35000D	34200D
T_2	56.41	56.50	207.56 B	206.50 B	18 B	19 B	105080B	106082B
T_3	56.42	56.40	215.50 B	207.75 B	21 B	20 B	107082B	107085B
T_4	56.37	56.50	218.70 A	215.50 A	19 B	20 B	107000B	105225B
T_5	56.53	56.40	214.72 A	214.75 A	23 A	24 A	124000A	123800A
T_6	55.43	56.49	208.16 B	207.50 B	22 A	23 A	123000A	124250A
T_7	56.00	56.45	200.50 C	201.25 C	17 C	16 C	88000C	87700C
LSD ($p \leq 0.05$)	NS	NS	3.86	3.93	1.06	1.11	632	442

Table 3. Effect of different N levels on millable canes, cane length and cane diameter of sugarcane crop under drip irrigation system.

Treatments	Cane length (cm)		Cane diameter (cm)		Stripped cane weight (kg)		Stripped cane yield (t ha^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016
T_1	141.13D	142.00D	4.06C	4.10C	0.95 D	0.97 D	35.25E	34.50D
T_2	155.30B	156.50B	5.74B	5.76B	1.80 B	1.82 B	100.50C	101.00B
T_3	158.00B	157.50B	6.19A	6.25A	1.88 B	1.90 B	103.25B	102.50B
T_4	159.50B	158.80B	6.25A	6.30A	1.85 B	1.87 B	102.50B	102.75B
T_5	218.75A	218.80A	6.15A	6.10A	2.06 A	2.10 A	114.25A	113.50A
T_6	216.70A	216.65A	5.75B	5.70B	2.04 A	2.09 A	112.50A	111.75A
T_7	150.20C	151.15C	5.55B	5.60B	1.27 C	1.25 C	77.97D	78.25C
LSD ($p \leq 0.05$)	1.37	1.44	0.06	0.08	0.11	0.18	1.56	1.76

T_1: 0-112-112 NPK kg ha^{-1} (Control), T_2: 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and flood irrigation, T_3: 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and drip irrigation, T_4: 125% N of 168 kg recommended nitrogen (210kg N ha^{-1} through fertigation), T_5: 100% N of 168 kg recommended nitrogen (168 kg N ha^{-1} through fertigation), T_6: 75% N of 168 kg recommended nitrogen (126 kg N ha^{-1} through fertigation), T_7: 50% N of 168 kg recommended nitrogen (84 kg N ha^{-1} through fertigation)

The N applied though soil and fertigation significantly influenced the millable canes, cane length and cane diameter during both years of study (Table 3). Nitrogen applied through fertigation at the rate of 100% N (168 kg recommended nitrogen applied through fertigation) produced the maximum millable canes ha^{-1} (124000) and cane length (218.75 cm, 218.80 cm) which was similar with the 75% N (75% N of 168 kg applied through fertigation). However, the maximum cane diameter (6.25 cm, 6.30 cm) was recorded with 75% N of 168 kg recommended nitrogen (126 kg N ha^{-1} through fertigation) that was comparable with 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and flood irrigation and 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and drip irrigation. Additionally, least millable canes, cane length and cane diamter during both years was recorded in control (0-112-112 NPK kg ha^{-1}) (Table 3).

Stripped cane weight and stripped cane yield are two important factors contributing substantially towards final sugar production. The effect of N application on the stripped cane weight and cane yield was highly significant during both years of study. N applied through fertigation at the rate of 168 kg ha^{-1} produced significantly higher cane weight (2.06 kg, 2.10 kg) and stripped cane yield (114.25 t ha^{-1}, 113.50 t ha^{-1}) that was comparable with the that of 75% N (75% N of 168 kg applied through fertigation) moreover, the least cane weight (2.06 kg, 2.10 kg) and stripped cane yield (114.25 t ha^{-1}, 113.50 t ha^{-1}) and cane weight during both years was recorded in control (Table 3).

***Quality attributes*:** The results regarding the qualitative attributes as affected by the N applied though soil and fertigation are given in Table 4. The results indicated that different N rates applied through the soil application and fertigation had non-significant impact on the qualitative attributes i.e., pol, fiber, CCS and sugar recovery during both years of experimentation (Table 4). However, the N application through the soil and fertigation had a remarkable impact on the total sugar yield (Table 4). The highest total sugar was obtained with 100% N applied through fertigation that was statistically at par with the 75% (126 kg N ha^{-1} through fertigation) while the least total sugar yield was recorded under conditions during both years of study. Interestingly, a linear relationship was found between the stripped cane yield and sugar yield; an increase in stripped cane yield positively increased the total sugar yield (Fig. 4).

