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RESEARCH ARTICLE

Production Potential and Nitrogen Fractionation of Sugarcane-Based Cropping System as Influenced by Planting Materials and Nitrogen Nutrition

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Abstract A field experiment was conducted during the spring season of 2013–2017 at Pusa to assess the effect of various planting materials (three bud setts, poly bag raised settlings and bud chip raised settlings) and nitrogen levels (0, 75, 100, 125 and 150% N/ha) on productivity and nitrogen fractionation of sugarcane (*Saccharum* spp. hybrid complex) plant–ratoon system. Amongst the planting materials, three bud setts and poly bag raised settlings both being at par produced higher dry matter and cane diameter compared with bud chip raised settlings in plant and ratoon crops. The maximum sugarcane yield (83.5 and 76.2 t/ha) was recorded under three bud setts which was found at par with poly bag raised settlings in plant and ratoon crops, respectively. Three bud setts gave significantly higher net returns, B:C ratio and N uptake over others, with greater N-use efficiency (167.2 and 147.9 kg cane/kg N applied) and apparent N recovery (59.1 and 49.7%) in plant and ratoon crops, respectively. The higher nitrogen levels were associated with higher growth, yield attributes and yield of plant and ratoon crops of sugarcane than those of lower nitrogen levels. The highest cane yield (92.9 and 84.4 t/ha), net returns (Rs. 1,43,900 and 1,45,300 /ha; 1US$=INR ~ 70.00) and B:C ratio (1.57 and 2.08) were obtained with 150% of recommended N, which was statistically at par with 125% of recommended N and significantly higher over lower levels in plant and ratoon cane, respectively. Similar trend was also observed for N uptake. The maximum N-use efficiency (176.3 and 149.2 kg cane/kg N applied) and apparent N recovery (58.6 and 50.5%) were observed at 125% of recommended N, and thereafter, it decreased with the increase in the N level in plant and ratoon crops, respectively. The relative contents of these fractions were in order: non-hydrolysable N > amino acid–N > unidentified –N > hydrolysable NH_4^+ –N > exchangeable NH_4^+ –N > hexoseamine –N > NO_3^- –N. All the fractions except NO_3^- –N were in dynamic equilibrium as indicated by significant and positive correlation amongst them. Correlation studies between plant parameters of sugarcane and soil N fractions indicated that the yield of sugarcane and sugar yield were significantly and positively correlated with all N fractions except NO_3^- –N.

Keywords Nitrogen level · Planting material · Productivity · N recovery · Soil N fractions

Introduction

The production potential of sugarcane depends on the quality of planting material and use of fertilizer, which are costlier inputs. Sugarcane crop requires 5–6 tonnes of seed cane for a hectare of land with conventional three bud setts planting under subtropical condition. Recently, released sugarcane varieties developed through conventional breeding following a multistage selection programme requiring over a period of approximately 10 years. Due to less availability of seed cane of a new variety at the time of its release, it further takes about 8–10 years to meet the farmers demand for commercial cultivation, by the time the variety starts deteriorating. To minimize the losses from varietal deterioration, farmers must obtain seeds just after

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release. This is achievable by changing the type of planting material, i.e. poly bag or bud chip raised settlings. As these are less bulky, easily transportable and more economical seed material, holds great promise in rapid multiplication of newly released sugarcane varieties. Establishing the sugarcane crop using bud chips in place of setts could save about 80% by weight of stalk material (Jain et al. 2010; Kumar 2019), which can be well utilized for preparing juice, jaggery and extraction of sugar. Longanandhan et al. (2013) reported that compared to the conventional method, bud chip raised settlings showed high and synchronous tillering with heavier canes which lead to higher yields. The use of single-bud technique was the right solution to provide the availability of the superior sugarcane seed (Budi et al. 2016; Gill and Kaur 2015). Amongst the agronomic factors, fertilizer stands first and is one of the productive inputs in agriculture. Amongst the major nutrient elements, nitrogen, which is scarce in most of the Indian soils, plays an important role in sugarcane crop. Prolonged application of fertilizers and organic manures differentially influenced mineral N, organic N fractions and total N in soils. The mineralizable N in soil plays a dominant role in crop nutrition (Umesh et al. 2014; Khanadagle et al. 2019), and all the fractions of N were highly significantly correlated with each other except NO_3^- –N (Kumar 2003). As studies carried out by Jain et al. (2010) in subtropical India pointed out that the bud chip seed material has relatively low food reserves (1.2–1.8 g sugars/bud). Due to inadequacy of food material and low availability of nutrients, productivity of sugarcane planted with bud chip raised settlings is very poor. Supplementing N through inorganic sources thus plays a vital role in increasing the yield of this crop. Hence, the study on requirement of nitrogen fertilizer for this changing type of seed material is of prime importance. Therefore, the present investigation was undertaken to study the effect of N on different planting materials of sugarcane and on the amount and distribution of different forms of N in soil.

