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Growth, yield and yield attributes of sweet corn as affected by plant density and nano-urea based nitrogen management

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Abstract
A field experiment was conducted during the summer seasons of 2024 and 2025 at the Agronomy Research Farm, Narain (PG) College, Shikohabad (Firozabad), Uttar Pradesh, to study the effect of plant density and nano-urea–based nitrogen management on growth, yield attributes and productivity of sweet corn (*Zea mays* L. *saccharata*). The experiment was laid out in a split-plot design with three plant spacings (60 × 20 cm, 50 × 20 cm and 45 × 20 cm) as main-plot treatments and six nitrogen management practices as sub-plot treatments, including prilled urea alone and its combinations with foliar application of nano-urea and prilled urea spray. Results revealed that closer spacing (45 × 20 cm) produced significantly higher plant height, leaf area index, green cob yield and green fodder yield, whereas wider spacing (60 × 20 cm) recorded higher dry matter accumulation per plant and superior yield attributes such as cob length, cob weight, number of grains per cob and 100-grain weight. Among nitrogen management practices, application of 75% nitrogen through prilled urea supplemented with two foliar sprays of nano-urea (4 ml L^{-1}) at 25 and 50 DAS resulted in significantly higher growth parameters, yield attributes, green cob yield and green fodder yield compared to other treatments. The unfertilized control recorded the lowest values for all parameters. The study indicates that integration of reduced prilled urea with nano-urea sprays can enhance productivity and nitrogen use efficiency of sweet corn under western Uttar Pradesh conditions.

Keywords: Nano-urea, plant density, growth, yield attributes, sweet corn productivity

Introduction
Sweet corn (*Zea mays* L. *saccharata*) is a specialized maize type characterized by high sugar content (13–20%) in immature kernels, which imparts superior taste and wide culinary use as a vegetable, roasted ears, soups, sweeteners and processed products. Its increasing demand among urban and health-conscious consumers offers substantial potential in domestic and international markets. Nutritionally, sweet corn provides approximately 90 kcal energy, 19 g carbohydrates, 3.2 g sugars, 2.7 g dietary fiber, 3.2 g protein, and appreciable amounts of vitamins and minerals per 100 g of fresh kernels (USDA Nutrient Database). It is also a good source of dietary fiber, β-carotene, niacin, calcium and potassium. Maize is cultivated across diverse environments unmatched by any other cereal crop and continues to expand into new agro-ecological regions. In India, maize is gaining popularity due to its wide adaptability, efficient utilization of radiant energy and high carbohydrate production potential compared to other cereals.
In modern agronomic practices, optimum plant population and efficient fertilizer application are key factors for enhancing crop productivity through improved utilization of soil moisture, nutrients and canopy resources. Plant population directly influences individual plant performance and overall yield potential (El-Ghobashi and Ismail, 2022) [5]. Proper maintenance of plant density is therefore a critical cultural practice governing cob yield and other agronomic traits in maize (Singh *et al*., 2012) [13]. Optimum plant spacing ensures favourable growth conditions by minimizing inter-plant competition, promoting timely reproductive development and effective sink formation. Establishment of an appropriate plant population enables efficient use of land and available resources, thereby improving growth and yield of individual plants.

Nutrient management plays a crucial role in determining the growth and productivity of sweet corn, with nitrogen (N) being the most important macronutrient governing maize yield. Nitrogen is a key constituent of amino acids, proteins, nucleic acids and enzymes, thereby regulating cell division, elongation and overall plant growth. Although urea is the most widely used nitrogen source, its low use efficiency due to leaching and volatilization results in reduced nitrogen availability to crops (Subbaiya *et al*., 2012) [14]. Foliar application of urea can partially improve nitrogen use efficiency; however, recent advances have led to the development of nano-urea, a biodegradable, slow-release formulation that facilitates efficient nutrient uptake through stomatal absorption. Nano-urea enhances growth and yield by minimizing nutrient losses and improving nitrogen availability at critical growth stages (Aher and Umesha, 2023) [1]. However, information on the combined use of reduced prilled urea and nano-urea sprays under varying plant densities in sweet corn is scarce under western Uttar Pradesh conditions. Hence, the present study was conducted.

