



Effect of nano urea plus on growth and yield of maize (*Zea mays* L.)

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Abstract

A field experiment was conducted during *kharif*, 2025 at the Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, under the Northern Dry Zone of Karnataka (Zone-III), to evaluate the effect of nano urea plus on the growth and yield of maize (*Zea mays* L.) hybrid MRM 4050. The experiment was laid out in a split-plot design with three replications, comprising two spraying methods, viz., knapsack sprayer and power-operated sprayer, as main-plot treatments and six nutrient management practices as sub-plot treatments. Growth and yield parameters were recorded at 30, 60, 90 days after sowing (DAS) and at harvest. The results revealed that soil application of the recommended dose of fertilizer (RDF) recorded significantly higher growth attributes at harvest, including plant height (217.4 cm), SPAD chlorophyll reading (39.3), leaf area (4291.6 cm² plant⁻¹), leaf area index (3.59) and total dry matter production (301.2 g plant⁻¹), and remained statistically on par with 75 per cent of the recommended dose of nitrogen (RDN) supplemented with foliar application of nano urea plus @ 4 ml L⁻¹ at 30 DAS. Similarly, RDF recorded significantly higher cob length (19.6 cm), cob girth (15.4 cm), grain yield (7923 kg ha⁻¹) and stover yield (9227 kg ha⁻¹), which were statistically on par with 75 per cent RDN supplemented with nano urea plus @ 4 ml L⁻¹ at 30 DAS, recording 19.0 cm, 14.9 cm, 7742 kg ha⁻¹ and 9004 kg ha⁻¹, respectively. The power-operated sprayer recorded numerically higher growth and yield attributes than the knapsack sprayer; however, the differences were statistically non-significant. Similarly, the interaction between spraying methods and nutrient management practices was non-significant for all the parameters studied. The findings indicate that foliar application of nano urea plus @ 4 ml L⁻¹ at 30 DAS can effectively substitute 25 per cent of the recommended nitrogen dose without significant reduction in maize yield, offering an efficient nutrient management option for irrigated maize production.

Keywords: Maize, nano urea plus, foliar application, spad chlorophyll meter, leaf area index, dry matter accumulation, grain yield

Introduction

Maize (*Zea mays* L.) is one of the most important cereal food grains in India after rice and wheat, and owing to its wide adaptability and high yield potential, it is often referred to as the "Queen of Cereals". As a dual-purpose crop, maize grain serves both human and livestock nutrition, containing about 7.7-14.6 % protein, 0.8-2.32 % crude fibre, 69.7-74.5 % carbohydrates, 3.2-7.7 % fat and 0.7-1.3 % ash (Anon, 2024a). Globally, maize is cultivated across a large area contributing substantially to food, feed and industrial needs, with the United States, China, Brazil, Argentina, India and Ukraine as major producers (Anon, 2024) [5]. In India, maize ranks third among cereal crops, cultivated over 12.09 million hectares with a production of 43.41 million tonnes and productivity of 3.59 t ha⁻¹ during 2024-25 (Anon, 2025). Karnataka contributes about 14.26 % to national maize production, with an area of 1.91 million hectares, production of 6.19 million tonnes and productivity of 3.23 t ha⁻¹.

Despite its high yield potential, maize productivity remains constrained by widespread nutrient deficiencies, as Indian

soils face an annual net nutrient deficit of nearly 10 million tonnes, with a declining fertilizer response ratio (Bhattacharyya *et al.*, 2015) [7]. Among mineral nutrients, nitrogen assumes primary importance as a constituent of chlorophyll, proteins and enzymes governing vegetative growth, though soil-applied nitrogen is prone to substantial losses through denitrification and leaching (Nduwimana *et al.*, 2020; Meena *et al.*, 2021) [20, 22], reducing both soil fertility and use efficiency. These challenges, compounded by escalating cultivation costs and labour scarcity, have intensified the search for precision nutrient-delivery technologies (Sinha and Singh, 2020) [32].

Nanotechnology has emerged as a promising alternative capable of addressing the declining nutrient use efficiency (NUE) associated with conventional fertilizers while minimizing environmental impact (Baruah and Dutta, 2009; Cui *et al.*, 2010) [6, 10]. Nano-fertilizers, formulated from raw materials in the 1-100 nm range (Lal, 2008; Sharma, 2008) [17, 31], possess a large surface area that enables slow and sustained nutrient release, thereby enhancing bioavailability and reducing environmental losses relative to conventional

fertilizers (Kothari and Khursheed, 2019) ^[15]. Nano urea plus (liquid), containing 16 % nitrogen by weight in nano forms (urea-amide, ammonical and amino), possesses nearly 10,000 times more surface area and 55,000 times more particles than a conventional 1 mm urea prill, resulting in an uptake efficiency exceeding 80 % when applied through foliage at critical crop growth stages. Given this potential to substitute a substantial proportion of soil-applied nitrogen while sustaining productivity, the present investigation was undertaken to study the effect of foliar application of nano urea plus, applied through two different spraying methods, on the growth and yield of maize under irrigated conditions of the Northern Dry Zone of Karnataka.

