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Integrating hydrogel-based moisture conservation and nano-fertilizer nutrition for enhanced growth, nutrient uptake, and profitability of hybrid maize (*Zea mays* L.)

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Abstract

A field experiment was conducted during the kharif seasons of 2024 and 2025 at the Soil Conservation and Water Management Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, to investigate the influence of moisture conservation practices and nano-fertilizer-based nutrient management on the growth of hybrid maize (*Zea mays* L.). The experiment was laid out in a split-plot design with four moisture conservation practices comprising conventional tillage, minimum tillage, organic crop residue mulch @ 4 t ha⁻¹, and hydrogel @ 5 kg ha⁻¹ in main plots, while seven fertility levels involving different combinations of RDF, nano urea, and nano zinc were assigned to subplots.

The results demonstrated that moisture conservation practices significantly improved crop growth. Hydrogel application @ 5 kg ha⁻¹ recorded the highest plant height, followed closely by organic residue mulch, indicating the beneficial effects of improved soil moisture retention and reduced moisture losses. Among fertility treatments, 75% RDF supplemented with one foliar spray each of nano urea and nano zinc @ 5 ml L⁻¹ exhibited superior growth performance compared with other nutrient management practices. Enhanced growth under nano-fertilizer treatments was attributed to improved nutrient use efficiency, greater nutrient absorption, profitability and better physiological activity of maize plants.

Keywords: Crop residue, economics, hydrogel, nano-urea and nano zinc, maize, N, P, K

Introduction

Maize (*Zea mays* L.), also referred as corn, is one of the most important cereal crops in the world. It plays a crucial role in global food security, animal feed and industrial applications. In addition to staple food for human being and quality feed for poultry and animals. It serves as a basic raw material for the manufacturing of starch for the textile, pharmaceutical, and cosmetic industries, as well as high quality maize oil, protein, alcoholic drinks, food sweeteners, and other products etc. More than 3000 goods have it as an ingredient. In addition, maize is grown for quality feed for animals and poultry, QPM for human nutrition, and other table uses like pickles, soup, kheer, and other value-added products; sweet corn for soup and other recipes; and baby corn for vegetables. Maize contains about 72% starch, 10% protein, and 4% fat, supplying an energy density of 365 Kcal/100 g, as compared to rice and wheat, but has lower protein content (Ranum *et al.*, 2014) [14]. Maize provides fiber, many of the B vitamins, along with essential minerals. Originating from the Americas, cultivation of maize has expanded throughout the world and become a staple food and a key component of the agricultural economy. here are 197 million hectares of maize worldwide, with a production of 1210 million tonnes in 2021. After rice and wheat, maize is the third-most significant food crop in India. With an output of 31.51 million tonnes and an average productivity of 3195 kg/ha, it is cultivated on an area of roughly 9.86 million hectares, making it the fifth greatest producer in the world and accounting for 3% of total global production. With a production of 1.80 million tonnes and an area of roughly 0.77 million hectares, Uttar Pradesh provides 7.98% to the total area of India'' [2]. In Indian soil zinc shortage issue. Zinc helps to make auxin, activates a number of enzymes, and increases meristematic activity. The majority of this crop's nutrition study has concentrated on major components, whereas micronutrients still receive little attention despite being just as important. The fields of nanoscience and nanotechnology represent a new frontier for the scientific community. Nano

