Original Research Article

EFFECT OF LIQUID NANO UREA FERTILIZER ON PERIODICAL GROWTH AND YIELD OF SUGARCANE

ABSTRACT

A field experiment on "~~Effect~~ effect of liquid nano urea fertilizer on periodical growth and yield of sugarcane" was ~~conducted~~ carried outduring *rabi* of 2021-22,~~(~~plant crop,~~)~~ and 2022-23,~~(~~ratoon crop~~)~~ ,at Navsari,~~(~~Gujarat~~)~~. The experiment was laid out in randomized block design including treatment comprising of nitrogen levels for soil application with foliar spray of nano urea and urea in both plant-ratoon system of sugarcane. The results recorded in respect to the periodical plant height and dry matter yield (DMY) from 90 to 180 days after planting (DAP) of plant crop and days after ratooning (DAR) of ratoon crop were significantly higher with the application of 100 % RDN (T_2) which was at par with treatments T_3 and T_4. However, at 210 DAP of plant crop and DAR of ratoon crop as well as at harvest plant height and DMY were recorded significantly higher with the application of 75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP which was at par with T_2 and T_4. In case of No. of tillers/hill at 180 DAP of plant and DAR of ratoon crop was significantly higher when with 75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP which was at par with T_2 and T_4. In plant crop and ratoon crop of 23sugarcane, millable cane yield (130.45 and 108.88 t/ha, respectively) and green top yield (~~23~~.93 and 21.71 t/ha, respectively) were found to be significant highest with the application of 75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP (T_3) which was at par with T_2 and T_4.Based on the results, it concluded that for achieving higher growth and yield in sugarcane

plant-ratoon cultivation should be fertilized with 100 % of recommended P_2O_5 and K_2O + 75 % RDN + two sprays of either liquid nano urea @ 4 ml/L or 2 % urea at 90 and 180 DAP of plant crop and DAR of ratoon crop. This application effectively replaces the 25% of recommended dose of nitrogen while matching the performance of the 100% RDN treatment.avoid unnecessary parenthesis as in lines 14 and 15

Keywords: Growth, IFFCO nano urea, Plant-ratoon sugarcane, Sugarcane, Yield

1 Introduction:

Excessive use of chemical fertilizers in modern agriculture has raised significant concerns due to its detrimental impact on soil health and the environment. Over-application leads to soil degradation, nutrient imbalances and disruption of microbial ecosystems, compromising long-term soil fertility (Ju *et al*., 2006; Lal, 2015). Runoff into water bodies causes algal blooms and oxygen depletion, harming aquatic ecosystems (Rabalais *et al.*, 2010; Carpenter and Bennett, 2011). Nitrogenous compounds from fertilizers contribute to air pollution and greenhouse gas emissions (Davidson *et al.*, 2000). Sustainable and precision nutrient management practices are essential to address these challenges. Nanotechnology offers a promising solution by improving nutrient delivery efficiency, minimizing wastage and reducing environmental impact. Nano-fertilizers enhance nutrient uptake, reduce soil degradation and balance microbial ecosystems (Thul *et al*., 2013). They also decrease nutrient runoff and atmospheric nitrogen release. Nano nitrogen for example, reduces urea losses and increases nutrient uptake efficiency, leading to higher yields with lower nitrogen deficiency (Yogendra *et al*., 2020). IFFCO's patented nano-urea features particles 20-80 nm in size, enhancing surface area and particle number, with a shelf life of about 2 years (Kumar *et al.*, 2021). However, thorough research on nanomaterials' environmental and health implications is crucial for safe use.