Materials and Methods

A field experiment was conducted during *kharif*, 2025 at the Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, situated at 15° 69' N latitude and 76° 89' E longitude at an altitude of 358 m above mean sea level, under the Northern Dry Zone of Karnataka (Zone-III). The soil of the experimental site was medium black clay in texture, classified as *Vertisol*, with a pH of 8.16, EC of 0.29 dS.m⁻¹, organic carbon 0.50 %, and available nitrogen, phosphorus and potassium of 253.3, 37.8 and 326.5 kg ha⁻¹, respectively.

The experiment was laid out in a split-plot design with three replications, comprising two types of sprayers as main-plot treatments, viz., M₁: knapsack sprayer and M₂: power operated sprayer, and six nutrient management practices as sub-plot treatments, viz., N₁: RDF (100 % soil application), N₂: 75 % RDN + foliar application of nano urea plus @ 4 ml L⁻¹ at 30 DAS, N₃: 50 % RDN + foliar application of nano urea plus @ 4 ml L⁻¹ at 30 and 45 DAS, N₄: RDN through foliar application of nano urea plus @ 8 ml L⁻¹ at 30 and 45 DAS, N₅: absolute control, and N₆: nitrogen free. The recommended dose of fertilizer was 150:75:37.5 kg N:P₂O₅:K₂O ha⁻¹, with recommended phosphorus and potassium applied uniformly to all treatments except the absolute control. The maize hybrid MRM 4050 was sown on 17th June 2025 by hand dibbling at 60 cm × 20 cm spacing in a gross plot of 6.0 m × 4.8 m and harvested on 18th October 2025 at physiological maturity.

Observations on growth parameters, viz., plant height, leaf area, leaf area index, chlorophyll content (SPAD meter readings) and dry matter accumulation, were recorded from five randomly tagged plants per plot at 30, 60, 90 DAS and at harvest. Plant height was measured from the base of the plant to the tip of the newly opened leaf. Leaf area was computed as the product of leaf length, breadth, number of leaves and a correction factor of 0.75 (Saxena and Singh, 1968) ^[29], and leaf area index was derived as the ratio of leaf area per plant to the ground area occupied by the plant (Sestak *et al.*, 1971) ^[30]. Chlorophyll content was measured using a SPAD-502 Plus chlorophyll meter (Konica Minolta®, Tokyo, Japan) between 9:30 and 11:30 h IST on sunny days. Dry matter accumulation in leaf, stem and reproductive parts (tassel and cob) was recorded through destructive sampling of five plants at each growth stage, oven-dried at 65 °C to constant weight and expressed on a per-plant basis. At harvest, yield parameters, viz., cob length, cob girth, grain weight per cob, test weight, grain yield and stover yield, were recorded from net-plot harvest and expressed on a hectare basis, while harvest index was computed as the ratio of grain yield to biological yield (Donald, 1962) ^[13].

The experimental data were subjected to Fisher's method of analysis of variance (ANOVA) for split-plot design as outlined by Panse and Sukhatme (1967) ^[23], and treatment means were compared using critical difference (CD) values at 5 % level of significance wherever the F-test was significant.

Results and Discussion

The results of the field experiment conducted to study the effect of nano urea plus on growth and yield of maize during *kharif* 2025 are presented and discussed in this section, with scientific interpretation supported by relevant literature.

1. Growth parameters

Data on plant height, chlorophyll content (SPAD meter reading) and total dry matter production of maize, as influenced by the types of sprayer and nutrient management practices at 30, 60, 90 DAS and at harvest, are presented in Table 1.

1.1 Plant height (cm)

Plant height differed significantly due to nutrient management practices at all the growth stages. Application of nano urea plus through the power operated sprayer recorded numerically taller plants at 30, 60, 90 DAS and at harvest (35.9, 141.1, 207.8 and 203.3 cm, respectively) compared with the knapsack sprayer (35.7, 140.8, 207.2 and 202.7 cm), although the difference between sprayer types remained non-significant throughout the crop growth period. Among the nutrient management practices, soil application of the recommended dose of fertilizer (RDF) recorded significantly taller plants at 30, 60, 90 DAS and at harvest (39.7, 153.3, 215.1 and 217.4 cm, respectively), which was on par with 75 % RDN supplemented with foliar application of nano urea plus @ 4 ml L⁻¹ at 30 DAS (38.4, 148.1, 214.5 and 215.0 cm). The absolute control recorded the shorter plants at all stages (31.0, 132.0, 192.3 and 194.2 cm). The interaction between sprayer type and nutrient management was non-significant.

The taller plants recorded under RDF may be attributed to balanced availability of nitrogen, phosphorus and potassium, which enhanced cell division, internodal elongation and overall vegetative growth. The comparable performance of 75 % RDN with foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS suggests that the nano-sized formulation facilitated efficient foliar absorption and nitrogen assimilation, sustaining stem elongation despite the reduction in soil-applied nitrogen. These findings corroborate the observations of Ajithkumar *et al.* (2021), Das *et al.* (2024) and Rathour *et al.* (2025) ^[1, 11, 25], who also reported improved plant height in maize under nano-fertilizer-supplemented nutrient management.

