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Growth, Yield and Quality of Sugarcane as Influenced by NP-1 Product Under Autumn and Spring Planting Conditions in Subtropical India

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Abstract: *A field experiment was conducted during 2012-14 at IISR farm, Lucknow with 12 treatments combinations of recommended fertilizer and NP1 product to study the effect of NP-1 product on growth, yield and quality of sugarcane. There were twelve treatment combinations replicated thrice in randomized block design. Sugarcane early maturing variety CoPk 05191 was planted in the experiment during autumn (October planted) and spring (February planted) seasons. The highest mean cation exchange capacity (CEC) of root and soil (41.5 meq/ 100 g roots and 12.45 meq/100 g soil, respectively) were determined with the application of 100% N through NP1+ 100% PK through commercial sources. Application of 100% N through NP1+ 100% PK through commercial sources of NP1 produced the highest number of millabe canes (142.07 thousand/ha), number of internodes/cane (25.33), cane length (246.33 cm), diameter (2.63 cm) and weight (1050 g) in autumn crop. Spring crop also behaved in similar fashion with marginally lower growth attributes. The reduction in N doses with conventional as well as NP1 fertiliser affected sugarcane growth and yield attributes adversely. Sugarcane juice quality parameters did not influence significantly in both the crops. The highest agronomic efficiency (AE) during both the seasons was observed with application of 25% N through NP-1 and 100% PK through commercial fertilizers (2522.7 kg cane/kg N applied in autumn crop and 1877.3 kg cane /kg N applied in spring crop, respectively). Although, the highest cane (116.5 tonnes/ha and 94.5 tonnes/ha in autumn and spring season crop, respectively) and sugar yields (12.37 t/ha and 11.23 t/ha in autumn and spring season, respectively) were obtained with application of 100% N through NP-1+ 100% PK through commercial fertilizers. Application of 75% N through NP-1 and 100% PK through commercial fertilizers (T_6) was found at par with 100% N through NP-1+100% PK through commercial fertilizers (T_5). Thus 25% saving in N fertilizer could be achieved through use of NP-1 source of N.*

Keywords: *Agronomic efficiency, Autumn cane, Millable canes, Cane weight, NP-1, Sugarcane yield.*

Short title: *Agronomic efficiency of N and sugar cane yield as influenced by NP-1 source of fertiliser.*

1. INTRODUCTION

Sugarcane being a long duration and huge biomass-accumulating crop removes substantial amount of plant nutrients from the soil. A crop of 100 t/ha exhausts 208 kg N, 53 kg P and 280 kg K besides 3.4 kg Fe, 1.2 kg Mn, 0.6 kg Zn, 0.2 kg Cu and 30 kg S (Yadav and Dey, 1997). Indian soils are universally deficient in N except in some parts of north eastern region. Nearly 50 per cent soils are deficient in P and 20% in K. Sulphur has become critical in low organic matter and coarse textured soils under S exhausting oilseed based cropping systems. There exists a huge regional disparity in fertilizer use and the consumption of plant nutrients in some of the states is far below the national average of 87.6 kg NPK/ha apart from wide ratio in their use. At national level the ratio of N: P_2O_5 and K_2O have become 5.9:2.4:1 against recommended ratio of 4:2:1. The increasing cost of phosphatic fertilisers enhanced the imbalance use of fertilisers. All these point out to greater opportunity for using more balanced fertilizers for enhancing cane yield,

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improving productivity, augmenting quality and maintaining system sustainability (Shukla *et al.*, 2008; Yadav *et al.* 2009).

In subtropical India, the larger area of sugarcane is under spring planting. However, autumn planting (October) always performed better and has been found advantageous. Fertilization schedule and nutrient availability pattern in autumn and spring planted crops are completely different. It has been found that increased tillering and growth period of autumn crop in most of the experiments improved cane yield by 15-20% as compared to spring cane (Pandey and Shukla, 2001; Verma *et al.* 1996). Nitrogen application in sugarcane is done only up to tillering stage. In most of the experiments, nitrogen use efficiency (NUE) has been found in the range of 40-45%. Thus increase in NUE, may decrease the consumption of N fertilizers besides improving crop yield. There is a great scope of increasing NUE in sugarcane based system. Sugarcane production efficiency (agronomic efficiency) also increased with integration of various products. Thus keeping above pints in view, the present experiment was taken up with two objectives *viz.*,

(i) to assess the effect of NP-1 product on growth, nutrient availability, sugarcane and sugar yields

(ii) to assess N use efficiency (agronomic efficiency) of NP-1 product *vis-a-vis* commercial fertilizers in sugarcane planted during autumn and spring seasons.