Table 4. Effect of different N levels on qualitative attributes of sugarcane crop under drip irrigation system.

Treatments	Pol (%)		Fiber (%)		CCS (%)		Sugar recovery		Sugar yield (t ha^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1	17.50	17.55	12.25	12.30	13.70	13.60	12.75	12.60	4.49D	4.37D
T_2	17.20	17.25	12.20	12.25	13.48	13.50	12.50	12.45	12.56B	12.57B
T_3	17.10	17.15	12.15	12.20	13.35	13.25	12.25	12.30	12.81B	12.84B
T_4	17.00	17.20	12.22	12.25	13.30	13.20	12.35	12.40	12.64B	12.60B
T_5	17.00	17.10	12.25	12.20	13.35	13.40	12.40	12.45	14.10A	14.07A
T_6	17.25	17.20	12.20	12.25	13.45	13.47	12.50	12.50	13.95A	13.91A
T_7	17.45	17.40	12.00	12.30	13.50	13.45	12.60	12.65	9.82C	9.89C
LSD ($p\leq0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	1.14	0.96

T_1: 0-112-112 NPK kg ha^{-1} (Control), T_2: 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and flood irrigation, T_3: 168-112-112 NPK kg ha^{-1} (recommended doze) as soil application and drip irrigation, T_4: 125% N of 168 kg recommended nitrogen (210kg N ha^{-1} through fertigation), T_5: 100% N of 168 kg recommended nitrogen (168 kg N ha^{-1} through fertigation), T_6: 75% N of 168 kg recommended nitrogen (126 kg N ha^{-1} through fertigation), T_7: 50% N of 168 kg recommended nitrogen (84 kg N ha^{-1} through fertigation)

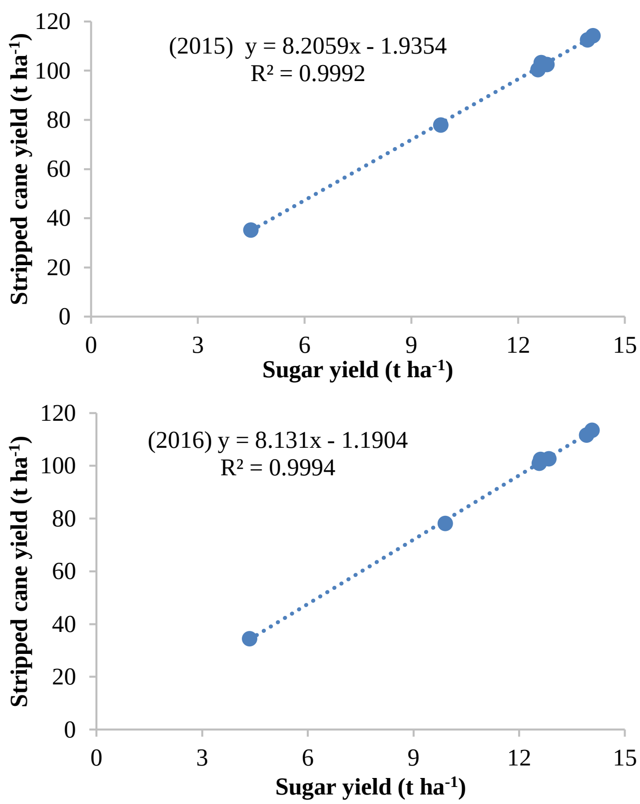

Figure 4. Relationships between sugar yield vs stripped cane yield and stripped cane yield vs. sugar yield.

DISCUSSION

The results indicated the significant impact of different rates of N on the growth attributes; LAI, LAD and CGR. Application of 100% N applied through fertigation remained at the top with respect to LAI, LAD and CGR. The higher LAI intercepts more light and consequently leads to an increase in the photosynthesis rate (Windenfeld and Enciso, 2008). The increase in LAI by the N application can be due to improvement in plant vegetative growth; as N is integral component of amino acids and proteins (Wiedenfeld and Enciso, 2008). Similarly, K was applied as recommended dose and the application of K increases the activities of certain enzymes involved in photosynthesis that eventually increase growth of leaves under regulated and controlled water supply with drip irrigation system (Ali *et al.,* 2018). The increase in leaf area duration will intercept more solar radiation and ultimately produce the more assimilates which leads to more dry matter production and thereby higher yield. The increase in the LAD was possible due to increase in LAI as by the application of N. Earlier Ali *et al.* (2018) reported N application significantly improved the LAD of sugarcane owing to improvement in the LAI under drip irrigation system (Ali *et al.,* 2018). The higher CGR was recorded in 100% N applied through fertigation that can be due to more LAI; as the more LAI resulted in more light interception and therefore, leads to more assimilates and dry matter production (Saleem *et al.,* 2012).