1.2 Chlorophyll readings by SPAD meter

Chlorophyll content, measured as SPAD meter readings, differed significantly due to nutrient management practices at all growth stages. The power operated sprayer recorded numerically higher SPAD readings at 30, 60, 90 DAS and at harvest (33.1, 47.3, 45.7 and 34.4, respectively) than the knapsack sprayer (33.0, 47.1, 45.6 and 34.3), the difference being statistically non-significant.

Soil application of RDF recorded significantly higher SPAD readings at 30, 60, 90 DAS and at harvest (36.1, 53.1, 51.7 and 39.3, respectively), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (35.3, 52.1, 50.9 and 38.4).

The absolute control recorded the lower SPAD readings throughout (30.2, 38.8, 38.1 and 28.0). The interaction effect was non-significant at all stages.

The higher chlorophyll readings under RDF may be ascribed to adequate nitrogen availability, which sustains chlorophyll synthesis and leaf nitrogen concentration, both critical determinants of SPAD readings. The comparable response with 75 % RDN + nano urea plus @ 4 ml L⁻¹ at 30 DAS indicates that foliar nitrogen effectively supplemented the reduced soil-applied dose, maintaining leaf greenness and photosynthetic potential during the active vegetative phase. Similar findings on enhanced chlorophyll content under nano-nitrogen nutrition were reported by Burhan and Al-Hassan (2019), Al-Juthery *et al.* (2020) and Navya *et al.* (2022) [2, 9, 21].

1.3 Total dry matter production (g plant⁻¹)

Total dry matter production differed significantly due to nutrient management practices at all crop growth stages. Application of nano urea plus through the power operated sprayer recorded numerically higher total dry matter at 30, 60, 90 DAS and at harvest (23.7, 97.3, 220.2 and 267.4 g plant⁻¹, respectively) compared with the knapsack sprayer (23.2, 94.7, 216.8 and 263.5 g plant⁻¹).

Among nutrient management treatments, RDF recorded significantly higher total dry matter production at 30, 60, 90 DAS and at harvest (28.2, 112.3, 249.6 and 301.2 g plant⁻¹, respectively), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (28.0, 110.5, 245.5 and 295.0 g plant⁻¹). The absolute control recorded the least dry matter accumulation at all stages (16.5, 71.5, 166.5 and 216.3 g plant⁻¹). The interaction between sprayer type and nutrient management practices remained non-significant throughout. The higher dry matter accumulation under RDF may be attributed to sustained nitrogen availability that favoured canopy development, photosynthetic carbon assimilation and efficient partitioning of assimilates among plant organs. The comparable performance under 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS suggests that nano-nitrogen supplementation compensated for the reduced soil-applied dose by improving foliar nitrogen uptake during the critical vegetative stage. These results are in agreement with the findings of Biswas *et al.* (2024), Dokhe *et al.* (2024) and Mandal *et al.* (2024) [8, 12, 19].

2. Leaf area and leaf area index

2.1 Leaf area (cm² plant⁻¹)

Leaf area differed significantly due to nutrient management practices at all crop growth stages and is depicted in Fig. 1. Application of nano urea plus through the power operated

sprayer recorded numerically higher leaf area at 30, 60, 90 DAS and at harvest (870.2, 3686.3, 5064.2 and 3644.2 cm² plant⁻¹, respectively) than the knapsack sprayer (849.7, 3558.3, 4918.3 and 3484.6 cm² plant⁻¹).

Soil application of RDF recorded significantly higher leaf area at 30, 60, 90 DAS and at harvest (989.7, 4262.5, 5888.5 and 4291.6 cm² plant⁻¹, respectively), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (986.0, 4236.7, 5858.0 and 4257.7 cm² plant⁻¹). The absolute control recorded the least leaf area at all stages (679.3, 2754.0, 3789.6 and 2642.8 cm² plant⁻¹). The interaction effect between sprayer type and nutrient management practices was non-significant.

The greater leaf area under RDF may be explained by balanced nutrient availability promoting cell division, cell enlargement and chloroplast development, resulting in a more expansive photosynthetic surface. The comparable performance with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS could be associated with efficient foliar penetration of the nano-sized formulation through the leaf cuticle and stomata, sustaining leaf expansion despite reduced soil nitrogen. These observations are consistent with the reports of Rop *et al.* (2019), Ajithkumar *et al.* (2021) and Das *et al.* (2024) [1, 11, 27].

2.2 Leaf area index (LAI)

Leaf area index also differed significantly due to nutrient management practices at all crop growth stages and is presented in Fig. 2. The power operated sprayer recorded numerically higher LAI at 30, 60, 90 DAS and at harvest (0.72, 3.09, 4.22 and 3.01, respectively) than the knapsack sprayer (0.70, 2.98, 4.09 and 2.88).