2. MATERIALS AND METHODS

A field experiment was conducted at Indian Institute of Sugarcane Research, Lucknow located at 26° 56' N, 80° 52' E and 111m above sea level with semi arid sub–tropical climate having dry hot summer and cold winter. The soil of the experimental field was sandy loam (16% clay, 28% silt and 56% sand) of Indo – Gangetic alluvial origin, pH 7.5, very deep (> 2m) well drained, flat and classified as non calcareous *mixed hyperthermic udic ustochrept.* Before planting of the crop, soil samples from 0-15 cm depth were collected by core sampler of 8-cm diameter from five spots in the field. Soil samples were pooled together and the representative homogeneous sample was analyzed for determination of organic carbon (Walkley and Black method), available N ($KMnO_4$ method), 0.5 M sodium bicarbonate ($NaHCO_3$. pH 8.5) - extractable P and 1N NH_4OAC–extractable K, following Jackson (1973).

Two experiments were conducted at IISR farm during 2012-14 with 12 treatments combinations of recommended fertilizer and NP1 product. Thus there were 12 treatment combinations replicated thrice in randomized block design. Sugarcane early maturing variety CoPk 05191 was planted in the experiment. Various sources of nutrients viz, urea, SSP, MOP + Ca and S to were balanced with CaO and Elemental S. Initial soil fertility levels indicated that soil had 0.45% OC, 261.89 kg available N/ha; 37.27 kg available P_2O_5/ha and 226.2 kg K_2O/ha in 0-15 cm depth. Recommended package of practices was followed for sugarcane crop grown in autumn and spring seasons. Row spacing during autumn planting was kept at 90 cm *vis-a-vis* 75 cm in spring planting.

Cation Exchange Capacity of soil as well as roots during grand growth phase was determined. Five gram air dried soil was placed in 250 ml Erlenmeyer flask and approximately 50 ml Ammonium acetate was added. Swirled and let stood for 18 hrs. Transferred the soil and solution to funnel with no. 1 Whatman filter paper. Washed this soil 4-5 times with ammonium acetate reagent. Again washed this soil with methanol to remove excess ammonium acetate and tested it by Nessler's reagent. Distilled this soil with filter paper using MgO and titrated with HCl/H_2SO_4 (Chapman 1965). For determining CEC of roots, 2 g fresh roots were placed in 250 ml Erlenmeyer flask and approximately 50 ml ammonium acetate was added to it. Swirled and let stood for 30 minutes. Transferred the root and solution to funnel with no. 1 Whatman filter paper. Washed this soil 4-5 times with ammonium acetate reagent. Again washed this soil with methanol to remove excess ammonium acetate, Tested it by Nessler's reagent. Distilled this root with filter paper using MgO and titrated with HCl/H_2SO_4 (Chamuah 1985). Nitrogen use efficiency was calculated in terms of Agronomic efficiency (Novoa and Loomis, 1981).

Table 1
Effect of different treatments on nutrient availability in soil, organic carbon, and T_{max} in autumn and spring planted crops at IISR, Lucknow