fertiliser offers promises for enhancing agricultural productivity by addressing problems that cannot be remedied naturally by using the smallest feasible particles. Nutrients are lost when fertilisers are applied directly to soil through a number of processes, such as photolysis, hydrolysis, leaching, and degradation. In order to promote the best growth and production of crops, it's likely that the applied fertiliser won't be able to reach the intended spots in the plant's system. To increase the efficiency of applied fertiliser in the form of nano fertiliser, an effort was made to spray foliar fertiliser onto the crop" [3]. "Zinc plays a very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase and stabilization of ribosomal proteins. Zn has a noticeable impact on key plant functions like photosynthesis and defence against reactive oxygen species. Carbonic anhydrase activity, chlorophyll synthesis, nitrogen metabolism, and resilience to biotic and abiotic stressors. One of the crops most vulnerable to a Zn deficit is maize. A vitamin called zinc raises grain productivity in the growing of maize. Zn can be provided to crops directly on the soil, as fertilizers, through foliar fertilization, or through seed treatments. The study's main goal was to determine how applying zinc to the soil and the leaves of maize affected its development and yield" [4]. "Around 30-40 per cent of nitrogen from urea is utilized by plants and the rest gets wasted due to quick chemical transformation as a result of leaching, volatilization, denitrification and run off, thereby low use efficiency. While nano urea is both environmentally friendly and has a high nitrogen utilisation efficiency. Because it lessens the emission of nitrous oxide, which is mostly to blame for polluting soil, air, and water bodies as well as contributing to global warming, this fertilizer is referred to as "smart fertilizer" in the popular culture. The greatest substitute for urea fertilizer right now is liquid nano fertilizer. One 500 ml bottle of nano urea is equal to 45 kg of urea fertilizer, which is 10% less than a bag of regular urea. It might reduce urea fertilizer imports. One nano urea liquid particle has a diameter of 30 nano meters and a surface area to volume ratio that is 10,000 times greater than that of regular granular urea. In comparison to conventional urea, foliar application of nano urea liquid at crucial crop growth stages of a plant effectively satisfies its nitrogen requirement and results in greater crop productivity and quality [5]. Due to these characteristics, it offers a possible substitute for traditional urea. In an agricultural eco-system, microorganisms are essential for fixing, solubilizing, mobilizing, and recycling both macro and micronutrients. Although they are 1047 present in soil naturally, their population is typically too low to achieve the appropriate degree of nutrient mobilization [6]. Urea is the most nutrient used as a commercial nitrogen fertilizer for increasing crop productivity. However, their imbalanced application has environmental and ecological consequences. When applied at the right time, split doses of nitrogen application can reduce environmental pollution and improve yield by increasing nutrient usage efficiency. Optimizing nutrient utilization, especially nitrogen, requires containing neem-coated urea in conventional crop cultivation practices. The losses of nitrogen by soil application in maize through leaching (NO_3) and gas emissions (NH_4 - and N_2O) are the leading causes of environmental pollution and climate change (Nair *et al.*, 2020) [13]. Recent advancements in agricultural technology have led to the development of innovative practices such as foliar spraying of urea. Foliar application involves spraying nutrients directly into plant leaves, facilitating rapid absorption and minimizing nutrient leaching compared to soil application. The application of nitrogen through foliar spray emerges as a potentially more efficient alternative (Mahil and Kumar, 2019) [11]. The present research

aimed to assess the impact of foliar spray of urea and nano-urea on the growth, yield and economic viability of maize (Syngenta NK 6802) cultivation. Globally, it is grown on 205.9 million hectares of land, producing 1236.8 million tonnes of grain with an average yield of 58.8 q/ha (FAO, 2023) [6]. Global consumption of maize has grown at a compound annual growth rate (CAGR) of 2.3% over a period of 10 years increasing from 988.6 million MT in 2013 to 1236.8 million MT in 2023. Global exports grew at a decadal CAGR (2013-2023) of 5.1%, increasing from 122.8 million MT in 2013 to 202.1 million MT in 2023. The global consumption pattern of maize is: feed- 61%, food and industry - 22%. It has attained a position of industrial crop globally as 83% of its production used in feed, starch and bio-fuel industries.

Materials and Methods

The field experiment was conducted during the *kharif* season of 2024-2025. The experimentation was done at the Soil Conservation & Water Management Farm of the Chandra Shekhar Azad University of Agriculture & Technology located in Kanpur district is situated in the sub-tropical region of Uttar Pradesh in part of Gangetic alluvium, lying between the river Ganga and Yamuna. It covers 115 km from North to South and 105 km from East to West. It lies between $25^{\circ} 26'$ and $26^{\circ} 58'$ North latitude and $79^{\circ} 31'$ and $80^{\circ} 34'$ East longitude. The elevation of the farm of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur is approximately 125.9 meters above Mean Sea Level. The average rainfall of the district is about 800 mm. The major portion of rainfall is received during the monsoon season from the first week of July to the last week of September. The experiment will be conducted using a Split Plot Design with three replications. Although the full experiment has factors like moisture conservation practice and fertility levels, this research conducted in 2024. A total of seven fertility levels treatments were studied: (A) Moisture Conservation practices - 4 (Main plot), M_1 - Conventional tillage (two harrowing), M_2 - Minimum tillage (one cross ploughing), M_3 -Organic crop residue @ 4 tons per ha, M_4 -Hydrogel @ 5 kg/ha (B) Fertility Levels - 7 (Sub plot) F_1 - Control (RDF 120:60:40), F_2 -50% RDF+ 2 spray each of nano urea and nano zinc @ 3ml/ltr each (35, 50 DAS), F_3 -50% RDF+ 2 spray each of nano urea and nano zinc @ 4ml/ltr each (35, 50 DAS), F_4 -50% RDF+ 2 spray each of nano urea and nano zinc @ 5ml/ltr each (35, 50 DAS), F_5 -75% RDF+ 1spray each of nano urea and nano zinc @ 3ml/ltr each (35 DAS), F_6 -75% RDF+ 1spray each of nano urea and nano zinc @ 4ml/ltr each (35 DAS), F_7 -75% RDF+ 1spray each of nano urea and nano zinc @ 5ml/ltr each (35 DAS).