Among nutrient management treatments, RDF recorded significantly higher LAI at 30, 60, 90 DAS and at harvest (0.83, 3.56, 4.91 and 3.59, respectively), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (0.81, 3.55, 4.89 and 3.57). The absolute control recorded the least LAI at all stages (0.55, 2.33, 3.14 and 2.02). The interaction effect between sprayer type and nutrient management practices remained non-significant.

The higher LAI recorded under RDF probably resulted from greater leaf expansion and canopy development supported by adequate nitrogen-driven chlorophyll synthesis and photosynthetic activity, enabling more efficient interception of solar radiation. The comparable response with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS indicates that foliar nitrogen supplementation partially compensated for the reduced soil-applied dose in sustaining canopy growth. These findings are in close agreement with Yasser *et al.* (2020), Das *et al.* (2024) and Rathour *et al.* (2025) [11, 25, 35].

Table 1: Plant height, chlorophyll readings by SPAD meter and dry matter accumulation of maize at different crop growth stages as influenced by the varying level of fertilizers and foliar application of nano urea plus

Treatment	Plant height (cm)				SPAD meter reading (chlorophyll index)				Total dry matter production (g plant ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Main plot: Types of sprayer (M)												
M ₁ : Knapsack sprayer	35.7	140.8	207.2	202.7	33	47.1	45.6	34.3	23.2	94.7	216.8	263.5
M ₂ : Power operated sprayer	35.9	141.1	207.8	203.3	33.1	47.3	45.7	34.4	23.7	97.3	220.2	267.4
S.E.m.±	0.6	2.1	3.8	3	0.7	1	0.8	0.9	0.28	1.3	2.1	3.5
C.D. @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot: Nutrient management practices (N)												
N ₁ : RDF (100 % Soil application)	39.7	153.3	215.1	217.4	36.1	53.1	51.7	39.3	28.2	112.3	249.6	301.2

N ₂ : 75 % RDN + NUP @ 4 ml L ⁻¹ at 30 DAS	38.4	148.1	214.5	215	35.3	52.1	50.9	38.4	28	110.5	245.5	295
N ₃ : 50 % RDN + NUP @ 4 ml L ⁻¹ at 30 & 45 DAS	36	140.3	212.7	199.2	32.4	49.5	46.8	35.1	25.2	100.9	226.8	273.8
N ₄ : RDN through NUP @ 8 ml L ⁻¹ at 30 & 45 DAS	35.7	138.9	207.4	196.3	32.4	48.6	46.3	33.8	21.9	93.7	214.3	259.2
N ₅ : Absolute control	31	132	192.3	194.2	30.2	38.8	38.1	28	16.5	71.5	166.5	216.3
N ₆ : Nitrogen free	34.3	133.1	202.8	195.9	32	41.3	40	31.4	20.7	87.1	208	247
S.Em.±	0.8	3.3	5.5	4.5	1	1.2	1.2	1.5	0.4	1.7	3.7	4.8
C.D. @ 5 %	2.5	9.7	16.3	13.3	2.9	3.6	3.4	4.5	1.1	4.9	11.1	14.2
Interaction effect (M × N)												
M ₁ N ₁	39.6	153	215	217.1	36.1	53	51.6	39.2	27.8	109.1	248.2	299.5
M ₁ N ₂	38.2	147.8	214.2	214.3	35.1	51.9	50.9	38.5	27.6	109.2	243.8	292.5
M ₁ N ₃	36.1	140.2	212.3	199.2	32.7	49.4	47.1	35.1	25	100	225.2	272.4
M ₁ N ₄	35.4	138.7	207.3	196.2	32	48.8	46.2	33.6	21.7	92.6	212.6	257.2
M ₁ N ₅	30.9	131.9	191.7	193.8	30.2	38.7	38	28	16.3	71	164.4	214.8
M ₁ N ₆	34.2	133	202.5	195.7	31.9	41	40	31.4	20.6	86.2	206.4	244.4
M ₂ N ₁	39.7	153.6	215.1	217.7	36.1	53.1	51.7	39.4	28.5	115.4	251.1	302.9
M ₂ N ₂	38.5	148.3	214.8	215.7	35.4	52.3	51	38.3	28.3	111.9	247.1	297.5
M ₂ N ₃	35.9	140.3	213.2	199.2	32.2	49.5	46.5	35.1	25.5	101.9	228.5	275.1
M ₂ N ₄	36	139.1	207.6	196.3	32.7	48.5	46.4	34	22.2	94.9	216	261.2
M ₂ N ₅	31.1	132.2	192.9	194.5	30.2	39	38.2	28.1	16.6	72	168.6	217.8
M ₂ N ₆	34.5	133.3	203.2	196.1	32.2	41.7	40.1	31.5	20.9	88	209.7	249.7
S.Em.±	1.2	4.6	7.83	6.4	1.4	1.7	1.6	2.2	0.5	2.4	5.3	6.8
C.D. @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: RDF: Recommended Dose of Fertilizer (150:75:37.5 kg N:P₂O₅:K₂O ha⁻¹); DAS: Days After Sowing; RDN: Recommended Dose of Nitrogen; NUP: Nano Urea Plus; NS: Non-Significant.