Treatments	*% OC*	*Available N (kg/ha)*	*Available P_2O_5 (kg/ha)*	*Available K_2O (kg/ha)*	*CEC (Root) meq/100g*	*CEC (soil) meq /100 g*	*Autumn season crop T_{max}. (June)*	*Spring crop T_{max}. (July)*
T_1	0.39	234.5	26.5	246.5	32.5	10.4	237.2	191.7
T_2	0.38	216.5	24.5	238.5	28.5	9.80	227.5	186
T_3	0.37	205.2	23.8	224.5	25.6	9.20	216.4	180.3
T_4	0.38	195.2	21.5	215.6	21.2	8.80	198.5	164.4
T_5	0.42	265.2	32.5	285.2	41.5	12.45	251.4	204.2
T_6	0.41	248.2	28.5	268.5	36.5	10.56	244	198.3
T_7	0.45	236.2	24.5	246.2	29.6	9.85	222	184.4
T_8	0.43	212.5	22.5	204.2	18.5	8.95	206.5	170.2
T_9	0.42	246.5	20.5	264.5	16.2	9.98	232.6	190.1
T_{10}	0.38	215.2	24.5	250.2	16.4	9.45	184.5	154.5
T_{11}	0.40	238.2	19.8	204.5	15.5	9.80	218.5	176.4
T_{12}	0.44	194.5	16.8	198.6	14.5	8.10	166.5	144.5
CD (P = 0.05)	0.024	11.50	1.40	13.42	1.80	0.62	7.40	6.56

T_1-100% NPK through conventional fertilizers (N in 3 splits), T_2 75% N + 100% PK through conventional fertilizers (N in 3 splits), T_3 50% N + 100% PK through conventional fertilizers* (N in 3 splits), T_4 25% N + 100% PK through conventional fertilizers (N single application), T_5 100% N through NP-1 + 100% PK through conventional fertilizer combinations, T_6 75% N through NP-1 + 100% PK through conventional fertilizer combinations, T_7 50% N through NP-1 + 100% PK through conventional fertilizer combinations, T_8 25% N through NP-1 + 100% PK through conventional fertilizers, T_9 75% NP-1 + 100% K through conventional fertilizers, T_{10} 0% N and 100% PK through conventional fertilizers, T_{11} 0% P and 100% NK through conventional fertilizers (N in 3 splits), T_{12} Absolute control (no fertilizers).

$$AE = \frac{\text{kg biomass (yield)}}{\text{kg N applied}}$$

(AE : Agronomic efficiency)

The observations on soil organic carbon and available NPK contents were recorded before sugarcane planting and at harvest of crops. Five plants having intact leaves (both dry and green) were selected randomly from sample row (2nd row of plot) of each plot. Border rows were left and yield of each crop recorded after harvesting of net plots and presented on hectare basis. The data of each crop season were statistically analyzed separately. Critical difference (CD) was computed to determine statistically significant treatment differences.

$$C.D. = (\sqrt{2}\ VEr^{-1}) \times t_{5\%}$$

Where VE is the error variance, r is number of replications, $t_{5\%}$ the table value of t at 5% level of significance at error degree of freedom.

3. RESULTS AND DISCUSSION

3.1 Effect on Soil OC, Nutrient Availability and CEC

Effect of different treatments on soil organic carbon, nutrient availability (N, P_2O_5 and K_2O/ha) and cation exchange capacity (soil and roots) has been presented in Table 1. Different nutrient propositions and source of nitrogen (NP-1 and urea) significantly influenced the soil organic carbon content during tilling stage. Soil organic carbon content ranged from 0.37% to 0.44%. Application of nitrogen through NP-1 as compared to conventional source of N (urea) increased soil organic carbon content. However, higher SOC content (0.44%) also determined with absolute control (No NPK) because of lowest removal of nutrients and less number of tillers produced by the crop. Thus lowest removal encouraged greater accumulation with T_{12} (absolute control). Available

Table 2
Effect of various treatments on growth attributes, juice quality parameters, agronomic efficiency (AE), sugarcane and sugar yields of autumn planted crop