IFFCO's liquid nano urea represents a transformative shift in fertilizer technology, leveraging nanoscale properties for enhanced nutrient absorption and efficiency. This formulation offers sustainable agriculture benefits by reducing environmental impact and addressing conventional urea challenges (Kumar and Gopal, 2023). Nano urea's precision application, with over 80% efficiency, is an eco-friendly nitrogen source for crops. Studies show nano urea's nanoscale formulation improves nutrient absorption, plant health and productivity, with controlled release minimizing nutrient losses (El-Ramady*et al.*, 2018). This technology reduces nitrogen runoff and proves economically viable for farmers due to lower application rates and enhanced efficacy. Sugarcane,~~(~~*Saccharum officinarum*~~)~~L., a crucial global crop, is cultivated primarily for its high sugar content. India, the largest sugar producer, cultivates sugarcane on 5.15 million hectares, producing 431.81 million tonnes (Anon., 2022a). In Gujarat, sugarcane covers 0.22 million hectares, with significant production in districts like Surat and Navsari (Anon., 2022b). Effective fertilizer management especially nitrogen, is vital for sugarcane growth and yield. Nitrogen supports key physiological processes and increases cane weight and sugar content. Foliar application of nano urea enhances nutrient uptake, photosynthesis and yields, offering an efficient, sustainable solution (Upadhyay *et al.*, 2023). Thus, study aims to investigate the effect of liquid nano urea fertilizer on growth and yield of sugarcane.

2 Materials and Methods

Field experiment on "~~Effect~~ effect of liquid nano urea fertilizer on periodical growth and yield of sugarcane" was ~~conducted~~ carried outfor consecutive years during *rabi* of 2021-22,~~(~~plant crop,~~)~~ and 2022-23,~~(~~ratoon crop~~)~~ at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat). The soil of the experimental field was clay in texture, low in organic carbon (0.37 %) and available nitrogen (228.5 kg/ha), medium in available phosphorus (37.62 kg/ha), high in available potassium (350.5 kg/ha). The soil was found slightly alkaline (pH 7.78) with normal electrical conductivity (0.46 dS/m). The climate of this region is typically tropical monsoon type characterized by three well-defined seasons *viz.*, warm and humid monsoon with heavy rainfall, moderately cold winter and fairly hot and humid summer. The climate of Navsari remains mild throughout the year owing to its location near the sea. The experiment was laid out in randomized block design including treatment comprising from nitrogen levels for soil application with foliar spray of nano urea or urea in sugarcane plant-ratoon system. Treatments including T_1: Absolute control, T_2: 100 % RDN, T_3: 75% RDN + 2 spray of liquid nano urea (at 90 and 180 DAP), T_4: 75% RDN + 2 spray of 2 % urea (at 90 and 180 DAP), T_5: 50% RDN + 4 spray of liquid nano urea (at 90, 120, 150 and 180 DAP), T_6: 50% RDN + 4 spray of 2 % urea (at 90, 120, 150 and 180 DAP), T_7: 25 % RDN + 6 spray of liquid nano urea (at 60, 90, 120, 150, 165 and 180 DAP) and T_8: 25 % RDN + 6 spray of 2 % urea (at 60, 90, 120,150, 165 and 180 DAP). Each spray of IFFCO nano urea @ 4 ml/L of water. Combinations of these all treatments were applied in plant crop as well as at same interval in ratoon crop to study and their effect on growth behavior and yield were assessed and analyzed during both plant crop and ratoon crop.The recommended doses of N-P_2O_5-K_2O at 250-125-125 kg/ha for plant crop and 300-62.5-125 kg/ha for ratoon crop were computed based on the treatment specifications for each plot area. A standard dose of 125/(for plant crop) or 62.5/ (for ratoon crop)kg P_2O_5/ha provided through single superphosphate and 125 kg K_2O/ha supplied *via* muriate of potash, were manually applied as basal dressing in furrows. Nitrogen was administered in the form of urea, divided into four splits in plant crop: 15% N at planting, 30% N at 60 days after planting, 20% N at 90 days after planting, and 35% N before the final earthingup, (150 days after planting). For the ratoon crop three splits of nitrogen application (25% as basal, 50% at 90 DAR and 25 % at 150 days after ratooning (DAR) of ratoon, according to the treatment allocations for each plot area. During the crop period, agronomic practices are applied in a timely manner and in accordance with requirements. A random sample technique was applied throughout the experiment to record observations. Five plants per plot were randomly selected for height measurement in both the plant and ratoon crop seasons. Height, measured in centimeters from ground level to the topmost point, was recorded at 60, 90, 120, 150, 180, and 210 days after planting (DAP) and at harvest for the plant crop as well as for the ratoon crop after the first ratooning. The average height per plant was then calculated. The number of tillers was counted for five plants from the net plot at 90 and 180 DAP in plant crop and during ratoon crop it was counted at 90 and 180 DAR. The average was calculated to report as the number of tillers per hill from the net plot. The whole plant from ring area samples were collected by taking three plant crops from each treatment periodically at 60, 90, 120,150, 180 and 210 DAP and at harvest after planting to know the periodical dry matter yield of plant crop. In ratoon crop cultivation, dry matter yield was measured at the same intervals days after ratooning (DAR). The whole plant was cut in to small pieces and representative samples were drawn and oven dried at 65±5 ^{o}C till constant weight to record oven dry weight and converted in to kg/ha on the area basis. The fresh weight of green top for sugarcane was recorded from both plant and ratoon crops and converted to tonnes per hectare (t/ha). Each net plot was harvested separately, with the canes de-trashed and millable canes prepared by cutting the top portion. The weight of these millable canes was recorded in kilograms at harvest for both plant and ratoon crops, then converted to t/ha using a conversion factor.