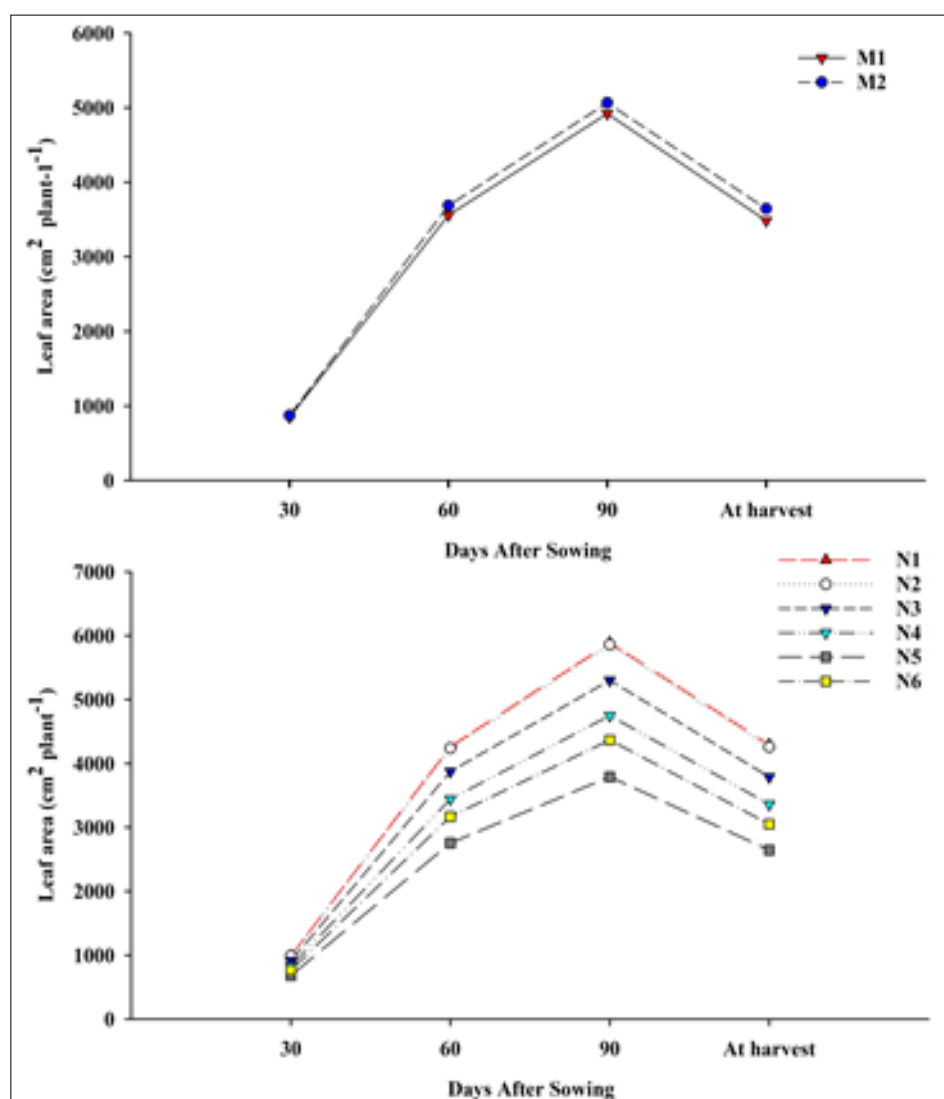


Fig 1: Leaf area (cm² plant⁻¹) of maize at different crop growth stages as influenced by varying levels of fertilizers and foliar application of nano urea plus

