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IMPACT OF FOLIAR-APPLIED NANO UREA AND NANO DAP ON CHLOROPHYLL CONTENT AND FODDER YIELD OF MAIZE

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ABSTRACT

A two-location field experiment was conducted at Main Forage Research Station, Anand and Main Maize Research Station, Godhra, Anand Agricultural University, Gujarat to evaluate the effect of Nano urea and Nano DAP on growth and yield of fodder maize during *rabi* 2025-26 under Randomized Complete Block Desing with three replications. According to present investigation, application of reducing dose of recommended fertiliser (75%) along with seed treatment of nano DAP @ 5 mL/kg seed followed by two foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS treatment recorded significantly higher cchlorophyll content (After first spray at 32 DAS, 62.0 and 48.0 SPAD value at Anand and Godhra, respectively), before second spray at 49 DAS (46.1 and 39.0 SPAD value) and after second spray at 57 DAS (50.7 and 40.5 SPAD value). Grain (3757 and 3122 kg/ha) and stover (22129 and 22413 kg/ha) yields were markedly improved in where application of 75% RDF + seed treatment with Nano DAP @ 5 mL/kg seed followed by foliar sprays of Nano urea and Nano DAP @ 4 mL/L at 25 and 50 DAS at Anand and Godhra location, respectively. Effect of integration approach, conventional application along with foliar application of Nano Urea and Nano DAP did not show significant response on seed index and harvest index, while higher protein content (10.00 and 10.03%) was reported higher in treatment application with 75% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS at both locations, respectively.
Keywords **:** Chlorophyll, Fodder maize, Nano DAP, Nano urea, SPAD value, Protein.

Introduction

Maize is one of the important cereal crops after wheat and paddy in India, it is cultivated throughout the year in dual purpose use, grain is used for human consumption as well as poultry feed purpose and after harvest stover is used for animal feed and fodder (Pujari *et al*., 2026). Maize is used for industrial raw material, food for human and feed/fodder for animals. Maize is rich sources of protein, carbohydrate and certain essential vitamins and minerals (Kour *et al*., 2025). For global agricultural development, livestock farming play's independent important role in rural economies. In India, livestock sector is deeply interwoven with crop production, forming a mutually beneficial relationship that enhances farm productivity, soil fertility and resource efficiency (Dileep *et al.*, 2026). Dairy nutrition based entirely on green forage is highly economical compared to concentrate diets.

The rapid expansion of the livestock sector has resulted in a critical feed deficit, as demand outstrips the availability of quality fodder. Data from the National Institute of Animal Nutrition and Physiology (NIANP) indicates a shortfall of 35% for green fodder, 11% for dry fodder, and 44% for concentrate feed (Anonymous, 2022). Boosting green fodder production can help meet the continuous feed demands of the livestock sector. Fodder maize is short duration ideal crop for feed and fodder as well as use for silage. It is highly succulent, rich in mineral and vitamins, high production potentially, high per day productivity and wider spread availability. Among the different fodder crops, fodder maize is widely preferred because of its high biomass production and the absence of anti-nutritional compounds.

Nitrogen management plays a crucial role in enhancing crop productivity. Optimized nitrogen application through soil and foliar improves chlorophyll content, photosynthetic efficiency, leaf area development and tillering, resulting in greater biomass accumulation and altimetry increased green forage yield (Horrocks and Vallentine, 2013, Iqbal *et al*., 2013 and Dileep *et al*., 2026). Under limited land availability and demanding impale green production cultivation makes efficient nutrient management critical for boosting crop yield and quality. Along with nitrogen, phosphorus is also an important plant nutrient. Phosphorus is an essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants (Chavan *et al.*,2024). High-quality fodder improves milk production by supplying vital crude protein and nutrients to the small intestine, enhancing the animal's nitrogen balance. On the other hand, nutrient-deficient feed damages livestock health and lowers dairy yields. In maize, foliar spraying of nano urea has been reported to enhance chlorophyll concentration, improve photosynthetic activity, and promote dry matter accumulation, thereby increasing green fodder yield (Kumar *et al*., 2022). Likewise, the application of nano phosphorus fertilizers has been found to stimulate root growth, improve nutrient uptake, and enhance yield-related traits. Furthermore, the combined use of nano urea and nano DAP has demonstrated a synergistic effect on crop growth and productivity by ensuring efficient nitrogen and phosphorus availability during the critical stages of plant development.

