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Cane yield, quality and nitrogen use efficiency of sugarcane varieties as influenced by nitrogen fertilizer in alfisols

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Abstract
Response of three sugarcane varieties to five levels of nitrogen fertilizer was studied in a split plot experiment during 2016-17 at Agricultural Research Station, Perumallapalle, ANGRAU, Andhra Pradesh. Sugarcane varieties *viz*. 2009 T 5, 2009 T 10 and 2003 V 46 were studied for uptake, nutrient use efficiency with 0%, 75%, 100%, 125% and 150% recommended dose of nitrogen at 90 days after planting (DAP), 180 DAP and harvest. Cane yield and yield parameters were recorded at harvest. Results revealed that a significant increase in N uptake by sugarcane with addition of N fertilizers was recorded at all stages of crop growth. The highest mean N uptake was observed in sugarcane fertilized with 150% RDN and the lowest mean N uptake was noticed in plants that did not received N fertilizers. Regarding interaction, application of 150% RDN to 2003 V 46 recorded higher nitrogen uptake at all stages of crop growth and it was at par with 2009 T 10 with 150% RDN and 100% RDN. Higher agronomic efficiency (AE) and physiological efficiency (PE) were observed in 2009 T 10 with 100% RDN. Among sugarcane varieties 2009 T 10 showed higher mean cane yield which is comparable with 2009 T 5. Application of 125% RDN recorded higher mean cane yield and was on par with cane yield obtained from 100% RDN and 150% RDN.

Keywords: Nitrogen uptake, nitrogen use efficiency, sugarcane, yield and quality

Introduction
Sugarcane is a tropical plant and requires warm, humid climate for good growth. However it is being grown throughout the subtropical area that requires huge quantity of nutrients. A number of factors are responsible for low yield of sugarcane including scarcity of irrigation water, low plant population per unit area and imbalanced as well as inadequate use of fertilizers. Moreover, continuous planting of sugarcane in the same field depletes soil nutrients. Nutrients extracted from the soil and accumulated by the plants vary accordingly to cultivar, soil management, crop cycle and other available inputs for the development of plants. A crop having yield of 100 t ha^{-1} removes 207 kg nitrogen, 30 kg phosphorus and 233 kg potassium from soil (Jagtap *et al.* 2006) [9]. This macronutrient plays a major role in physiological functions, biochemical reactions, growth and development of sugarcane (Obreza *et al*. 1998) [17]. Therefore these elements must be added in adequate quantities to the crop to obtain higher yield. Among these elements, nitrogen (N) is the primary nutrient limiting sugarcane production (Wiedenfeld and Enciso, 2008) [34]. Application of nutrients in imbalanced and in adequate manner causes nutrient deficiencies. Besides N, P and K deficiencies emerging secondary and micro nutrient deficiencies also create significant constraints to higher yields in Andhra Pradesh.
Different sugarcane cultivars have different yield potentials and other specific attributes (Stevenson *et al.* 1992) [25]. New varieties developed have different yield potentials, resistance to pest and diseases and adoptability to various locations. Variations in various response to different fertilizers were also reported by Srinivas *et al.* (2003) [22]. One of the cause of declining sugarcane yield is speculated to be declining soil fertility as result of depletion of the essential plant nutrients *viz.* N, P and K with low rate of replenishment (George *et al.* 2013, Vajantha *et al.* 2017) [5, 30]. In this connection, the study was undertaken to determine the optimum fertilizer dose for sustaining higher yield and to identify high nitrogen use efficient varieties in Southern zone of Andhra Pradesh.