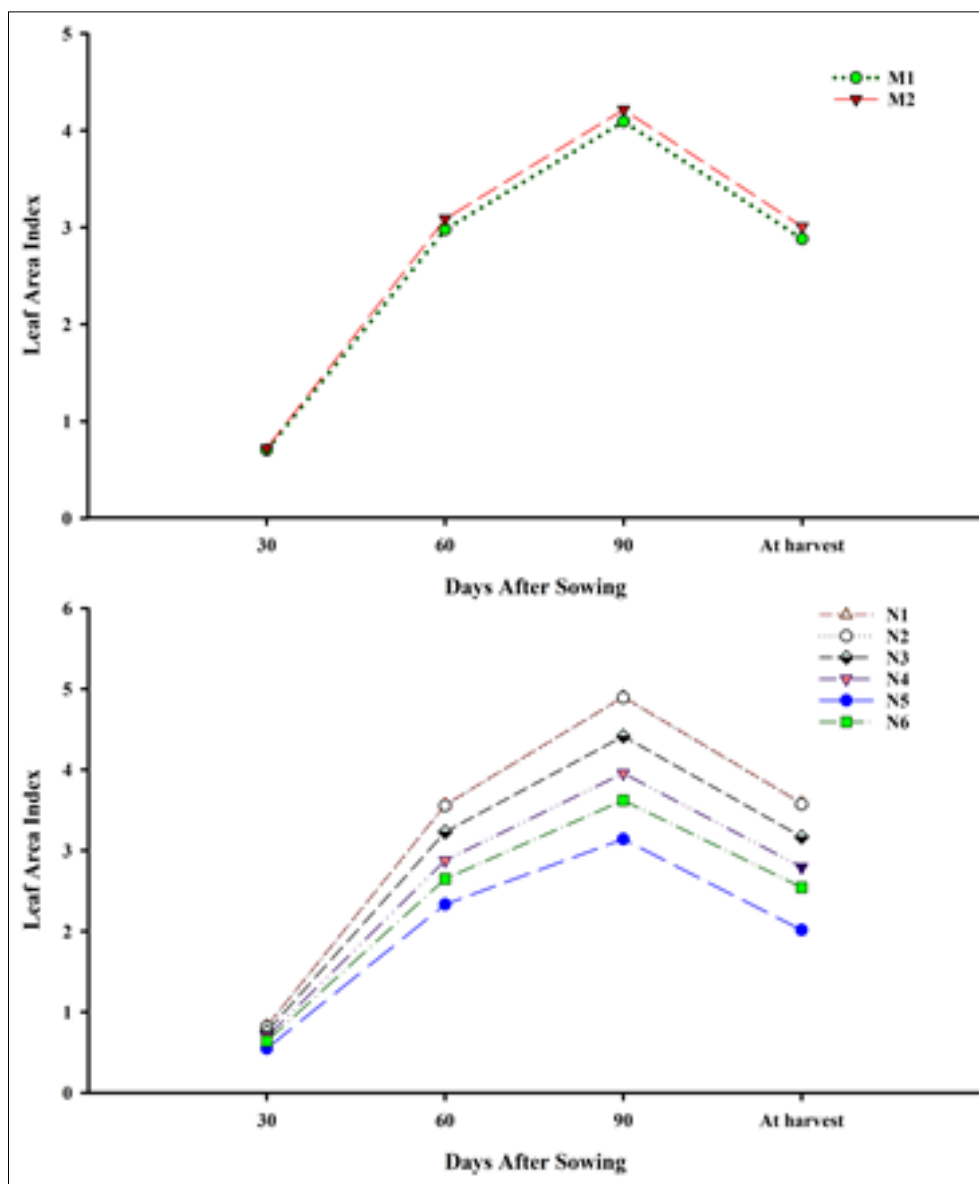


Fig 2: Leaf area index (LAI) of maize at different crop growth stages as influenced by varying levels of fertilizers and foliar application of nano urea plus

3. Yield and yield parameters

The data pertaining to yield and yield parameters of maize, viz., cob length, cob girth, grain yield, stover yield and harvest index, as influenced by types of sprayer and nutrient management practices, are presented in Table 2.

3.1 Cob length (cm)

Cob length differed significantly due to nutrient management practices. Application of nano urea plus through the power operated sprayer recorded numerically longer cobs (17.2 cm) than the knapsack sprayer (16.6 cm). Among nutrient management treatments, RDF recorded significantly higher cob length (19.6 cm), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (19.0 cm), while the absolute control recorded the shorter cobs (12.7 cm). The interaction effect was non-significant.

The significantly higher cob length under RDF could be attributed to sustained nitrogen availability supporting vigorous vegetative growth and greater assimilate production during the reproductive phase, in agreement with Samui *et al.* (2022) [28]. The comparable performance of 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS suggests that foliar nitrogen supplementation effectively

complemented the reduced soil-applied dose, favouring preferential translocation of photosynthates to the developing cob, as also reported by Kumari *et al.* (2024) and Triveni *et al.* (2026) [16, 33].

3.2 Cob girth (cm)

Cob girth also differed significantly due to nutrient management practices. The power operated sprayer recorded numerically higher cob girth (14.1 cm) than the knapsack sprayer (13.6 cm). Among nutrient management treatments, RDF recorded significantly higher cob girth (15.4 cm), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (14.9 cm), while the absolute control recorded the least cob girth (11.9 cm). The interaction effect remained non-significant.

The greater cob girth under RDF may be linked to adequate nitrogen nutrition favouring ear growth and kernel setting through improved metabolic activity, corroborating the findings of Kumari *et al.* (2024) [16]. The comparable response under 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS could be associated with efficient foliar absorption of the nano-sized nitrogen particles, supporting

cell expansion and filling of the developing ear, in agreement with Triveni *et al.* (2026) [33].

3.3 Grain yield (kg ha⁻¹)

Grain yield differed significantly due to nutrient management practices. The power operated sprayer recorded numerically higher grain yield (6484 kg ha⁻¹) than the knapsack sprayer (6293 kg ha⁻¹). Among nutrient management treatments, RDF recorded significantly higher grain yield (7923 kg ha⁻¹), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (7742 kg ha⁻¹), while the absolute control recorded the least grain yield (4730 kg ha⁻¹). The interaction effect between sprayer type and nutrient management practices was non-significant.