The results indicated that N applied through the soil and fertigation had non-significant impact on the sprouting percentage (Table 1) because all the treatments were applied after germination. Likewise, Hussain *et al.* (2010) also found that fertilizer application did not have any significant impact on the germination % age of sugarcane. Moreover, the application of different N rates via, soil and fertigation considerably influenced the plant height, tillers, millable cane and cane length. The plant height increases with the application of N because it promotes vegetative growth of sugarcane plants (Uribe *et al.,*2013). The height was significantly higher in N application as compared to control, because N was applied through drip irrigation which ensured uniform and proper availability of N (Yadav *et al.,* 2015; Bhingradeve *et al.,* 2017; Bhanuvally *et al.,* 2017) and ultimately leads to production of taller plants. We recorded a significant increase in the tillers count with applied N. As nitrogen is integral component of important molecules (protein and amino acids) and its application promotes the vegetative growth, moreover, water use efficiency significantly increased under drip irrigation owing to reduction in water loss, which leads to production of more assimilates and therefore resulted in more tillers (Hussain *et al.,* 2010). There is direct relation between the millable canes and number of tillers; more tillers lead to production of more millable canes (Saleem *et al.,* 2012). The maximum millable canes in 100% N (recommended nitrogen supplied through fertigation) was due to maximum tillers (Table 2).

The length of the cane is most important as far as sugarcane production is concerned (Hajjari *et al.,* 2015). The increase in length of cane is suitable to enhance the overall yield of sugarcane (Hajjari *et al.,* 2015). The application of N resulted in more LAI, which leads to interception of more solar radiations and leads to production of more assimilates and consequently produced the plants with more cane length (Hajjari *et al.,* 2015). The application of N (100% N applied through fertigation) produced the more stripped cane weight and stripped cane yield. The maximum stripped cane weight and cane yield in this treatment can be due to more LAI, and CGR which increase the assimilates production, total dry matter accumulation and produced the more tillers, millable and cane length, which resulted in more stripped cane weight and stripped cane yield. Previously, different authors reported that N application improved the vegetative growth and yield contributing traits and therefore, leads to significant increase in the final stripped cane weight and stripped cane yield (Allison and Pammenter, 2002; Saleem *et al.,* 2012; Ghaffar *et al.,* 2012; Hussain *et al.,* 2017).

The results indicated that N rates hadnon-significant impact on the qualitative attributes i.e., pol fiber, CCS and sugar recover, however, the N rates significantly affected the total sugar yield. Since the qualitative characters are the varietal character, therefore, they were not affected by the N rates in this study. These results are in accordance with the earlier findings of Chattha *et al.* (2017) they stated that qualitative attributes are varietal character and they are not affected by other factors. Total sugar yield is the product of stripped cane yield and sugar recovery. We noted the maximum sugar yield with 100% N (recommended nitrogen dose applied through fertigation) that can be attributed to maximum stripped cane yield in this treatment as compared to the others. There was a significant positive co-relation among the stripped cane yield and total sugar yield in this study. The increase in the stripped cane yield significantly increase the total sugar yield, as treatment T_5 (100% N of applied through fertigation) has maximum stripped cane yield and therefore, it had the maximum total sugar yield. Similarly, various other authors also reported the significant positive co-relation between the stripped cane yield and total sugar yield (Chattha *et al.,* 2017; Nawaz *et al.,* 2017).

***Conclusion*:** Application of N at different rates through soil and fertigation significantly affected the growth, yield and total sugar yield of sugarcane crop. However, application of N at168 kg supplied through fertigation produced better growth, yield and total sugar, however, it remained statistically similar with 126 kg N supplied through fertigation and resultantly save the 25% N.

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[Received 20 March 2019: Accepted 30 Dec 2019: Published (online) 08 June 2020]