Materials and Methods

A field experiment was conducted at Agricultural Research Station, Perumallapalle, ANGRAU, Andhra Pradesh during 2016-17 to study the impact of varied levels of nitrogen on nutrient uptake and yield of sugarcane genotypes. Composite soil sample was drawn from the experimental site at 0-15 cm depth prior to conduct the experiment. The soil samples were analysed by adopting standard procedures for pH and electrical conductivity (Tandon, 1993) [27], available nitrogen (Subbaiah and Asija, 1959) [26], available phosphorus (Olsen *et al.* 2019), available potassium (Jackson *et al.* 1973) [8] and organic carbon content (Walkely and Black, 1934) [32]. The experimental site was sandy clay loam in texture neutral in soil reaction, non-saline nature, low in organic carbon content, available nitrogen, medium in available phosphorus and high in available potassium (Table 1). The experiment was laid out in split plot design with three replications, varieties as main treatments and nitrogen levels as sub treatments. Three promising early maturing varieties *viz.* 2009 T5, 2009 T 10 and 2003 V 46 were evaluated in this study with five levels of nitrogen *viz.* 0%, 75%, 100%, 125% and 150% recommended dose of nitrogen (100% RDN: 224 kg ha^{-1}). Nitrogen was applied in the form of urea, phosphorus was applied in the form of single super phosphate and potassium applied in the form of muriate of potash. All the agronomic practices like hand weeding, earthing up, trash twist propping etc. were carried out according to recommendations. Plant samples were collected at 90 to 180 days after planting (DAP) and at harvest stages to estimate nutrient concentration by adopting the standard procedures as outlined by Tandon (2005) [28]. Uptake was calculated from nutrient content and dry matter production. Cane yield was recorded at harvest. Data were statistically analysed by following the method given by Panse and Sukhatme (1985) [19]. Nitrogen use efficiency (NUE) parameters were calculated by using the following formulae (SSSP. 1994) [23].

Agronomic efficiency (AE)(kg/kg)

$$=\frac{\text{Yield in treatment (kg) - Yield in control (kg)}}{\text{N applied (kg)}}$$

Recovery efficiency (RE)(%)

$$=\frac{\text{N uptake in treatment – N uptake in control}}{\text{N applied (kg)}}$$

Physiological efficiency (PE)

$$=\frac{\text{Cane yield in treatment-Cane yield in control}}{\text{N uptake in treatment-N uptake in control}}$$

Table 1: Initial soil properties of experimental field

S. No.	Particulars	Value
1	Texture	Sandu clay loam
2	pH	7.48 (Neutral)
3	Electrical Conductivity (dS m^{-1})	0.247 (Non saline)
4	Organic carbon (%)	0.42 (Low)
5	Available nitrogen (kg ha^{-1})	245 (Low)
6	Available phosphorus (kg ha^{-1})	49.78 (Medium)
7	Available potassium (kg ha^{-1})	228 (Medium)

Results and Discussion

Nitrogen uptake by sugarcane

Nitrogen (N) uptake by sugarcane plant at 90 DAP, 180 DAP and harvest was depicted in table 2, 3 and 4, respectively. At 90 DAP and 180 DAP, the N uptake by sugarcane was not significantly influenced by varieties. However N levels and the interaction between varieties and N levels showed significant effect on N uptake by plant. At 90 DAP, among N levels, application at 125% RDN recorded maximum mean N uptake (52.67 kg ha^{-1}) which was at par with 150% RDN (51.66 kg ha^{-1}) and 100% RDN (48.24 kg ha^{-1}). Lowest N uptake (27.84 kg ha^{-1}) was observed in control (Table 2). Regarding interactions, higher N uptake was noticed with 2003 V 46 at 150% RDN (56.01 kg ha^{-1}) and it is comparable with 2003 V 46 at 125% RDN, 2009 T 10 with 125% RDN, 2009 T 5 with 150% RDN, 2009 T 10 with 150% RDN and 2003 V 46 with 100% RDN.

Table 2: Effect of nitrogen doses on N uptake (kg ha^{-1}) by sugarcane genotypes at 90 DAP

Varieties	0% RDN	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T 5	26.28	42.62	48.34	49.45	50.15	43.36
2009 T 10	30.06	44.64	47.25	53.21	48.83	44.79
2003 V 46	27.18	41.31	49.12	55.34	56.01	45.79
Mean	37.84	42.86	48.24	52.67	51.66	

	CD (0.05)	SE (m)
Varieties	N.S.	0.69
N levels	5.08	1.65
V x N	N.S.	2.56
N x V	N.S.	2.84

At 180 DAP, application of 125% RDN recorded higher mean N uptake (162 kg ha^{-1}) which is on par with 150% RDN (160 kg ha^{-1}). The interaction between varieties and N levels showed significant effect on N uptake by plant. 2009 T 5 with 125% RDN recorded higher N uptake (172 kg ha^{-1}) which is at par with other treatments (Table 3).