Materials and Methods

Experiment location and climate

A field experiment was carried out at Main Forage Research Station, Anand and Main Maize Research Station, Godhra, Anand Agricultural University, Gujarat to evaluate the effect of Nano urea and Nano DAP on growth, yield and nutrient content of Fodder maize during *rabi* season of 2025-26. The experiment site of Anand geographically located at 22°35′ North latitude and 72°56′ East longitude and Godhra geographically located at 22° 47'N latitude, 73° 39'E longitude. All metrological observation for Anand location recorded from Department of Agrometeorology, B.A. College of Agriculture, Anand and Godhra location all meteorological observation was recorded from Main Maize Research Station Godhra Meteorological observatory. At Anand temperatures ranged between 12.1°C to 35.4°C and average relative humidity during this period fluctuated between 55.9 % and 82.6 %. While at Godhra temperatures ranged between 10.4°C to 38.5°C and average relative humidity during this period fluctuated between 48.4 % and 77.9 %.

Initial soil physicochemical properties

Before sowing, experimental soil samples were collected from a depth of 0–15 cm at two locations, Anand and Godhra, using standard soil sampling methods. The experimental soil exhibited the following characteristics, which were analysed according to standard analytical procedures (Table 1).

Experiment material and treatment details

Toothful seed of fodder maize, Gujarat Fodder Maize 1 (GFM-1) was used for the present experiment with seed rate 80 kg/ha kept sowing distance 30 cm. The variety released from Main Forage Research Station, Anand Agricultural University, Anand in the year 2023. Experiment laid out in Randomized Complete Block Design (RCBD) with ten different integrated Nano urea, Nano DAP treatments along with seed treatment to fodder maize. Experiment was replicated three time. For experiment treatment material, IFFCO Nano urea and Nano DAP was used and for seed treatment purpose *Azospilillum* was used from Department of Agricultural Microbiology, B. A. College of Agriculture, Anand Agricultural University, Anand. Treatment received recommended dose of fertilizer at the rate of 80-40-0 kg/ha, fifty percent dose of nitrogen and full dose of phosphorus were applied through urea and single super phosphate at time of sowing, remaining half dose of nitrogen applied after 30 days of sowing. Seed treatment of *Azospilillum* 5 mL/kg seed done before sowing of seed and applied to respective treatments. As per set treatments, foliar spray of Nano urea and Nano DAP was applied at 25 and 50 Days after sowing. Details set of treatment is depicted in Table 2.

Observation recorded

For obtaining growth and yield attributes, from net plot area five random plants were selected and tagged properly for recording observations.

Table 1: Anand and Godhra location physicochemical properties of soil

Sr No.	Particular	Value		Reference
		Godhra	Anand	
1	Texture class	Loamy Sand	Loamy Sand	
2	Soil pH (1:2.5 Soil: Water)	7.35	8.00	Potentiometric Method (Jackson, 1973)
3	EC (dS/m) at 25 °C	0.18	0.18	Conductivity meter Method (Jackson, 1973)
4	Organic carbon (%)	0.43	0.32	Walkley and Black Method (Walkley and Black, 1934)
5	Available N (kg/ha)	205	200	Alkaline KMnO4 Method (Subbiah and Asija, 1956)
6	Available P_2O_5 (kg/ha)	58.0	48.0	Olsen's Method (Olsen *et al.*, 1954)
7	Available K_2O (kg/ha)	240	167	Flame Photometry method (Jackson, 1973)

Table 2: Nano urea and Nano DAP treatment details

Tr	Treatment details
T_1	100% recommended dose of fertilizer (RDF: 80-40-0 NPK kg/ha)
T_2	ST with *Azospirillum* @ 5 mL/kg seed + Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS
T_3	50% RDF & foliar spray of Nano urea 4 mL/litre at 25 & 50 DAS
T_4	75% RDF & foliar spray of Nano urea 4 mL/litre at 25 & 50 DAS
T_5	50% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano DAP 4 mL/ litre at 25 & 50 DAS
T_6	75% RDF + ST with Nano DAP @ 5 mL/ kg seed *fb* foliar spray with Nano DAP 4 mL/litre at 25 & 50 DAS
T_7	50% RDF+ ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 2 mL/litre at 25 & 50 DAS
T_8	75% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 2 mL/litre at 25 & 50 DAS
T_9	50% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS
T_{10}	75% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS

Mean experimental obtained data collected from ten different treatments and replicated thrice. Results were analyzed using Randomized Complete Block Design ANOVA method (Cohran and Cox, 1957).