Methods and Materials

The experiment was carried out at the Agronomy Research Farm, Narain (PG) College, Shikohabad, district Firozabad, Uttar Pradesh. The experimental site is geographically located at approximately 27.10° N latitude and 78.59° E longitude, at an elevation of about 163 m above mean sea level. The location lies in the western plain zone of Uttar Pradesh, representing typical agro-ecological conditions of the district. The soil of the experimental plot was sandy loam in texture, slightly alkaline in nature having pH (7.74), low organic carbon 0.41% and electrical conductivity 1.87 ds m^{-1} low in available Nitrogen (188.4 kg ha^{-1}), medium in available Phosphorous (20.5 kg ha^{-1}) and moderately rich in available potassium (261.3 kg ha^{-1}). The experiment was conducted in split-plot design, during summer season comprising 2 factors as main factor consist of three spacings (S_1- 60 cm × 20 cm, S_2- 50 cm × 20 cm and S_{3-} 45 cm × 20 cm) and sub-plots consist of 6 treatments (N_1: No Nitrogen, N_2: $N_{100\%}$, N_3: $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml $litre^{-1}$ at 25 and 50 DAS each coincide with split doses of prilled urea application, N_4: $N_{75\%}$ through prilled urea + 2% prilled urea spray at 25 and 50 DAS each coincide with split doses of prilled urea application, N_5: $N_{50\%}$ through prilled urea + 2 sprays Nano-N @ 4ml $litre^{-1}$ at 25 and 50 DAS each coincide with split doses of prilled urea application and N_6: $N_{50\%}$ through prilled urea + 2% prilled urea spray at 25 and 50 DAS each coincide with split doses of prilled urea application. A popular sweet corn hybrid in this region, Sugar-75, released by a private company M/s Syngenta India Limited was used for the study. The fertilizers such as Nano urea, single super phosphate and muriate of potash were supply of NPK and the entire quantity of phosphorus and potassium as basal and nitrogen was applied through prilled urea and Nano urea at 25 and 50 DAS and other agronomical operations were carried out as per recommendation. The observations were recorded on growth, yield attributes and yield at the time of harvest of crop. The department supplied all the facilities needed for crop production.

Results and Discussion

Growth characters

The growth parameters (Plant height, Dry matter accumulation and leaf area index) had significant variation with the influence of plant spacing in present investigation (Table 1). The highest height of plants was observed with treatment 45 cm x 20 cm, which was higher than other treatment. The wider spacing 60cm x 20 cm observed shorter plants which were closer with spacing 50cm x 20 cm. The leaf area index at harvest was significantly influenced by plant spacing and found significantly highest value of leaf area index with treatment 45 cm x 20 cm, which remained at par with treatment 50 cm x 20 cm. The dry matter accumulation (g/plant) at harvest (Table 1) was significantly higher with treatment 60 cm x 20 cm and lowest with closer spacing in experimentation. This may be due to the profound influence of plant spacing on performance of sweet corn crop could be an area available for each plant which indirectly dictated the availability of various growth inputs to individual plants in the population and also the extent of competition between and within the plants for various growth inputs. The significant increase in plant height with decreased intra row spacing seems to be the resultant of competition for light. Ahmad *et al*., (2014) [2] and Thakur *et al*., (2015) [15] also found maximum plant height with the closer spacing. The result is in close accordance with findings of Singh *et al*. (2012) [13].

Growth parameters *viz*., plant height, LAI and dry matter recorded at harvest (Table 1) were significantly influenced by foliar application of nano-urea. Significantly the highest values of these growth parameters were recorded with the application of $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml $litre^{-1}$ at 25 & 50 DAS, while, lowest value were observed under no fertilization application. The treatment 100% application of prilled urea also gave second best results followed by $N_{50\%}$ through prilled urea + 2 sprays Nano-N @ 4ml $litre^{-1}$ at 25 and 50 DAS in these experiments. The improvement in growth parameters with application of $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml $litre^{-1}$ at 25 & 50 DAS might have resulted in better and timely availability of nitrogen for their utilization by plant as judged from nitrogen content of cob and stover. Application of nano-urea to poaceae family plants at specific growth stages can lead to a dramatic increase in both growth and yield. This is due to the fact that nano-urea provides a more efficient form of nutrient delivery than conventional fertilizers, as it reduces leaching and emissions, as well as the long-term incorporation of soil microorganisms (Aher and Umesha 2023) [1]. The significant improvement in nutrient status of plant parts (cob and stover) might have resulted in greater synthesis of proteins, amino acids and growth promoting substances, which seems to have enhanced the meristematic activity and increased cell division and cell elongation. The enhanced growth with nano-urea was also reported by Ghobashy *et al*., and Singh *et al*., (2023) [12] in sweet corn.