3 RESULTS AND DISCUSSION

3.1 Effect on Growth Parameters

According to data presented in Table 1,significantly higher plant height was recorded at 90, 120, 150 and 180 DAP of plant crop and DAR of ratoon crop with the application of 100% RDN (T_2) which was at par with treatments T_3 and T_4, additionally T_5 at 120, 150 and 180 DAP of plant crop and DAR of ratoon crop and T_6 at 120 and 150 DAP of plant crop and DAR of ratoon crop at par with treatment T_2. However, at 60 days plant height in each plant crop and ratoon crop season was found to be non-significant. Furthermore, sugarcane plant height at 210 DAP and at harvest of plant crop as well as 210 DAR and at harvest of ratoon crop was recorded significantly higher with the application of 75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP (T_3) which was at par with treatments T_2 and T_4.

In case of No. of tillers/hill at 90 DAP of plant crop and DAR of ratoon crop (Table 2) was found non-significant however, at 180 DAP of plant crop and DAR of ratoon crop was observed significantly higher with the treatment T_3 (7.40 and 9.07, respectively) which was at par with T_2 and T_4.

The results indicate that reducing the recommended nitrogen dose by 25% and applying nano urea and 2% urea at 90 and 180 DAP (T_3) can enhance sugarcane growth. This is because foliar application of nano urea at critical stages fulfills the fertilizer requirement. This finding aligns with studies by Bhargavi and Sundari (2023), Chinnappa *et al.* (2023), Singh *et al.* (2023), Srivastava *et al.* (2023), Upadhyay *et al*. (2023) and Gajbhiye *et al.* (2024). Nano fertilizers improve nutrient availability, solubility and dispersion, boosting metabolic processes and stimulating meristematic activities, leading to increased apical growth and expanded photosynthetic areas. Foliar spraying of nano nitrogen enhances growth attributes by facilitating nutrient availability through easy and direct penetration of nano N through leaf stomata (Midde *et al*., 2022; Navya *et al*., 2022). According to Sharma *et al*. (2022) and Upadhyay *et al*. (2023), nano fertilizers release nutrients over an extended period, ensuring sustained nutrient supply, positively impacting plant growth. Foliar application of nano nitrogen increases nitrogen uptake through leaves and roots, promoting the mobilization of synthesized carbohydrates into amino acids and proteins, stimulating rapid cell division and elongation (Anushka *et al*., 2023; Dhayalan *et al*., 2023). The number of tillers in sugarcane can be increased by foliar spraying of nano urea due to improved specific surface area and nutrient uptake (Midde *et al*., 2022; Sing *et al*., 2023). Nano fertilizers enhance chloroplast activity, rubisco, antioxidant enzyme system and nitrate reductase activity, promoting vigorous vegetative growth and tiller proliferation (Rawate*et al*., 2022; Bhargavi and Sundari, 2023; Choudhary *et al*., 2022). Additionally, nano urea formulations contain additives that improve nutrient solubility and dispersion, ensuring a sustained nitrogen supply and supporting continuous tiller development throughout the sugarcane growth cycle.