Results and Discussion

Chlorophyll content

Chlorophyll content of fodder maize at different period was depicted in Table 3. Significantly affected different integrated Nano urea and Nano DAP treatment of fodder maize at Anand and Godhra locations were measured at 24 (Before first spray), 32 (After first spray), 49 (Before second spray) and 57 (After second spray) days of sowing. Before first spray at 24 DAS did not show significant effect on spade value of chlorophyll content of fodder maize. At both locations, after first spray (at 32 DAS), Before second spray (49 DAS) and after second spray (at 57 DAS) recorded significantly higher Chlorophyll content. After first spray (32 DAS), treatment T_{10} (75% RDF along with seed treatment with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS) recorded higher SPAD value chlorophyll content (62.0) at Anand while application of 50% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS (T_9) recorded higher SPAD value chlorophyll content (49.1) at Godhra location. At 49 DAS, before second spray (46.1 and 39.0, Anand and Godhra, respectively) and at 57 DAS, after spray SPAD value of chlorophyll (50.7 and 40.5, at Anand and Godhra, respectively) recorded higher in treatment T_{10} (75% RDF along with seed treatment with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS).

The probable reason could be that nano urea and nano DAP provide nitrogen and phosphorus in a highly available nano form. Nitrogen is a structural component of chlorophyll molecules (porphyrin ring with central Mg atom). Adequate nitrogen supply directly stimulates chlorophyll biosynthesis, leading to greener leaves and higher photosynthetic activity. While, phosphorus efficiently, which is essential for ATP and NADPH production during photosynthesis. Better energy transfer supports chlorophyll stability and leaf expansion, indirectly boosting chlorophyll concentration. Overall, the higher chlorophyll content was recorded with foliar application with nano urea and nano DAP. There was no adverse effect observed during the field experiment at both locations. However, nano urea and nano DAP helped in synthesis of chlorophyll content in leaves of fodder maize. N and P in plant essential for chlorophyll synthesis and improved fodder quality (Kumar *et al.*,2021, Mucchadiya *et al.*, 2024, Jadhav *et al.*,2023, Sahoo *et al.*, 2024 and Sushma *et al.*,2025) all of whom confirmed that nano formulations improve nutrient use efficiency, sustain chlorophyll biosynthesis, and enhance photosynthetic activity compared to conventional fertilizers. Chlorophyll fluorescence is an absorption of photons from chlorophyll molecules to an excited state which the fluorescence photon is emitted repeatedly during the return of molecules to the ground state. Fv / fm is the maximum quantum yield of dark-adopted Photo System II. Applying foliar NFs directly to the crop increases the photosystem-II activity in the thylakoid membrane and increases the effective quantum yield of photosystem-II (Sanjeev Kumar *et al.*, 2024).

Grain and stover yield

Nitrogen stands out as one of the crucial nutrients for fodder cereals, playing a vital role in photosynthesis and various biological processes such as xylem movement, vacuole storage, and absorption of water and minerals. Therefore, ensuring an efficient supply of nitrogenous fertilizer is paramount for achieving optimal crop growth and yield (Rashid *et al.*, 2025). The experimental data of both the locations exhibited that the grain and stover yield of fodder maize was significantly influenced by different treatments application of nano urea and nano DAP along with recommended dose of fertilizer.

The data presented in Table 4 indicated that the significantly higher grain yield (3757 and 3122 kg/ha, at Anand and Godhra location, respectively) were recorded under treatment received with reducing dose of recommended fertiliser (75%) along with seed treatment of nano DAP @ 5 mL/kg seed followed by two foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS (T_{10}). While higher stover yield (22129 and 22413 kg/ha) was reported higher in treatment T_{10} (75% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS) at both locations respectively. Minimum grain yield (2323 kg/ha and 2396 kg/ha) and stover yield (13210 kg/ha and 17290 kg/ha) was observed in treatment T_2 at Anand and Godhra locations respectively where ST with *Azospirillum* @ 5 mL/kg seed + Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS was used. The increase in yield can be attributed to improved nitrogen assimilation from nano urea, enhanced phosphorus uptake from nano DAP, better seedling establishment through seed priming, and efficient foliar nutrient delivery at critical growth stages, all of which sustained chlorophyll biosynthesis, photosynthetic activity, and source–sink balance. Similar results were also obtained by Mahachandramuki *et al.* (2023), Poudel *et al.* (2023), Maloth *et al.* (2024), Gopinath *et al.* (2025) and Sushma *et al.* (2025) who reported that nano fertilizers improve nutrient use efficiency, sustain chlorophyll content, and enhance both grain and biomass yield in different crops. Another reason might be due to attributed to the swift absorption and translocation of nano-fertilizers by the plant, enhancing the rate of photosynthesis, particularly at higher concentrations. These findings align with some previous studies (Rashid *et al.*, 2025, Kumar *et al.*, 2020 and Rajesh *et al.*, 2021). The nano-sized urea facilitates efficient uptake and utilization, as well as penetration into the plant from the applied leaf surface, leading to robust vegetative growth of additional fodder maize (Sankar *et al.*, 2020. Samui *et al.*, 2022 and Kashyap *et al.*, 2023). These findings might help in increasing nitrogen use efficiency and consequently reduce the leaching of urea residues in the environment (Rashid *et al.*, 2025).