Table 3: Effect of nitrogen doses on N uptake (kg ha^{-1}) by sugarcane genotypes at 180 DAP

N levels varieties	0% RDN	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T 5	94	130	151	172	160	141
2009 T 10	97	128	142	161	159	137
2003 V46	91	122	140	155	162	134
Mean	94	127	144	162	160	

	CD (0.05)	SE (m)
Varieties	N.S.	2.52
N levels	5.39	1.75
V x N	13.68	5.63
N x V	14.12	5.91

At harvest stage, N uptake by plant was significantly influenced by varieties, N levels as well as with their interaction (Table 4). Among the varieties 2003 V 46 recorded higher mean N uptake (235 kg ha^{-1}) which is on par with 2009 T 10 (231 kg ha^{-1}). Among N levels, even though 150% RDN recorded higher N uptake (262 kg ha^{-1}) it is comparable with 125% RDN (258 kg ha^{-1}). Regarding interactions, application of 150% RDN to 2003 V 46 showed higher N uptake (274 kg ha^{-1}) which is at par with 2003 V 46 at 125% RDN (263 kg ha^{-1}) and 2009 T 10 with 150% RDN (263 kg ha^{-1}). The lowest N uptake was noticed with 2009 T 10 + 0% RDN (166 kg ha^{-1}) and it was comparable with 2009 T 5 and 2009 T 10 without N application.

Table 4: Effect of nitrogen doses on N uptake (kg ha^{-1}) by sugarcane genotypes at harvest

N levels varieties	0% RDN	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T 5	178	225	242	254	247	229
2009 T 10	166	221	251	256	263	231
2003 V 46	174	217	246	263	274	235
Mean	173	221	246	258	262	

	CD (0.05)	SE (m)
Varieties	N.S.	1.38
N levels	7.06	2.29
V x N	13.83	3.98
N x V	14.16	5.04

At all stages of crop growth a significant increase in N uptake by sugarcane with addition of N fertilizer was recorded. The highest N uptake was observed in sugarcane fertilized with 150% RDN and the mean lowest N uptake was recorded in plants that did not receive N fertilizers. The highest N uptake at higher N doses may be due to higher availability of N as well as by higher production of dry biomass at that dosage (Garside and Bell. 2003) [3]. Vale *et al.* (2013) [31] observed that the accumulation of N in sugarcane incremented with increase of N dosage. Hussein *et al.* (2013) evaluated the extraction of nutrient by sugarcane varieties as observed that varieties differed with respect to extraction of N. The element N is an essential constituent of amino acids, the main constituent of protein, which besides playing a role in cell division, production of chlorophyll and contributes to the growth and development of plant (George *et al.* 2013: Bologna *et al.* 2013 and Saleem *et al.* 2012) [1, 5, 20].

Cane yield

Data pertaining to cane yield was presented in table 5. Significant difference in cane yield was noticed with application of N fertilizer at different levels to varieties. Varieties showed significant effect on cane yield. Higher mean cane yield (104 t ha^{-1}) was recorded with 2009 T 10 which is comparable with 2009 T 5 (103 t ha^{-1}). The mean cane yield received with 125% RDN (113 t ha^{-1}) was at par with cane yield obtained from 100% RDN (110 t ha^{-1}) and 150% RDN (107 t ha^{-1}). Without N application significantly lowest cane yield (76 t ha^{-1}). Regards to interaction effect, 2009 T 10 with 100% RDN recorded significantly highest cane yield (120 t ha^{-1}) which is on par with 2009 T 5 at 125% RDN (116 t ha^{-1}). 2003 V 46 without N application recorded lowest cane yield (71 t ha^{-1}) which is at par with 2009 T 10 without N application (76 t ha^{-1}).