Materials and Methods

Field experiments were conducted during spring seasons of 2013–2014 to 2015–2016 for plant crop and 2014–2015 to 2016–2017 for ratoon crop at Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, located at 25° 59′ N latitude 85° 40′ E longitudes and at an altitude of 52.1 m above mean sea level. The climate of the experimental site was sub-humid, subtropical with moderate rainfall, hot dry summer and cold winter. The soil of experimental site had pH 8.2, organic carbon content 0.43%, electrical conductivity 0.28 ds/m, available N 210 kg/ha, available P 8 kg/ha and available K 102 kg/ha. Treatment comprising of three planting materials (three bud setts, poly bag and bud chip raised settlings) and five nitrogen levels (0, 75, 100, 125 and 150% recommended dose) was arranged in randomized block design with three replications. The recommended dose of fertilizers was 150 kg N + 37.1 kg P + 49.8 kg K/ha for plant crop and 170 kg N + 21.8 kg P + 49.8 kg K/ha for ratoon crop. A total amount of phosphorus, potassium and half of N to plant and ratoon crops of sugarcane were applied as per treatments at the time of planting in the form of urea, single super phosphate and muriate of potash. The remaining amount of the nitrogen was top-dressed in two equal splits at initial and final stages of tillering in plant crop and 7–8 weeks of stubble shaving and final stages of tillering in ratoon crop. Sugarcane variety ‘BO 153’ was planted at 90-cm row distance, keeping three-budded four setts/m row length in the first week of March and ratooned in the second week of February during all the cropping season. The bud chips and poly bag settlings were also initiated in nursery during the first week of March and transplanted in the last week of March in all the years with spacing of 90 × 45 cm. The total rainfall 980.8, 1112.5, 932.6 and 1016.2 mm were received during 2013–2014, 2014–2015, 2015–2016 and 2016–2017, respectively. All the recommended package of practices was adopted for harvesting of healthy crops. Sugarcane plant and ratoon crop were harvested in the second week of February in all the years. Observations on plant population, cane length, dry matter accumulation, cane diameter, millable canes and cane yield in plant and ratoon canes were recorded at their respective growth and harvesting stages following standard procedures. Whole cane samples were taken at the time of harvest, and cane juice was extracted with power crusher, and sucrose content in juice was estimated as per the method given by Spencer and Meade (1955). The economics was worked out based on pooled yield data and considering price of inputs and output of the last year of study. Nitrogen content was determined by digesting the samples in sulphuric acid followed by analysis for total N by the micro-Kjeldahl method, and uptake was calculated by multiplying the content with the dry matter yield of crop. Nitrogen use efficiency (kg cane/kg N applied) was worked out by dividing the cane yield in given treatment minus cane yield in control plot by nitrogen applied in the given treatment. Apparent N recovery of absorbed N was calculated by dividing the nitrogen uptake in treated plot minus nitrogen uptake in control plot by the amount of nitrogen applied in the given treatment multiplied by 100. Composite surface soil samples (0–15 cm) from each plot were collected after sugarcane in plant–ratoon system. The soils were air-dried and pulverized to pass through 2-mm sieve. Different forms of N, viz. NO_3^- –N, exchangeable NH_4^+ –N, hydrolysable–N, non-hydrolysable–N, amino acid –N, hexoseamine –N and unidentified–N, were determined following the fractionation scheme as outlined by Bremner (1965). Statistical analysis was carried out as per Panse and Sukhatme (1985).