The data presented in Table 4 indicated that there was no any significantly improvement in the seed index as well as harvest index of maize at both locations. Application of 75% RDF + ST with Nano DAP @ 5 mL/kg seed *fb* foliar spray with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS (T_{10}) shows significantly higher seed protein content (10.00 and 10.03 at Anand and Godhra location, respectively) of fodder maize (Table 4). Nitrogen correspondingly increased meristematic activity due to which absorption of mineral salts increases leading to rapid respiration process and conversion of most of the carbohydrates into fat. Apart from that nitrogen plays a major role in protein synthesis, the nitrogen free extract is a part of carbohydrate (Harikesh *et al.*, 2017).

Table 3: Effect of nano urea and nano DAP on chlorophyll content of fodder maize

Tr. No.	Chlorophyll content (SPAD Value)							
	Before first spray (24 DAS)		After first spray (32 DAS)		Before second spray (49 DAS)		After second spray (57 DAS)	
	Anand	Godhra	Anand	Godhra	Anand	Godhra	Anand	Godhra
T_1	36.6	28.4	61.6	41.4	45.1	38.3	46.5	40.3
T_2	28.5	21.6	36.7	30.6	28.8	29.4	28.6	28.8
T_3	33.2	25.5	49.2	34.4	38.5	33.3	42.3	32.4
T_4	34.2	27.4	50.5	39.2	42.5	34.5	45.3	34.4

T_5	33.1	23.2	47.3	34.4	37.8	31.1	42.1	31.6
T_6	32.2	26.3	49.6	42.0	40.3	33.8	42.9	34.1
T7	36.0	28.4	52.5	36.9	43.3	36.5	46.3	38.3
T_8	35.1	29.4	59.3	47.4	44.7	37.9	47.5	39.9
T_9	34.1	28.7	56.6	49.1	44.2	37.4	47.4	40.3
T_{10}	36.8	32.0	62.0	48.0	46.1	39.0	50.7	40.5
S.Em.±	**1.8**	**2.0**	**3.0**	**2.7**	**1.7**	**1.2**	**2.0**	**3.0**
CD (P=0.05)	**NS**	**NS**	**8.8**	**8.0**	**5.0**	**3.7**	**6.1**	**6.1**
CV %	**9.2**	**12.5**	**9.7**	**11.5**	**7.0**	**6.1**	**8.0**	**9.9**

Table 4: Effect of nano urea and nano DAP on grain yield, stover yield and quality of fodder maize

Tr. No.	Grain yield (kg/ha)		Stover yield (kg/ha)		Seed index (g)		Harvest index (%)		Grain Protein (%)	
	Anand	**Godhra**	**Anand**	**Godhra**	**Anand**	**Godhra**	**Anand**	**Godhra**	**Anand**	**Godhra**
T_1	3752	3088	21589	21243	25.48	20.75	14.62	12.72	9.97	10.01
T_2	2323	2396	13210	17290	24.48	21.83	15.20	12.22	8.57	8.63
T_3	3373	2842	19710	19840	26.58	21.25	15.73	12.55	9.03	9.03
T_4	3317	2796	20202	19150	24.90	20.99	14.62	14.00	9.44	9.16
T_5	3196	2748	19648	18064	25.05	20.21	13.97	13.23	9.21	9.04
T_6	3550	2904	20593	19618	25.36	21.58	14.70	12.82	9.50	9.38
T_7	3674	2935	20870	20050	25.54	20.70	13.76	12.78	9.33	9.04
T_8	3692	3088	21262	20408	25.22	21.18	14.95	12.07	9.56	9.50
T_9	3452	2873	20355	19467	25.39	21.34	15.62	13.00	9.38	9.16
T_{10}	3757	3122	22129	22413	27.03	20.33	13.26	12.11	10.00	10.03
S.Em.±	**194**	**94**	**835**	**602**	**0.91**	**0.77**	**0.92**	**0.47**	**0.17**	**0.25**
CD (P=0.05)	**575**	**278**	**2481**	**1788**	**NS**	**NS**	**NS**	**NS**	**0.52**	**0.73**
CV %	**9.8**	**5.6**	**7.2**	**5.3**	**6.18**	**6.32**	**10.88**	**6.43**	**3.20**	**4.58**

Conclusion

From two-year location results regarding chlorophyll content, grain yield, stover yield and protein content significantly affected by conventional and foliar application of fertilizer. According to experiment result, reducing dose of recommended fertiliser (75%) along with seed treatment of nano DAP @ 5 mL/kg seed followed by two foliar sprays with Nano urea and Nano DAP 4 mL/litre at 25 & 50 DAS treatment noted higher economical and quality parameter of fodder maize.

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