Treatments	*Millable canes (000/ha)*	*No. of internodes/ cane*	*Cane length (cm)*	*Cane diameter (cm)*	*Cane weight (g)*	*°Brix*	*Pol (%) juice*	*Purity (%)*	*Cane yield (t/ha)*	*AE (kg cane/ kg N applied)*	*Sugar yield (t/ha)*
T_1	132.26	24.33	240.00	2.43	980	18.37	15.47	84.06	108.2	721.3	11.30
T_2	114.82	22.67	223.33	2.43	920	18.34	15.10	82.16	102.4	910.2	10.32
T_3	106.68	21.67	214.67	2.40	870	18.20	15.38	84.50	94.6	1261.3	9.84
T_4	96.67	20.00	206.33	2.33	660	18.92	16.14	85.31	84.5	2253.3	9.27
T_5	142.07	25.33	246.33	2.63	1050	18.47	15.67	84.80	116.5	776.7	12.37
T_6	126.52	23.33	233.67	2.53	990	18.53	15.75	84.92	110.7	984.0	11.83
T_7	116.87	22.67	227.00	2.40	945	18.60	15.43	82.91	102.3	1364.0	10.58
T_8	118.63	21.33	212.7	2.30	720	18.60	15.83	85.13	94.6	2522.7	10.17
T_9	118.49	24.00	213.4	2.43	956	18.77	16.01	85.28	103.7	921.8	11.28
T_{10}	84.92	22.67	186.4	2.33	590	18.11	15.22	84.03	74.5	-	7.65
T_{11}	98.96	23.88	201.2	2.40	645	18.78	15.93	84.63	89.6	597.3	9.67
T_{12}	76.5	20.67	167.3	2.20	546	18.67	15.70	84.05	62.5	-	6.62
CD (P = 0.05)	8.46	2.78	9.40	0.22	36.50	nS	NS	NS	6.40	-	0.75

AE: Agronomic Efficiency

T_1-100% NPK through conventional fertilizers* (N in 3 splits), T_2 75% N + 100% PK through conventional fertilizers (N in 3 splits), T_3 50% N + 100% PK through conventional fertilizers (N in 3 splits), T_4 25% N + 100% PK through conventional fertilizers (N single application), T_5 100% N through NP-1 + 100% PK through conventional fertilizer combinations, T_6 75% N through NP-1 + 100% PK through conventional fertilizer combinations, T_7 50% N through NP-1 + 100% PK through conventional fertilizer combinations, T_8 25% N through NP-1 + 100% PK through conventional fertilizers, T_9 75% NP-1 + 100% K through conventional fertilizers, T_{10} 0% N and 100% PK through conventional fertilizers, T_{11} 0% P and 100% NK through conventional fertilizers* (N in 3 splits), T_{12} Absolute control (no fertilizers).

N, P_2O_5 and K_2O/ha showed almost similar trend and were determined at the highest level with T_5 (100% N through NP-1+ 100% P and K through conventional fertilizers). The N, P_2O_5 and K_2O contents in soil with this treatment were determined as 265.2, 32.5 and 285.2 kg/ha, respectively. Cation exchange capacity of root was higher than soil. CEC (root) during tillering stage ranged from 14.5 meq/ 100 g roots to 41.5 meq/100 g roots. The lowest CEC (root) was determined with absolute control (14.5 meq / 100 g roots). This was mainly due to lower amount of functional roots in absolute control (T_{12}). Thus nutrient application also increased root volume, root mass as well as their functional capacity. NP-1 was found better as compared to conventional fertilizer in increasing CEC of root as well as soil. CEC of soil ranged between 8.10 meq/ 100 g soil to 12.45 meq / 100 g soil. CEC (root) and CEC (soil) behaved in similar fashion in different treatments. As CEC (soil) increased with increasing doses of N or with application of NP-1 (source of N), CEC (root) also increased. Degree of reduction in N application with conventional as well as NP_1 decreased nutrient availability during crop growth. However, application of NP-1 showed higher availability of nutrients as compared to conventional fertilizers.

3.2 Growth Attributes, Sugarcane, Sugar Yield and Agronomic Efficiency of N

It is clear from Table 2 that the highest number of millable cane (142.07 thousand/ha) in autumn planted cane was counted with T_5 (100% N through NP-1+100% PK through conventional fertilizers). Decreasing N through conventional and/or as well as NP-1 source decreased the millable canes production. However, in both the products 75% and 50% N were found at par. The lowest number of

Table 3
Effect of various treatments on growth attributes, juice quality parameters, agronomic efficiency (AE), sugarcane and sugar yields of spring planted crop