Results and Discussion

Growth and Yield Attributes

Planting materials had similar effect on plant population and millable canes that ranged from 1,30,200 to 1,39,400 and 1,44,100 to 1,51,300 in plant population and 99,400 to 1, 03,900 and 1,03,300 to 1,07,600/ha in millable canes under plant and ratoon crops, respectively (Tables 1, 2). Three bud setts recorded higher cane length (252 cm) and were significantly superior to bud chip raised settlings in plant crop, but non-significant differences were observed on ratoon crop. Similarly, higher values of dry matter production (31.2 and 28.5 t/ha) and cane diameter (2.12 and 2.09 cm) were observed with three bud setts as compared to bud chip raised settlings on plant and ratoon crop, respectively. The highest cane weight in plant (850 g/cane) and ratoon (741 g/cane) crop was recorded with three bud setts. It was happened due to the early vigour and fast growth in three bud setts.

Data recorded on growth and yield attributes, viz. plant population, cane length, dry matter production and cane diameter as well as millable canes and cane weight of sugarcane plant and ratoon crops, exhibited significant differences with the nitrogen levels (Tables 1, 2). The higher value of plant population (1,53,800/ha and 1,66,300/ha) was recorded with 150% RDN, which was statistically comparable to 125% RDN in plant cane and 125 and 100% RDN in ratoon cane, respectively. Nitrogen induced early emergence and better photosynthetic efficiency which eventually resulted in higher plant population. The application of 150% recommended dose of nitrogen being at par with 125% recommended dose of nitrogen registered higher values of dry matter production and millable canes over 100% recommended dose of nitrogen in plant and ratoon canes. 150, 125 and 100% recommended dose of nitrogen being at par recorded the taller plants with thicker canes compared to control and 75% recommended dose of nitrogen in plant and ratoon crops of sugarcane. Nitrogen is important in vegetative growth and, being the constituent of enzymes, nucleotides and chlorophyll, its application resulted in higher dry matter accumulation, more number

Table 1 Effect of planting materials and nitrogen levels on growth, yield attributes, cane yield, sucrose content and economics of sugarcane plant crop (pooled data of 3 years)

Treatment	Plant population (× 10^3/ha)	Cane length (cm)	Dry matter production (t/ha)	Cane diameter (cm)	Millable canes (× 10^3/ha)	Cane weight (g/plant)	Cane yield (t/ha)	Sucrose in juice (%)	Cost of cultivation (× 10^3 Rs./ha)	Net returns (× 10^3 Rs./ha)	B:C ratio
Planting material											
Three bud setts	130.2	252	31.2	2.12	99.4	850	83.5	16.91	83.5	129.4	1.55
Poly bag raised settlings	139.4	241	29.6	2.02	103.9	775	79.8	16.83	104.7	98.8	0.94
Bud chip raised settlings	134.6	233	25.8	1.99	101.9	722	70.3	16.72	87.0	92.3	1.06
SEm ±	3.24	5.4	0.66	0.041	2.21	17.1	1.82	0.133	–	3.01	0.032
CD ($P = 0.05$)	NS	16	1.9	0.12	NS	50	5.1	NS	–	8.7	0.09
Nitrogen level (% RDN)											
00	108.5	209	20.7	1.84	81.7	694	56.2	17.14	89.8	53.5	0.61
75	125.1	232	26.3	1.97	94.6	754	70.2	16.82	91.4	87.7	0.98
100	138.0	247	30.2	2.08	104.7	801	80.8	16.79	92.0	114.0	1.26
125	148.1	257	32.8	2.15	112.1	826	89.2	16.76	92.5	135.1	1.49
150	153.8	264	34.3	2.16	115.6	837	92.9	16.59	93.0	143.9	1.57
SEm ±	4.18	7.0	0.86	0.053	2.85	22.1	2.35	0.160	–	3.89	0.041
CD ($P = 0.05$)	11.8	20	2.5	0.15	8.0	64	6.6	NS	–	11.3	0.12

Table 2 Effect of planting materials and nitrogen levels on growth, yield attributes, cane yield, sucrose content and economics of sugarcane ratoon crop (pooled data of 3 years)