Table 5: Effect of nitrogen doses on cane yield (t ha^{-1}) by sugarcane early varieties at harvest

N levels varieties	0% RDN	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T 5	81	99	112	116	107	103
2009 T 10	76	101	120	113	111	104
2003 V46	71	87	99	110	102	94
Mean	76	95	110	113	107	

	C.D.	SE (m)
Varieties	3.68	0.59
N levels	3.17	1.03
V x N	6.17	1.63
N x V	6.85	1.76

Higher cane yield at higher levels might be attributed to more cane length, girth, dry matter production and nutrient uptake. Significant increase in cane yield in response to higher levels of N has already been reported (Mishra *et al.* 2004, Singh *et al.* 2004 and Vajantha *et al.* 2017) [14, 21, 30]. Sugarcane yield was lowest with no nitrogen application indicating that the nitrogen which is available inherently at initial stages might not have remained available later stages of crop growth due to leaching concerns which leads to reduce uptake of other nutrients and finally yield reduction (Gascho *et al.* 1986) [4]. Higher cane yield with 125% RDN might be due to higher shoot population coupled with efficient conversion of shoots to millable canes at harvest that may contributed to higher cane yields. Similar results were obtained by Thornbun *et al.* 2005, Manjunatha *et al.* 2017) [13].

Juice quality

Sugarcane quality is assessed by the sugar produced per tonne of cane, and the major elements essential for cane growth, nitrogen has the greatest influence on cane growth, ripening and juice quality (Hussain *et al.* 1990) [6]. Quality parameters which include Brix, sucrose, % purity and % CCS were not affected by increasing nitrogen application (Table 6). This could be due to the early application of nitrogen (12 weeks after planting). Thus the detrimental effect of high nitrogen on juice quality was minimized before the maturity age of the cane (Gana *et al.* 2007 and Muchow *et al.* 1995) [2, 15]. Use of N fertilizers showed no significant influence on juice quality parameters such as Brix and purity. Juice quality mainly depends on genetic nature of the variety. Neman *et al.* (1995) [16] reported increased juice cation, chlorine and nitrogen content with application of nitrogen. However, when applied in excess or late in growth period, N impaired juice quality and the recoverable sugar % was reduced. High application of nitrogen fertilizers generally results in luxurious growth and high percentage of reducing sugars but as crop ages and matures, it is expected that nitrogen content will be reduced and there is an increasing conversion of the reducing sugars to sucrose (Kumar *et al.* 1996) [11].

Table 6: Juice quality parameters of sugarcane under different nitrogen levels

Treatments	Sucrose (%)	Purity (%)	CCS (%)
Varieties			
2009 T5	17.52	86.52	11.26
2009 T10	17.72	89.20	11.75
2003 V46	17.83	84.57	10.68
CD (0.05)	N.S	1.36	0.42
SE (m)	0.31	4.42	1.40
N levels			
0% RDN	17.44	84.21	11.56
75% RDN	17.70	86.26	11.24
100% RDN	17.69	87.28	11.94
125% RDN	17.81	83.50	11.78
150% RDN	17.80	87.26	11.92
CD (0.05)	N.S	N.S.	N.S.
SE (m	0.54	5.62	1.94
Interaction	N.S.	N.S.	N.S.