Treatments	*Millable canes (000/ha)*	*No. of internodes/ cane*	*Cane length (cm)*	*Cane diameter (cm)*	*Cane weight (g)*	*°Brix*	*Pol (%) juice*	*Purity (%)*	*Cane yield (t/ha)*	*AE (kg cane/ kg N applied)*	*Sugar yield (t/ha)*
T_1	130.45	23.00	233.0	1.89	870	18.66	16.01	85.81	78.5	523.3	8.57
T_2	114.55	22.6	212.70	1.84	845	19.91	17.19	86.29	72.5	597.8	8.52
T_3	105.14	21.6	195.50	1.80	780	19.44	16.67	85.74	66.5	886.7	7.55
T_4	96.77	19.6	184.30	1.98	684	19.64	16.89	85.96	59.4	1584	6.85
T_5	146.16	24.5	250.20	2.17	920	19.52	17.20	88.04	94.5	630	11.23
T_6	124.27	23.6	232.00	2.03	880	19.36	16.55	85.49	86.4	768.0	9.73
T_7	116.74	22.2	206.60	1.98	845	19.84	17.34	87.38	79.6	1061.0	9.49
T_8	104.07	20.4	196.60	1.77	732	19.73	16.96	85.94	70.4	1877.0	8.15
T_9	116.64	23.2	198.70	1.94	820	19.28	16.71	86.65	74.3	660.4	8.51
T_{10}	74.5	21.5	189.50	1.85	634	19.98	17.27	86.43	54.6	–	6.45
T_{11}	89.9	22.6	196.4	1.94	690	19.69	16.95	86.03	64.6	430.7	7.48
T_{12}	74.6	18.6	174.2	1.81	550	19.19	16.29	86.13	52.4	–	5.79
CD (P = 0.05)	8.25	1.23	15.88	0.19	45.60	NS	NS	NS	3.87	–	0.45

AE: Agronomic Efficiency

T_1-100% NPK through conventional fertilizers (N in 3 splits), T_2 75% N + 100% PK through conventional fertilizers (N in 3 splits), T_3 50% N + 100% PK through conventional fertilizers (N in 3 splits), T_4 25% N + 100% PK through conventional fertilizers (N single application), T_5 100% N through NP-1 + 100% PK through conventional fertilizer combinations, T_6 75% N through NP-1 + 100% PK through conventional fertilizer combinations, T_7 50% N through NP-1 + 100% PK through conventional fertilizer combinations, T_8 25% N through NP-1 + 100% PK through conventional fertilizers, T_9 75% NP-1 + 100% K through conventional fertilizers, T_{10} 0% N and 100% PK through conventional fertilizers, T_{11} 0% P and 100% NK through conventional fertilizers* (N in 3 splits), T_{12} Absolute control (no fertilizers)

millable canes (76.5 thousand/ha) was counted with absolute control (No NPK application-T_{12}). Although, the highest number of millable canes (142.07 thousand/ha) was counted with T_5 but this was found at par with 100% N through conventional system (T_1). Other growth attributes such as number of internodes/ cane, cane length, diameter and weight also behaved in similar fashion. The number of internodes per cane ranged between 20.67 to 25.33. Individual cane length in different treatments ranged between 167.3 cm to 246.33 cm. Thus higher magnitude of increase was reported in cane length as compared to number of internodes. It was due to shorter internodes produced with absolute control (T_{12}). The highest cane diameter (2.63 cm) in autumn planted cane was measured with T_5 (100% N through NP1 and 100% PK through conventional fertilizers). The higher length and diameter culminated into the highest individual cane weight (1050 g) with T_5. The significant highest cane weight (1050 g) with T_5 was observed as compared to T_1 (980 g-100% NPK through conventional sources). Juice quality parameters (°brix, pol% juice and purity) could not produced tangible differences with application of different treatments. The highest sugarcane and sugar yields (116.5 t/ha and 12.37 t/ha) was obtained with T_5 (100% N through NP-1 + 100% *PK* through conventional sources).

The growth, yield attributes and sugar quality parameters in spring planted cane have been presented in Table 3. Spring planted cane also behaved in similar fashion as autumn planted cane. Although the slightly higher number of millable cane were counted with spring planted crop as compared to autumn crop. The reduced row spacing of spring crop (75 cm) as compared to autumn crop (90 cm) marginally increased production of millable canes per unit area. Even though, these millable canes could not attained the level of cane diameter and individual cane weight of autumn planted crop. The cane diameter in spring cane ranged between 1.81 cm to 2.17 cm *vis-à-vis* 2.20 cm to 2.63 cm in autumn crop. Individual cane weight in autumn crop also ranged in between 546 g to 1050 g *vis-à-vis* 550 to 920 g in spring crop. The highest sugarcane and sugar yields in spring crop were obtained with application of 100% N through NP1+ 100% PK through conventional sources (94.5 t/ha cane yield and 11.23 t/ha sugar yield). Although 75% N through NP-1+ 100% PK (T_6) was found at par with 100% N through NP1 + 100% PK (T_5).