Treatment	Plant population (× 10^3/ha)	Cane length (cm)	Dry matter production (t/ha)	Cane diameter (cm)	Millable canes (× 10^3/ha)	Cane weight (g/plant)	Cane yield (t/ha)	Sucrose in juice (%)	Cost of cultivation (× 10^3 Rs./ha)	Net returns (× 10^3 Rs./ha)	B:C ratio
Planting material											
Three bud setts	146.9	245	28.5	2.09	104.4	741	76.2	17.18	68.4	125.9	1.83
Poly bag raised settlings	151.3	236	26.8	2.01	107.6	675	72.3	17.13	68.4	115.9	1.69
Bud chip raised settlings	144.1	231	23.3	1.97	103.3	621	63.7	17.03	68.4	94.0	1.37
SEm ±	3.59	5.4	0.62	0.039	2.48	14.1	1.58	0.150	–	2.86	0.040
CD ($P = 0.05$)	NS	NS	1.8	0.11	NS	41	4.6	NS	–	8.3	0.11
Nitrogen level (% RDN)											
00	116.1	204	18.2	1.81	78.5	635	49.5	17.28	66.2	60.0	0.91
75	138.8	226	24.1	1.96	96.7	671	64.7	17.16	68.1	96.9	1.42
100	153.4	242	27.4	2.05	108.8	690	73.9	17.09	68.7	119.7	1.74
125	162.5	253	30.4	2.12	117.6	698	81.2	17.06	69.3	137.8	1.99
150	166.3	262	30.9	2.16	123.9	701	84.4	16.97	69.9	145.3	2.08
SEm ±	4.64	6.9	0.80	0.051	3.20	18.3	2.04	0.200	–	3.70	0.051
CD ($P = 0.05$)	13.4	20	2.3	0.15	9.3	53	5.9	NS	–	10.7	0.15

of millable canes, taller plants and thicker canes. Singh et al. (2010) also reported the similar results.

Cane Yield and Sucrose

Yield is the manifestation of various yield components. Three bud setts being at par to poly bag raised settlings produced significantly higher cane yield of both plant (83.5 t/ha) and ratoon (76.2 t/ha) crops (Tables 1, 2) over bud chip raised settlings. This result corroborates with Tamil-Selvan (2000). They found that the conventional method gave the highest yield and turned out to be the most economical. The influence of planting materials on sucrose content juice was non-significant. The increasing nitrogen level from 0 to 125% recommended dose significantly increased cane yield of plant and ratoon cane. Further increase in the nitrogen level to 150% recommended dose could not bring about significant improvement in yield of plant and ratoon crops (Tables 1, 2). The magnitude of increase in cane yield by 150, 125, 100 and 75% recommended dose of nitrogen over control was 65.3, 58.7, 43.8 and 24.9% in plant crop and 70.5, 64.0, 49.3 and 30.7% in ratoon crop, respectively. The higher yield at the higher level of N was owing to better partitioning of photosynthates as nitrogen being an important constituent of amino acids, and protoplast directly influences plant growth and development through better utilization of photosynthesis, and thus, an adequate supply of N results in higher tonnage in plant and ratoon canes. Though the influence of nitrogen on sucrose content in juice was non-significant (Tables 1, 2) in both plant and ratoon canes. However, higher doses of nitrogen recorded numerically less sucrose content when compared with lower doses.

Economics

Three bud setts gave maximum net returns (Rs. 1,29,400 and 1,25,900/ha) and benefit/cost ratio (1.55 and 1.83), hence proved more remunerative than the other planting materials in plant and ratoon canes, respectively. The next best planting material of sugarcane was poly bag raised settling followed by bud chip raised settling, but the position of net returns and benefit/cost ratio reversed for them in plant crop because of more cost of investment (Rs. 1, 04,700 /ha) required for poly bag raised settlings than bud chip raised settlings (Rs. 87,000/ha).

There was a significant increase in net returns and benefit/cost ratio with each successive increment of N from 0 to 125% recommended dose beyond which 150% recommended dose did not show significant variation. The percentage increase in net returns and benefit/cost ratio by 150, 125, 100 and 75% recommended dose over control in plant crop was 169.0 and 157.4; 152.5 and 144.3; 113.1 and 106.6; 63.9 and 60.7%, respectively. The corresponding increase was 142.2 and 128.6; 129.7 and 118.7; 90.5 and 91.2; 61.5 and 56.0% in ratoon crop, respectively (Tables 1, 2). It was because the additional cost of nitrogen was compensated by the additional yield.