The higher grain yield under RDF could be attributed to sustained nitrogen availability along with adequate phosphorus and potassium, favouring chlorophyll formation, root activity and efficient assimilate partitioning towards developing grains, similar to the reports of Das *et al.* (2024) and Dokhe *et al.* (2024) [11, 12]. The comparable yield under 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS may be associated with rapid foliar absorption and efficient nitrogen utilization sustaining crop nitrogen status through to reproductive development, with phosphorus supporting energy metabolism and potassium facilitating carbohydrate translocation and grain filling. Similar yield responses under nano-nitrogen management were reported by Kumari *et al.* (2024), Maloth *et al.* (2024) and Jyothsna *et al.* (2025) [14, 16, 18].

3.4 Stover yield (kg ha⁻¹)

Stover yield differed significantly due to nutrient management practices. The power operated sprayer recorded numerically higher stover yield (7759 kg ha⁻¹) than the knapsack sprayer (7607 kg ha⁻¹). Among nutrient management treatments, RDF recorded significantly higher stover yield (9227 kg ha⁻¹), on par with 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS (9004 kg ha⁻¹), while

the absolute control recorded the lower stover yield (5692 kg ha⁻¹). The interaction effect was non-significant.

The higher stover yield under RDF could be attributed to adequate nitrogen nutrition favouring vigorous vegetative growth through enhanced cell division and development of photosynthetically active foliage, in line with Ajithkumar *et al.* (2021) and Das *et al.* (2024) [1, 11]. The equivalent response under 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS may be associated with efficient foliar nitrogen uptake supporting canopy development and structural biomass accumulation despite reduced soil-applied nitrogen, as also reported by Dokhe *et al.* (2024) and Vasanth *et al.* (2025) [12, 34].

3.5 Harvest index

Harvest index differed significantly due to nutrient management practices. The power operated sprayer recorded a numerically higher harvest index (0.46) than the knapsack sprayer (0.45). Among nutrient management treatments, RDF, 75 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 DAS, 50 % RDN + foliar nano urea plus @ 4 ml L⁻¹ at 30 and 45 DAS and the absolute control recorded a harvest index of 0.46, on par with the nitrogen-free treatment (0.45), while the lower harvest index (0.42) was recorded with RDN entirely through foliar nano urea plus @ 8 ml L⁻¹ at 30 and 45 DAS. The interaction effect was non-significant.

The higher harvest index under RDF and comparable treatments could be attributed to efficient dry matter partitioning towards the economic sink, resulting in a favourable grain-to-biological-yield ratio, as also observed by Rajesh *et al.* (2021) [24]. The lower harvest index recorded when the entire nitrogen requirement was met through foliar nano urea plus @ 8 ml L⁻¹ could be associated with relatively lower allocation of accumulated biomass towards grain formation, consistent with the reports of Reddy *et al.* (2022) and Samui *et al.* (2022) [26, 28].