3.2 Effect on Yield attributes and Yield

Data presented in Table 3, dry matter yield at 60 DAP of plant crop observed as non-significant while in ratoon crop season at 60 DAR dry matter yield found to be significantly higher with treatment T_2 which was at par with T_3, T_4, T_5 and T_6. However, dry matter yield at 90, 120, 150 and 180 DAP of plant crop and DAR of ratoon crop was found to be significant with treatment T_2 it was remained at par with T_3 and T_4. Whereas dry matter yield at 210 DAP and harvest of plant crop as well as 210 DAR and harvest of ratoon cane that was recorded significant higher with the application of 75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP (T_3) which was at par with treatments T_2 and T_4.

A summary of the data presented in Table 2 showed that different treatments had a significant effect on millable cane yield and green top yield in plant crop and ratoon crop. Data clearly showed that significantly higher millable cane yield,(130.45 and 108.88 t/ha during the years 2021-22 and 2022-23, respectively,) of sugarcane was recorded in treatment T_3 (75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP. However treatment T_3 was remained statistically at par with treatments T_2 and T_4 in terms of millable cane yield. Same trends were observed in plant-ratoon cycle (total of both crop season yield)**avoid unnecessary parentheses**. Whereas significantly lower millable can yield (77.99 and 55.33 t/ha during the years 2021-22 and 2022-23, respectively) was found with treatment T_1 (absolute control). However, as compare to absolute control,millable cane yield significantly increased 67.25%, 62.62% and 52.53% during plant crop season, 96.78%, 93.19% and 78.89% during ratoon crop season with the treatments T_3, T_2 and T_4, respectively. Furthermore, treatments T_5, T_6, T_7 and T_8 increased the millable cane yield as compared to absolute control but it was not statistically significant. The response of different treatments in millablecane yield (t/ha) of sugarcane was in order $T_3 > T_2 > T_4 > T_5 > T_6 > T_7 > T_8 > T_1$. **avoid unnecessary parentheses**

The data presented in Table 2 clearly demonstrates that various treatments had a significant impact on green top yield in both plant crop and ratoon crop. The findings for green top yield closely mirrored those of millable cane yield. Significantly maximum green top yield (23.93 and 21.71 t/ha during plant crop and ratoon crop, respectively)**avoid unnecessary parentheses** was obtained under treatment T_3 (75% RDN + 2 spray of liquid nano urea at 90 and 180 DAP) avoid **unnecessary** parenthesesand it was statistically at par with treatments T_2 and T_4 during both year 2021-22 (plant crop) and 2022-23 (ratoon crop). While the lowest green top yield (13.72 and 11.79 t/ha during plant and ratoon crop, respectively) in treatment T_1 (absolute

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control). However, treatments T_5, T_6, T_7 and T_8 did not significant increased the green top yield as compared to absolute control. **avoid unnecessary parentheses**