Nitrogen Uptake Its Use Efficiency and N Status in Soil

Planting material showed marked improvement in nitrogen uptake and maximum (233.3 and 209.9 kg/ha) was recorded with three bud setts followed by poly bag raised settlings (215.4 and 192.0 kg/ha) in plant and ratoon crops, respectively (Table 3). The results can be attributed to improvement in dry matter accumulation and N concentration in plant tissue. N-use efficiency and apparent N recovery also followed the similar trend as that of N uptake (Table 3). The N-use efficiency (167.2 and 147.9 kg cane/kg N applied) and apparent N recovery (59.1 and 49.7%) were the highest with three bud setts followed by poly bag and bud chip raised settlings in plant and ratoon crop, respectively. Planting material could not cause significant improvement in available N in soil at harvest of plant and ratoon canes.

The N uptake increased significantly with successive rise in N levels up to 125% recommended dose (Table 3). The highest N uptake of 259.0 and 233.1 kg/ha was recorded at 150% recommended dose of nitrogen, though the statistical differences amongst 125 and 150% recommended dose were non-significant in both plant and ratoon crops, respectively. With the increment in supply of N to the soil, their availability, acquisition, mobilization and influx in to the plant tissues increased under balanced N nutrition and resulting in more tonnage, which ultimately increased the N uptake by plants. There was a progressive increase in N-use efficiency and apparent N recovery up to 125% recommended dose of N (Table 3). Maximum N-use efficiency (176.3 and 149.2 kg cane/kg N applied) and apparent N recovery (58.6 and 50.5%) were recorded with 125% recommended dose of nitrogen, when the effect of N was significant on cane yield and N uptake in plant and ratoon crops, respectively. Further, the increase in N rates decreased the N-use efficiency and apparent N recovery in both plant and ratoon canes. Nitrogen at 75 and 100 kg/ha were found at par but significantly superior to control plot in influencing available N status in soil after harvest of plant and ratoon canes.

Table 3 Effect of planting materials and nitrogen levels on N uptake and its use efficiency on sugarcane plant–ratoon system (pooled data of 3 years)

Treatment	Plant crop				Ratoon crop			
	N uptake (kg/ha)	N-use efficiency (kg cane/kg N applied)	Apparent N recovery (%)	Post-harvest N status	N uptake (kg/ha)	N-use efficiency (kg cane/kg N applied)	Apparent N recovery (%)	Post-harvest N status
Planting material								
Three bud setts	233.3	167.2	59.1	228	209.9	147.9	49.7	226
Poly bag raised settlings	215.4	158.9	55.2	233	192.0	140.2	45.9	230
Bud chip raised settlings	185.2	145.6	47.4	242	164.6	123.5	39.2	238
SEm ±	4.41	–	–	5.4	3.68	–	–	5.1
CD (*P* = 0.05)	12.8	–	–	NS	10.7	–	–	NS
Nitrogen level (% RDN)								
00	137.5	–	–	205	119.1	–	–	202
75	187.8	125.0	44.7	226	167.3	119.2	37.8	225
100	224.8	164.0	58.2	240	198.4	143.5	46.7	236
125	247.4	176.3	58.6	248	226.3	149.2	50.5	245
150	259.0	163.4	54.0	253	233.1	136.9	44.7	249
SEm ±	5.69	–	–	7.0	4.76	–	–	6.6
CD (*P* = 0.05)	16.5	–	–	20	13.8	–	–	19