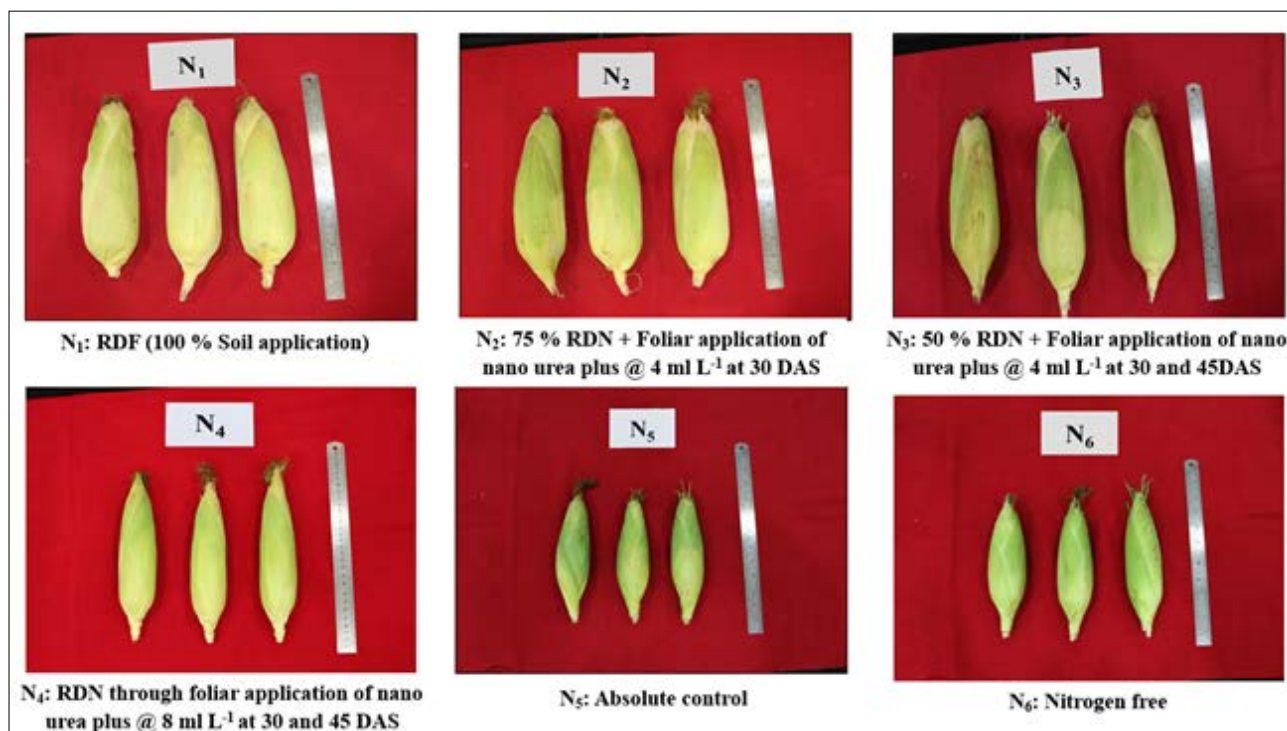


Plate 1: Cob length and girth of maize at harvest as influenced by the varying level of fertilizers and foliar application of nano urea plus

Table 2: Cob length, cob girth, grain yield, stover yield and harvest index of maize at harvest as influenced by the varying level of fertilizers and foliar application of nano urea plus

Treatment	Cob length (cm)	Cob girth (cm)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index
Main plot: Types of sprayer (M)					
M ₁ : Knapsack sprayer	16.6	13.6	6293	7607	0.45
M ₂ : Power operated sprayer	17.2	14.1	6484	7759	0.46
S.E.m.±	0.3	0.2	85	152	0.01
C.D. @ 5 %	NS	NS	NS	NS	NS
Sub plot: Nutrient management practices (N)					
N ₁ : RDF (100 % Soil application)	19.6	15.4	7923	9227	0.46
N ₂ : 75 % RDN + NUP @ 4 ml L ⁻¹ at 30 DAS	19	14.9	7742	9004	0.46
N ₃ : 50 % RDN + NUP @ 4 ml L ⁻¹ at 30 & 45 DAS	18	14.4	7378	8483	0.46
N ₄ : RDN through NUP @ 8 ml L ⁻¹ at 30 & 45 DAS	17.1	14.1	5344	7322	0.42
N ₅ : Absolute control	12.7	11.9	4730	5692	0.46
N ₆ : Nitrogen free	15.1	12.7	5211	6372	0.45
S.E.m.±	0.5	0.3	135	218	0.01
C.D. @ 5 %	1.4	1	397	644	0.03
Interaction effect (M × N)					
M ₁ N ₁	19.4	15	7809	9154	0.46
M ₁ N ₂	18.9	14.6	7662	8965	0.46
M ₁ N ₃	17.9	14.3	7294	8365	0.46
M ₁ N ₄	16.3	13.6	5223	7201	0.42
M ₁ N ₅	12.5	11.6	4607	5652	0.45
M ₁ N ₆	14.7	12.6	5159	6304	0.45
M ₂ N ₁	19.8	15.8	8037	9299	0.46
M ₂ N ₂	19.2	15.2	7822	9042	0.46
M ₂ N ₃	18.1	14.6	7463	8600	0.46
M ₂ N ₄	17.8	14.5	5464	7443	0.42
M ₂ N ₅	12.9	12.1	4853	5731	0.46
M ₂ N ₆	15.4	12.8	5262	6440	0.45
S.E.m.±	0.7	0.47	190	309	0.02
C.D. @ 5 %	NS	NS	NS	NS	NS

Note: RDF: Recommended Dose of Fertilizer (150:75:37.5 kg N:P₂O₅:K₂O ha⁻¹); DAS: Days After Sowing; RDN: Recommended Dose of Nitrogen; NUP: Nano Urea Plus; NS: Non-Significant.

Conclusion

The present investigation revealed that soil application of the recommended dose of fertilizer (150:75:37.5 kg N:P₂O₅:K₂O ha⁻¹) resulted in significantly superior growth parameters (plant height, SPAD chlorophyll reading, leaf area, leaf area index and total dry matter production) and yield parameters (cob length, cob girth, grain yield, stover yield and harvest index) in maize. Notably, substitution of 25 % of the recommended nitrogen dose through foliar application of nano urea plus @ 4 ml L⁻¹ at 30 DAS produced growth and yield performance statistically on par with full soil-applied RDF, without any significant yield penalty. Application of nano urea plus through the power operated sprayer recorded numerically superior, though statistically non-significant, growth and yield over the knapsack sprayer, and the interaction between sprayer type and nutrient management practices was non-significant for all the parameters studied. These findings suggest that integrating conventional nitrogen fertilization with foliar application of nano urea plus is a scientifically sound and input-efficient nutrient management strategy for enhancing maize productivity under irrigated conditions, while reducing dependence on soil-applied nitrogen.

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