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The results indicate that combining conventional and nano fertilizers significantly enhances nutrient absorption and utilization in sugarcane. This finding is consistent with several studies, including Navya *et al*. (2022), Rawate*et al*. (2022), Sharma *et al*. (2022), Chinnappa *et al*. (2023) and Dhayalan *et al*. (2023). Bhargavi and Sundari (2023) emphasized that higher crop yields depend on total dry matter production and efficient translocation of photosynthates. The combined application boosts chlorophyll production and leaf greening, enhancing photosynthesis and overall plant growth.Singh *et al*. (2023) noted that nano fertilizers increase plant height, tillers per row meter and leaf area index, contributing to dry matter accumulation. The enhanced leaf area index improves nutrient utilization and solar radiation absorption, crucial for dry matter production. The observed yield increase in both plant and ratoon crops is attributed to liquid nano urea optimizing nutrient availability throughout sugarcane's growth stages, facilitating better nutrient absorption and nitrogen utilization.Foliar application of nano urea enhances photosynthesis and carbohydrate metabolism, leading to increased photosynthate translocation and total dry matter production. This includes higher chlorophyll production and prolonged leaf greening, resulting in increased dry matter yield. Nano urea's effects on chloroplast activity, rubisco and antioxidant enzyme systems also promote growth and development, notably increasing tiller numbers, which is crucial for yield.Nano urea's controlled-release properties ensure sustained nitrogen supply, supporting continuous tiller development and overall growth. The enhanced nutrient uptake, facilitated by nano urea's penetration through leaf stomata, promotes carbohydrate mobilization into amino acids and proteins, stimulating cell division and elongation. This results in increased plant height, tillers, cane weight, millable canes and cane girth.Improved nutrient use efficiency, as measured by agronomic nutrient efficiency, partial factor productivity and nitrogen apparent recovery efficiency, highlights the superior effectiveness of combined nano and conventional urea applications. This approach consistently outperformed the sole application of 100% recommended nitrogen (RDN), as noted by Alimohammadi *et al*. (2020) and Kumar *et al*. (2023b).The combined application of conventional and nano urea fertilizers, particularly treatment T_3, significantly increases sugarcane yield by optimizing nutrient availability, enhancing photosynthesis and promoting growth. These outcomes align with studies in maize, rice, mustard and wheat, such as those by Salama and Badry (2020), Ninama *et al*. (2023), Sahu *et al*. (2022), Bhargavi and Sundari (2023), Dhyalan*et al*. (2023), Gajbhiye *et al*. (2024), Navya *et al*. (2022), Pandav *et al*. (2022) and Rawate*et al*. (2022).

4 CONCLUSION

Based on the results of two years of experimentation, it concluded that for achieving higher growth and yield in sugarcane plant-ratoon cultivation should be fertilized with 100 % of recommended P_2O_5 and K_2O + 75 % RDN combined with two sprays of either liquid nano urea @4 ml/L or 2 % urea at 90 and 180 days after planting (DAP) of plant crop as well as 90 and 180 days after ratooning (DAR) of ratoon crop. This application effectively replaces the 25% of recommended dose of nitrogen while matching the performance of the 100% RDN treatment.

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Table 1: Periodical plant height as influenced by different treatments in plant (2021-22) and ratoon sugarcane (2022-23)

Treatments	Plant height (cm)													
	60		90		120		150		180		210		At harvest	
	DAP	DAR	DAP	DAR	DAP	DAR	DAP	DAR	DAP	DAR	DAP	DAR		
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T_1	69.40	63.22	76.01	66.13	97.76	95.96	130.07	121.59	149.67	146.63	203.60	185.67	295.50	284.95
T_2	76.35	72.04	99.97	93.71	132.48	128.25	170.67	161.02	207.29	191.57	263.25	241.07	372.61	354.76
T_3	75.08	70.11	95.51	88.96	129.28	125.46	160.96	154.38	198.67	188.10	265.65	245.10	380.77	360.56
T_4	73.19	68.86	93.68	88.22	125.75	124.96	154.52	152.71	196.88	184.00	258.84	239.87	364.80	350.14
T_5	73.08	68.01	86.14	78.25	119.63	112.79	151.67	145.23	178.35	170.53	230.86	211.67	328.79	318.67
T_6	71.60	67.74	86.87	78.01	117.36	112.68	150.03	143.35	174.29	167.60	229.20	210.27	319.53	317.33
T_7	71.59	66.19	84.47	75.08	112.33	111.50	143.04	136.71	171.19	165.30	224.54	206.57	321.38	311.91
T_8	71.42	65.33	83.12	72.36	111.96	111.16	142.55	136.23	168.56	163.37	220.36	202.40	312.10	307.13
S.Em.±	3.27	3.16	3.86	3.97	6.40	5.28	7.14	6.10	9.63	7.29	11.28	10.56	16.10	13.30
C.D. (P=0.05)	NS	NS	11.69	12.03	19.43	16.02	21.66	18.51	29.21	22.11	34.22	32.02	48.83	40.34
C.V.%	7.80	8.09	7.57	8.58	9.38	7.93	8.22	7.35	9.23	7.33	8.24	8.40	8.28	7.07