Distribution of Nitrogen in to Different Fractions

Distribution of different fractions of N in post-harvest soil after sugarcane ratoon is presented in Table 4. The NO_3^- –N was significantly higher at the higher level of N application and planting materials. The effects of planting materials were statistically at par except three bud setts significantly reduced NO_3^- –N. There was significant variation in NO_3^- –N (14.9–15.8 mg/kg) and (12.1–17.7 mg/kg) due to planting materials and different levels of nitrogen treatment. As a low build-up of NO_3^- –N in soil due to high dose of N fraction due to incomplete nitrification of applied urea or loss of NO_3^- –N due to denitrification and leaching under rainy season (Kumar 2003; Umesh et al. 2014; Sinha et al. 2017). A significant increase in exchangeable NH_4^+–N and hydrolysable NH_4^+–N fraction was observed with increasing levels of N and planting materials. These treatments significantly increased the exchangeable NH_4^+–N from 69.4 to 72.5 mg/kg and 54.8 to 85.2 mg/kg due to planting materials and different levels of N, respectively. Amongst the hydrolysable –N with the application of different levels of N, the highest was amino acid–N (99.2 to 121.8 mg/kg) followed by NH_4^+–N (78.3 to 129.3 mg/kg), unidentified–N (68.0 to 88.2 mg/kg) and least in the form of hexoseamine–N (24.4 to 46.2 mg/kg). Non-hydrolysable N varies from 158 to 166 mg/kg and 143 to 179 mg/kg with planting materials and application of different levels of N, respectively, while total N varied from 575 to 608 mg/kg and 479 to 669 mg/kg, respectively. It seems that amongst N fractions NO_3^- –N, exchangeable NH_4^+–N and hydrolysable–N appear to be more susceptible to changes than other fractions under sugarcane-based cropping system. Consequently, these fractions may serve as relatively more available on depletion of N in soil (Sihag et al. 2005; Sinha et al. 2017).

Correlation Studies

The correlation coefficient values amongst different forms of soil N are presented in Table 5. With regard to inter-relationships amongst N fractions, total soil N was found to have significant and positive correlation with exchangeable NH_4^+–N (0.981**), hydrolysable NH_4^+–N (r = 0.991**), hexoseamine-N (r = 0.994**), amino acid N (r = 0.993**), unidentified–N (r = 0.993**), total hydrolysable –N (r = 0.996**) and non-hydrolysable –N (r = 0.980**). Non-hydrolysable N had highly significant and positive correlation with unidentified –N (r = 0.953**), amino acid-N (r = 0.953**), hexoseamine –N (r = 0.956**), hydrolysable NH_4^+–N (r = 0.945**) and exchangeable NH_4^+–N (r = 0.993**). The correlation

Table 4 Effect of planting materials and nitrogen levels on different fractions of soil nitrogen (mg/kg) in post-harvest soil after three rotations of sugarcane plant–ratoon system

Treatment	N fractions (mg/kg)								
	NO_3^- –N	Exchangeable NH_4^+–N	Hydrolysable –N						Total N
			NH_4^+–N	Hexoseamine –N	Amino acid –N	Unidentified–N	Total hydrolysable –N	Non-hydrolysable –N	
Planting material									
Three bud setts	14.9	69.4	106.2	35.9	111.7	78.9	336	158	575
Poly bag raised settlings	15.3	70.9	111.5	38.2	113.6	81.3	344	162	591
Bud chip raised settlings	15.8	72.5	114.4	40.2	115.1	82.3	353	166	608
SEm ±	0.20	1.33	1.29	0.22	2.06	0.18	4.77	3.24	14.59
CD (P = 0.05)	0.59	3.84	5.05	0.64	NS	0.52	13.82	NS	42.26
Nitrogen level (% RDN)									
00	12.1	54.8	78.3	24.4	99.2	68.0	274	143	479
75	14.8	63.8	106.5	36.0	112.2	79.4	333	154	567
100	15.4	71.1	117.0	40.5	114.9	82.5	355	161	602
125	16.8	79.7	122.4	43.4	119.3	86.0	372	172	640
150	17.7	85.2	129.3	46.2	121.8	88.2	386	179	669
SEm ±	0.26	1.71	1.67	0.28	2.66	0.23	6.16	4.19	18.83
CD (P = 0.05)	0.76	4.96	6.53	0.82	7.71	0.68	17.85	12.13	54.55

Table 5 Correlation coefficients (*r*) amongst different fractions of soil nitrogen

N fractions	NO_3^- –N	Exchangeable NH_4^+–N	Hydrolysable –N						Total N
			NH_4^+–N	Hexoseamine –N	Amino acid –N	Unidentified–N	Total hydrolysable–N	Non-hydrolysable –N	
NO_3^- –N	1.00	− 0.048	− 0.119	0.146	− 0.125	− 0.093	− 0.085	0.246	0.019
Exchangeable NH_4^+–N		1.00	0.949**	0.956**	0.955**	0.954**	0.963**	0.993**	0.981**
Hydrolysable NH_4^+–N			1.0	0.999**	0.996**	0.998**	0.998**	0.945**	0.991**
Hexoseamine –N				1.0	0.996**	0.998**	0.999**	0.956**	0.994**
Amino acid –N					1.0	0.999**	0.997**	0.953**	0.993**
Unidentified –N						1.0	0.998**	0.953**	0.993**
Total hydrolysable –N							1.0	0.959**	0.996**
Non-hydrolysable –N								1.0	0.980**
Total N									1.0