Nitrogen use efficiency

Agronomic efficiency (AE), physiological efficiency (PE) and recovery efficiency (RE) of nitrogen for different sugarcane genotypes at various levels of nitrogen are presented in tables 7, 8 and 9, respectively. The AE ranged from 103 to 155 kg/kg with different doses of nitrogen (Table 7). In various doses, 100% RDN showed significantly highest AE (155 kg/kg) followed by 125% RDN (133 kg/kg) which is at par with 75% RDN (118 kg/kg). The RE at 90 DAP has not significantly influenced by varieties, N levels as well as with their interaction. However at 180 DAP and harvest, the varieties, N levels and their interaction showed significant effect on RE at 180 DAP and harvest. At 180 DAP, the mean RE is more with 2009 T5 (23.64%) followed by 2003 V 46 and 2009 T10. Among N doses, 125% RDN showed significantly highest RE (24.45%) followed by 100% RDN (22.44%). Interaction effects, 2009 T5 with 125% RDN recorded highest RE than others. At harvest, 2009 T10 recorded significantly highest mean RE (32.87%) followed by 2003 V 46 (29.82%) and 2009 T5 (25.90%). Among various levels of N, 100% RDN showed significantly highest RE (32.81%) followed by 125% RDN (30.29%). Regarding to interaction effect, 2009 T10 with 100% RDN (37.95%) showed significantly highest RE followed by 2009 T10 with 125% RDN (32.04%) (Table 8). PE of sugarcane genotypes were significantly affected by nitrogen levels as well as with interaction between genotypes and N levels. Among genotypes, significantly highest PE is noticed with 2009 T5 (468 kg/kg) which is significantly differed with each other (Table 9). Among various N levels application of 100% RDN recorded higher PE (469 kg/kg) followed by 125% RDN (440 kg/kg). Among interaction, 2009 T10 and 100% RDN showed higher PE (520 kg/kg) followed by 2009 T5 at 100% RDN (489 kg/kg).

Table 7: Effect of nitrogen doses on agronomic efficiency (kg kg^{-1}) of sugarcane early varieties

N levels varieties	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T5	107	139	125	109	120
2009 T10	153	197	135	106	148
2003 V46	95	128	138	94	114
Mean	118	155	133	103	

	C.D.	SE (m)
Varieties	N.S.	7.51
N levels	19.46	6.38
V x N	N.S.	15.19
N x V	N.S.	14.64

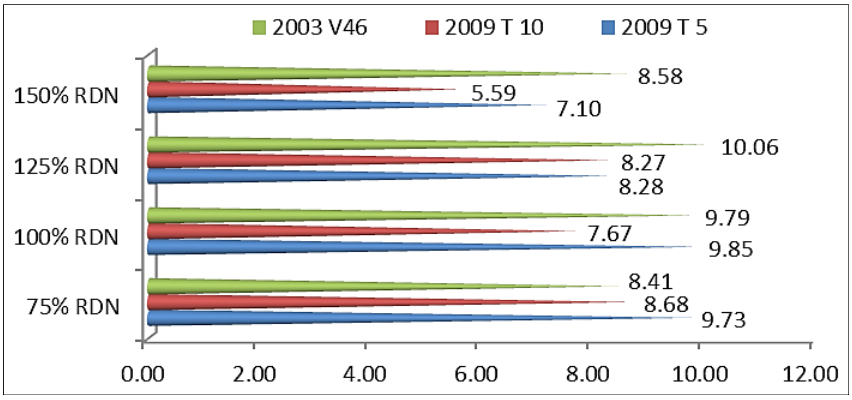

Fig 1: Effect of nitrogen doses on recovery efficiency (%) of sugarcane early varieties at 90 DAP

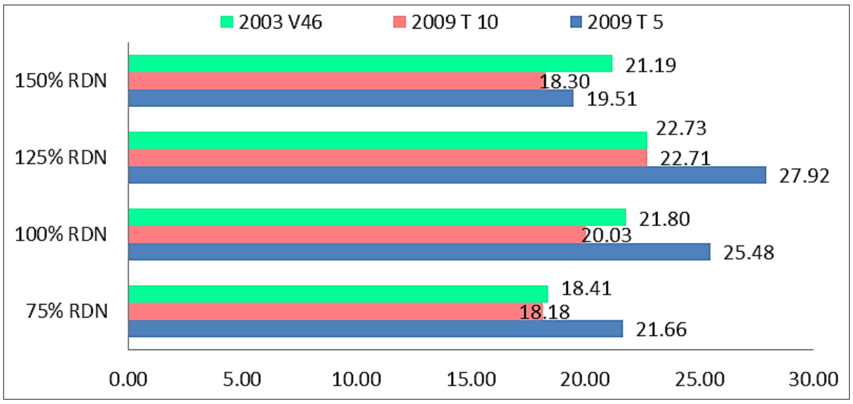

Fig 2: Effect of nitrogen doses on recovery efficiency (%) of sugarcane early varieties at 180 DAP