Table 2: Periodical number of tillers/hill and yield at harvest as influenced by different treatments in plant (2021-22) and ratoon (2022-23) sugarcane

Treatments	Number of tillers/hill				Millable cane yield (t/ha)			Green top yield (t/ha)		
	Plant crop		Ratoon crop		Plant crop	Ratoon crop	Plant-ratoon cycle	Plant crop	Ratoon crop	Plant-ratoon cycle
	90 DAP	180 DAP	90 DAR	180 DAR						
T_1	2.80	4.87	4.27	5.00	77.99	55.33	133.32	13.72	11.79	25.51
T_2	3.27	6.93	5.67	7.73	126.83	106.89	233.73	23.61	21.46	45.07
T_3	3.20	7.00	5.53	7.87	130.45	108.88	239.33	23.93	21.71	45.64
T_4	3.13	6.80	5.47	7.40	118.96	98.98	217.94	21.17	19.99	41.17
T_5	3.07	6.00	5.33	6.40	104.86	86.58	191.44	20.28	18.87	39.15
T_6	3.00	5.93	5.27	6.27	100.97	83.29	184.25	19.86	18.60	38.46
T_7	2.97	5.93	5.13	6.13	97.59	79.28	176.87	18.43	16.32	34.75
T_8	2.93	5.73	5.07	5.73	92.59	75.19	167.78	17.64	15.86	33.50
S.Em.±	0.19	0.33	0.29	0.46	6.07	6.47	11.34	1.16	0.88	2.05
C.D. (P=0.05)	NS	0.99	NS	1.39	18.40	19.61	34.41	3.53	2.68	6.21
C.V.%	10.70	9.16	9.54	12.07	9.89	12.90	10.18	10.17	8.48	9.36

Table 3: Periodical dry matter yield as influenced by different treatments in plant (2021-22) and ratoon sugarcane (2022-23)

Treatment	Dry matter yield (kg/ha)															
	60		90		120		150		180		210		At harvest cane		At harvest trash	
	DAP	DAR	DAP	DAR	DAP	DAR	DAP	DAR	DAP	DAR	DAP	DAR				
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T_1	292	266	597	616	1143	1145	2796	2635	6918	6584	10407	9726	18495	14983	5064	4474
T_2	312	332	818	872	1665	1700	4157	3973	10215	9927	15405	14865	29904	28121	7989	7454
T_3	306	325	771	817	1623	1681	4021	3910	9905	9813	15826	15200	30525	28661	8115	7614
T_4	304	320	767	813	1604	1643	3864	3873	9509	9644	15031	14771	28673	27609	7704	7046
T_5	302	302	706	757	1449	1469	3645	3420	9070	8697	13576	13017	26400	25039	7016	6618
T_6	302	298	708	756	1453	1455	3639	3302	9005	8568	13528	12935	24805	23660	6585	6200
T_7	295	284	678	745	1419	1429	3622	3218	8772	8469	13475	12699	23069	21364	6104	5588
T_8	293	279	667	738	1400	1408	3614	3229	8730	8385	13274	12485	21987	20315	5841	5428
S.Em.±	11.8	14.2	34.3	33.6	68.3	73.9	156	169	357	390	736	711	1220	1123	340	289
C.D. (P=0.05)	NS	43	104	102	207	224	473	514	1083	1182	2233	2157	3700	3405	1030	876
C.V.%	6.8	8.2	8.3	7.6	8.0	8.6	7.4	8.5	6.9	7.7	9.2	9.3	8.3	8.2	8.7	7.9