Nitrogen use efficiency (agronomic efficiency) in sugarcane autumn and spring seasons has been presented in Table 2 and 3 indicated that NP-1 application at all levels increased cane production efficiency (AE). In autumn sugarcane, the highest N use efficiency (2522.7 kg cane/ha) was obtained where 25% N was applied through NP1 + 100% PK through conventional fertilizers (T_8). Although application of 100% N application through NP-1 + 100% PK through conventional fertilizers (T_6) showed that 721.3 kg cane could be produced per kg N applied. In all the cases, N use efficiency increased with the decreasing levels of N. With conventional fertilizers, it was observed in the range of 721.3 to 2253.3 kg cane per kg N applied *vis-à-vis* 776.7 to 2522.7 kg cane/kg N applied with use of NP-1 product.

Agronomic efficiency in spring planted cane was lower as compared to autumn crop. In spring crop, conventional N fertilizers showed the agronomic efficiency from 523.3 to 1584.0 kg cane/ kg N applied, whereas, NP-1 application improved it in the range of 630 to 1877.3 kg cane per kg N applied. In both the crops, the lowest agronomic efficiency of N was determined with T_{11} (0% P + 100% N and K fertilizers with conventional sources). In autumn cane, it was 597.3 kg cane/kg N applied whereas it reduced to 430.7 kg cane / kg N applied in spring crop. Thus it was clear that application of P fertilizers also increased agronomic efficiency of N. N and P for growth of roots and formation of tillers acted in synergistic way which could increase the agronomic efficiency and thus higher growth, cane and sugar yields could be obtained. The lower agronomic efficiency of N in spring crop as compared to autumn crop was due to lesser time available for tillering, growth and lower soil and root CEC. It affected the sugarcane yield adversely as compared to autumn crop. The higher CEC of soil and root (Table 1) with NP-1 was main reason for higher accumulation of biomass, cane yield, sugar yield and higher agronomic efficiency of N. Although decreasing rate of N with any type of fertilizer/source improved its efficiency despite lower yield obtained at graded levels of N. It was because of higher capacity of nitrogen to produce 1 kg of biomass at lower levels. Balanced fertilization with NPK improved N use efficiency as compared to NK or PK fertilization alone.

Sugarcane crop with luxuriant vegetative growth and heavy tonnage removes substantial amount of plant nutrients from the soil that need to be replenished to maintain the soil fertility for longer period. A high concentration of nitrogen in sugarcane plant is initially necessary for inducing profuse tillering in turn affects the yield potential (Shukla 2007). Judicious N application is of paramount importance to the production of high sugar.

Autumn planting in subtropical India has already been reported superior to spring or summer crop (Pandey and Shukla, 2001; Verma *et al.* 1996). Nitrogen requirement in sugarcane ranges from 112 – 400 kg/ha in sub-tropical and tropical conditions varying with soil type and duration of the crop (Pandey and Shukla, 2001). Thus nitrogen being the expensive input in sugarcane needs to be used judiciously to improve plant growth and yield. In present experiment, NP1 increased the N use efficiency and improved growth and yield attributes. NP-1 released nitrogen at slow rate, thus maintained optimized condition around the root zone for longer time. Role of nitrogen in increasing tillering and growth is well recognized (Pandey and Shukla, 2003).

4. CONCLUSIONS

Thus, after experimentation with autumn and spring planted cane, it could be concluded that application of NP1 increased the nutrient use efficiency, growth, agronomic efficiency of N, sugarcane and sugar yields. About 25% N dose may be saved by the application of NP-1 equivalent to inorganic fertilizers available in the market. The sugarcane juice quality parameters could not be influenced by the application of NP-1 source of nutrients. Agronomic efficiency of N could be increased with reducing N doses in both the seasons.

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