Table 8: Effect of nitrogen doses on recovery efficiency (%) of sugarcane early varieties at harvest

N levels varieties	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T5	27.68	28.39	26.96	20.57	25.90
2009 T10	32.50	37.95	32.04	28.99	32.87
2003 V46	25.60	32.00	31.86	29.73	29.82
Mean	28.59	32.81	30.29	26.43	

	C.D.	SE (m)
Varieties	2.14	0.74
N levels	0.93	0.35
V x N	3.02	1.09
N x V	3.86	1.34

Table 9: Effect of nitrogen doses on physiological efficiency (kg kg^{-1}) of sugarcane early varieties

N levels varieties	75% RDN	100% RDN	125% RDN	150% RDN	Mean
2009 T5	387	489	465	431	443
2009 T10	471	520	421	367	445
2003 V46	370	398	434	315	379
Mean	409	469	440	372	

	C.D.	SE (m)
Varieties	11.12	3.67
N levels	9.75	3.07
V x N	19.12	6.91
N x V	23.15	8.36

Maximum AE with 2009 T10 and 100% RDN was perhaps due to more cane yield. More PE might be attributed to better distribution of N throughout the crop. Similar results were eported by Stalin *et al*. 1999 [24]. Higher N rates might have made the vegetation growth period longer and shortened the period of sugar accumulation (Weigel *et al*. 2010) [33]. A better balance was achieved with a medium fertilizer dose (Koochekzadeh *et al*. 2009) [10]. Lee and Jose (2005) [12] revealed that increasing N application rates raises N leaching without making any difference in growth (Vajantha *et al*. 2007).

Available nutrient status

The available N in soil after harvest was differed significantly with N levels only. Varieties and the interaction between varieties and N levels showed non-significant effect on available nitrogen Table 10). The treatment which received 150% RDN recorded higher available N (259 kg ha^{-1}) which is at par with 100% RDN (252 kg ha^{-1}). The soil properties *viz*. pH, EC, organic carbon, available P and K were not significantly affected by varieties, N levels and their interaction.

Table 10: Effect of nitrogen doses on soil properties after harvest

Treatments	Ph	EC (Ds m-1)	OC (%)	Avail N (kg ha-1)	Avail P_2O_5 (kg ha-1)	Avail K_2O (kg ha-1)
Varieties						
V1: 2009 T5	7.43	0.220	0.43	257	41.70	283
V2-2009 T10	7.38	0.227	0.46	245	43.05	265
V3-2003 V46	7.41	0.206	0.44	243	43.85	260
CD (0.05)	N.S	N.S	N.S	N.S	N.S	N.S
SE (m)	0.07	0.003	0.001	6.19	2.23	5.19
N levels						
N1-0% RDN	7.35	0.214	0.42	244	43.10	262
N2-75% RDN	7.33	0.213	0.45	240	43.33	267
N3-100% RDN	7.47	0.219	0.45	252	41.11	272
N4-125% RDN	7.49	0.228	0.45	246	43.35	277
N5-150% RDN	7.40	0.215	0.44	259	43.46	267
CD (0.05)	N.S	N.S.	N.S.	11.82	N.S.	N.S.
SE (m)	0.07	0.006	0.0018	3.57	0.71	3.90
Interaction	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Conclusion

Significant effect on N uptake, cane yield and NUE parameters were observed with application of different levels of N (0% RDN to 150% RDN). The N uptake by sugarcane was increased with increasing dose of N. Highest N uptake was recorded with 125% RDN at 180 DAP and with 150% RDN at harvest stages of crop growth. The higher cane yield was noticed in 125% RDN and it was comparable with 100% RDN and 150% RDN. The AE, RE and PF were higher with 100% RDN and these were on par with 125% RDN and 150% RDN. Among the genotypes studied, 2009 T10 showed higher cane yield, high AE, RE and PFP compared with other varieties. Finally it concluded that 2009 T10 with 100% RDN recorded higher cane yield along with higher nitrogen efficiency.

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