*Significant at 5% probability level

**Significant at 1% probability level

Table 6 Correlation coefficients (r) of yield attributes, cane yield and sucrose content in sugarcane with different fractions of N in post-harvest soil after sugarcane plant-ratoon system

Treatment	N fractions (mg/kg)								
	NO_3^- –N	Exch. NH_4^+–N	Hydrolysable –N						Total N
			NH_4^+–N	Hexoseamine –N	Amino acid –N	Unidentified –N	Total hydrolysable –N	Non-hydrolysable –N	
Sugarcane plant									
Plant population	0.226	0.980**	0.967**	0.968**	0.964**	0.970**	0.971**	0.970**	0.979**
Cane length	0.039	0.911**	0.891**	0.882**	0.893**	0.888**	0.901**	0.861**	0.895**
Millable canes	0.236	0.984**	0.974**	0.975**	0.971**	0.975**	0.979**	0.970**	0.984**
Cane yield	0.245	0.911**	0.880**	0.871**	0.882**	0.880**	0.889**	0.861**	0.887**
Sucrose	− 0.199	− 0.900**	− 0.959**	− 0.963**	− 0.959**	− 0.959**	− 0.956**	− 0.922**	− 0.956**
Sugarcane ratoon									
Plant population	0.256	0.958**	0.968**	0.963**	0.964**	0.967**	0.970**	0.932**	0.966**
Cane length	0.132	0.946**	0.917**	0.912**	0.919**	0.915**	0.928**	0.905**	0.928**
Millable canes	0.248	0.979**	0.969**	0.967**	0.968**	0.970**	0.975**	0.958**	0.977**
Cane yield	0.286	0.904**	0.889**	0.878**	0.891**	0.888**	0.896**	0.854**	0.890**
Sucrose	− 0.222	− 0.921**	− 0.931**	− 0.944**	− 0.926**	− 0.930**	− 0.935**	− 0.949**	− 0.949**

*Significant at 5% probability level

**Significant at 1% probability level

coefficient values as given in Table 5 indicated that since NO_3^- –N failed to produce significant correlation with any of the other N fractions, this fraction is not in equilibrium with other fractions. This could be attributed to highly mobile nature of NO_3^- –N. The other fractions were in dynamic equilibrium indicating interchangeable behaviour of those N fractions (Singh and Singh 2007; Umesh et al. 2014). Data presented in Table 6 indicated that plant parameter like plant population, cane length, millable canes and cane yield by sugarcane plant and sugarcane ratoon were positively and significantly correlated with all the N fractions except NO_3^- –N. The NO_3^- –N fractions did not produce significant correlation with any of the plant parameters. Umesh et al. (2014) and Yadav and Singh (1991) reported positive and significant correlation between different forms of nitrogen (NH_4^+–N, hydrolysable –N and non-hydrolysable –N). Hydrolysable and non-hydrolysable –N were significantly correlated with all the forms of N and yield of cane indicating that those forms are more important at later stage or near harvest.

Conclusions

Based on the study, it is concluded that three bud setts was superior in terms of net returns, benefit/cost ratio, N uptake, N-use efficiency and apparent N recovery over other planting materials despite its lower plant population and millable canes; however, in spite of the several benefits of poly bag and bud chip raised settlings particularly in seed cane economy, it was not economical because of lower cane diameter, thinner canes and comparatively more labour engagement in preparation of poly bag and bud chip raised settlings. Amongst the nitrogen level, application of 125% recommended dose was found to be optimum for enhancement of cane yield, net returns, benefit/cost ratio and nutrient use efficiency in plant and ratoon crops of sugarcane. The application of N fertilizer increased exchangeable NH_4^+–N, hydrolysable –N and total N with increasing levels of N fertilizer. Plant growth parameters and sugarcane yield were highly correlated with most of N fractions. Multivariate analysis established the importance of all N fractions in one way or other towards the N nutrition of sugarcane.

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Compliance with Ethical Standards

Conflict of interest We, the authors, declare that we have no conflict of interest.

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