Table 1: Effect of Plant Density and Nitrogen (Prilled Urea, Nano Urea & Prilled Urea Spray) on growth of Sweet Corn at harvest

Treatments	Plant height (cm)		Dry matter production (g/plant)		Leaf area index	
Spacing	**2024**	**2025**	**2024**	**2025**	**2024**	**2025**
60 cm × 20 cm (S_1)	168.48	171.52	85.87	87.19	4.57	4.67
50 cm × 20 cm (S_2)	170.89	171.99	79.26	80.47	5.36	5.47
45 cm × 20 cm (S_3)	173.17	174.43	77.75	78.97	5.60	5.72
SE(m)	0.744	0.689	1.88	1.91	0.085	0.087
CD at 5%	2.625	2.430	6.63	6.73	0.300	0.307
Nano Urea Foliar Application						
N_1 - N_0	153.73	152.20	56.03	56.86	4.65	4.74
N_2 - $N_{100\%}$	180.17	182.52	96.99	98.44	5.43	5.55
N_3 - $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 & 50 DAS	188.45	189.42	107.00	108.64	5.51	5.64
N_4 - $N_{75\%}$ through prilled urea + 2% prilled urea spray at 25 and 50 DAS	168.09	171.73	77.20	78.35	5.17	5.28
N_5 - $N_{50\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 and 50 DAS	172.49	174.30	88.12	89.62	5.34	5.45
N_6 -$N_{50\%}$ through prilled urea + 2% prilled urea spray at 25 and 50 DAS	162.15	165.71	60.44	61.34	4.96	5.07
SE(m)	1.47	1.24	2.61	2.65	0.191	0.195
CD at 5%	4.20	3.53	7.45	7.56	0.545	0.556

Yield and yield attributes

Yield attributes of sweet corn were significantly influenced by plant spacing. Yield attributes *viz.* cob length, cob weight, number of grains per cob, and 100 seed weight (g) were significantly superior at higher planting density 60 cm X 20 cm compared to that of lower plant 45 x 20 cm. The higher values of yield attributing characters of sweet corn were recorded under wider plant density of 60 cm x 20 cm, which may be due more space available for plant growth and also efficient utilization of natural resources. Similar results were reported by Massey and Gaur (2013) [8], Singh *et al.*, (2015) [11] and Dangariya *et al.*, (2017) [3]. Yield attributes of sweet corn increased significantly with the application prilled and nano-urea (foliar spray) in present investigation. The treatment $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 & 50 DAS recorded significantly maximum value of sweet corn yield attributes followed by $N_{100\%}$. While minimum value of yield attributes were observed with unfertilized control. The combined application prilled urea and foliar application of nano urea increased nutrients availability to plants, which resulted into higher values of yield attributes under treatment of $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 & 50 DAS. These results of increasing trend of attributes over the remaining levels with incremental addition of nitrogen were consistent with findings of Singh *et al.*, (2012) [13].

Significantly higher green cob yield of sweet corn (18.19 and 18.54 t ha^{-1}) and green fodder yield (33.76 and 34.32 t ha^{-1}) were obtained at narrow spacing (45 cm x 20 cm) while, lower green cob yield and green fodder yield under wider density during first and second year. However, harvest index was higher in wider spacing compared to other spacing. In present investigation higher values of yield attributing characters in wider spacing (60 x 20 cm) which may be due more space available for plant growth and also efficient utilization of natural resources. The green cob yield and green fodder yield per hectare of sweet corn were recorded under narrow plant density of 45 cm x 20 cm, due to a greater number of plants in narrow spacing resulting higher yield. Manishaben *et al.*, (2018) [7] reported that spacing 60×20 cm gave significantly higher green cob and fodder yield. Similar results were reported by Krishna *et al.*, (2022) [6].

The effect of different levels of nano-urea with prilled urea found significant variation (Table-3) on yield of sweet corn yield in both the years. The application of $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 & 50 DAS recorded significantly higher green cob yield (21.22 and 21.93 t ha^{-1}) and green fodder yields (41.06 and 41.35 t ha^{-1}) of sweet corn than remaining nitrogen levels during summer season of 2024 and 2025 respectively. The application $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 & 50 DAS increased nutrients availability to plants, which resulted into higher values of green cob yield and green fodder yield. Maximum harvest index was obtained under treatment $N_{75\%}$ through prilled urea + 2% prilled urea spray at 25 DAS and 50 DAS. The results corroborated with those reported by Singh *et al.* (2012) [13], Rajesh *et al.*, (2021) [9] and Samui *et al.*, (2022) [10].

Table 2: Effect of Plant Density and Nitrogen (Prilled Urea, Nano Urea & Prilled Urea Spray) on yield attributes of Sweet Corn at harvest

Treatments	Cob Length (cm)		Cob weight (g)		Number of grains per cob		100 grains weight (g)	
Spacing	**2024**	**2025**	**2024**	**2025**	**2024**	**2025**	**2024**	**2025**
60 cm × 20 cm (S_1)	17.24	17.75	260.29	262.49	387.46	401.33	17.28	17.57
50 cm × 20 cm (S_2)	16.84	17.20	252.82	254.48	372.18	384.73	16.95	17.50
45 cm × 20 cm (S_3)	16.70	16.92	244.91	246.32	356.04	372.46	16.89	17.23
SE(m)	0.070	0.150	2.77	2.84	2.82	3.42	0.090	0.067
CD at 5%	0.246	0.531	9.79	9.95	9.90	11.12	0.271	0.235
Nano Urea Foliar Application								
N_1 - N_0	14.08	14.42	204.23	206.46	304.16	316.95	16.37	16.71
N_2 - $N_{100\%}$	17.82	18.04	277.94	279.36	442.63	454.78	17.58	17.96
N_3 - $N_{75\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 & 50 DAS	18.44	18.76	279.48	280.98	458.66	473.10	17.89	18.30
N_4 - $N_{75\%}$ through prilled urea + 2% prilled urea spray at 25 and 50 DAS	17.09	17.86	264.28	265.87	339.99	355.29	16.78	17.48
N_5 - $N_{50\%}$ through prilled urea + 2 sprays Nano-N @ 4ml litre^{-1} at 25 and 50 DAS	17.66	17.87	255.86	258.53	368.90	386.22	17.04	17.41
N_6 -$N_{50\%}$ through prilled urea + 2% prilled urea spray at 25 and 50 DAS	16.46	16.77	234.22	235.38	317.02	330.72	16.60	16.76
SE(m)	0.231	0.210	2.81	3.50	4.845	3.765	0.187	0.237
CD at 5%	0.660	0.601	8.03	9.99	13.845	10.759	0.533	0.678

Table 3: Effect of Plant Density and Nitrogen Management Practices on yield of Sweet Corn

Treatments	Green cob yield with husk (t per ha)		Green fodder yield (t per ha)		Harvest Index (%)	
Spacing	**2024**	**2025**	**2024**	**2025**	**2024**	**2025**
60 cm × 20 cm (S_1)	16.05	16.35	28.44	28.71	36.07	36.24
50 cm × 20 cm (S_2)	17.04	17.65	31.57	32.59	35.33	35.36
45 cm × 20 cm (S_3)	18.19	18.54	33.76	34.32	35.26	35.29
SE(m)	0.156	0.116	0.131	0.139	0.166	0.168
CD at 5%	0.552	0.408	0.463	0.485	0.583	0.593
Nano Urea Foliar Application						
N_1	12.89	13.19	23.13	23.71	35.72	35.66
N_2	19.49	19.96	35.87	36.40	35.22	35.45
N_3	21.22	21.93	41.06	41.35	34.17	34.78
N_4	16.25	16.58	28.13	28.44	36.64	36.85
N_5	17.16	17.57	33.80	34.82	33.71	33.58
N_6	15.56	15.85	25.56	26.53	37.86	37.45
SE(m)	0.209	0.217	0.452	0.388	0.408	0.441
CD at 5%	0.597	0.619	1.293	1.109	1.165	1.259

Conclusion

The results clearly indicate that nitrogen management had a stronger influence on sweet corn growth and productivity than plant spacing. Application of 75% nitrogen through prilled urea supplemented with two foliar sprays of nano-urea (4 ml L^{-1} at 25 and 50 DAS) consistently recorded the highest plant height, dry matter accumulation, leaf area index, yield attributes, green cob yield and green fodder yield during both years. Although wider spacing improved individual yield attributes and closer spacing enhanced yield per unit area, the superiority of nano-urea based nitrogen management was evident across all spacings, enabling a 25% reduction in conventional nitrogen fertilizer without yield reduction.

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