Results and Discussion

Plant height

Among the moisture conservation practices, Hydrogel application @ 5 kg ha⁻¹ (M_4) recorded the highest plant height in both years, registering 170.80 cm and 171.64 cm at 60 DAS and 190.18 cm and 192.19 cm at 90 DAS during 2024 and 2025, respectively. In contrast, the minimum tillage treatment (M_2) recorded the lowest plant height, with 158.97 cm and 160.65 cm at 60 DAS and 177.48 cm and 178.52 cm at 90 DAS during 2024 and 2025, respectively.

Regarding fertility levels, the treatment F_7 (75% RDF + one foliar spray each of nano urea and nano zinc @ 5 ml L⁻¹ at 35 DAS) recorded the maximum plant height of 171.23 cm and 172.50 cm at 60 DAS and 192.32 cm and 193.61 cm at 90 DAS during 2024 and 2025, respectively. The lowest plant height was observed under F_1 (control; RDF 120:60:40), recording 155.63 cm and

156.63 cm at 60 DAS and 158.52 cm and 160.55 cm at 90 DAS during 2024 and 2025, respectively.

Number of leaves

The results presented in Table 2 revealed that moisture conservation practices and fertility levels significantly influenced the number of leaves per plant of hybrid maize at both 60 and 90 DAS during the years 2024 and 2025.

Among the moisture conservation practices, Hydrogel application @ 5 kg ha⁻¹ (M₄) recorded the highest number of leaves per plant, with 13.68 and 14.90 leaves at 60 DAS and 15.82 and 16.14 leaves at 90 DAS during 2024 and 2025, respectively. The lowest number of leaves per plant was observed under minimum tillage (M₂), which recorded 12.43 and 13.45 leaves at 60 DAS and 14.71 and 14.81 leaves at 90 DAS during 2024 and 2025, respectively. Similar findings were reported by Aikins *et al.* (2012) ^[1] and Memon *et al.* (2013) ^[12],

Among the fertility levels, F₇ (75% RDF + one spray each of nano urea and nano zinc @ 5 ml L⁻¹ at 35 DAS) recorded the maximum number of leaves per plant, with 13.72 and 16.95 leaves at 60 DAS and 16.60 and 17.10 leaves at 90 DAS during 2024 and 2025, respectively. The lowest number of leaves per plant was recorded under F₁ (Control: RDF 120:60:40), which registered 11.85 and 12.85 leaves at 60 DAS and 13.42 and 13.55 leaves at 90 DAS during 2024 and 2025, respectively. Similar results have been reported by Uma *et al.* (2019) ^[19], Deepak Sathyan (2022) ^[5], and Mahesh *et al.* (2022) ^[10],

Nutrient uptake

The results presented in Tables 3, 4, 5 and 6 revealed that moisture conservation practices and fertility levels significantly influenced the uptake of nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn) in both grain and straw of hybrid maize during 2024 and 2025.

Among the moisture conservation practices, Hydrogel application @ 5 kg ha⁻¹ (M₄) consistently recorded the highest nutrient uptake in both years. It registered maximum nitrogen uptake of 113.60 and 114.61 kg ha⁻¹ in grain and 48.37 and 50.11 kg ha⁻¹ in straw during 2024 and 2025, respectively. Similarly, phosphorus uptake was highest under M₄, recording 34.49 and 35.53 kg ha⁻¹ in grain and 29.53 and 30.57 kg ha⁻¹ in straw during 2024 and 2025, respectively. Potassium uptake was also maximum with M₄, recording 33.00 and 33.67 kg ha⁻¹ in grain and 154.91 and 157.43 kg ha⁻¹ in straw during the respective years. Likewise, zinc uptake under M₄ was highest, with values of 198.63 and 202.62 g ha⁻¹ in grain and 279.17 and 282.50 g ha⁻¹ in straw during 2024 and 2025, respectively. In contrast, the lowest uptake of all nutrients was recorded under minimum tillage (M₂), which registered nitrogen uptake of 96.78 and 97.73 kg ha⁻¹ in grain and 37.19 and 39.31 kg ha⁻¹ in straw; phosphorus uptake of 28.78 and 29.82 kg ha⁻¹ in grain and 23.46 and 24.47 kg ha⁻¹ in straw; potassium uptake of 29.53 and 30.20 kg ha⁻¹ in grain and 139.42 and 141.94 kg ha⁻¹ in straw; and zinc uptake of 185.57 and 189.56 g ha⁻¹ in grain and 266.01 and 269.34 g ha⁻¹ in straw during 2024 and 2025, respectively.

The higher nutrient uptake under hydrogel application may be attributed to its capacity to retain soil moisture for longer periods and maintain a favorable rhizosphere environment, which enhanced root proliferation, nutrient solubility, nutrient mobility and absorption by plants. Improved soil water availability under hydrogel application also promoted greater biomass production and grain yield, resulting in increased nutrient accumulation in both grain and straw. Similar findings were reported by Song *et al.* (2000) ^[18], Kayode and Ademiluyi (2004) ^[8], and Wasaya *et*

al. (2012) ^[21], who observed improved nutrient uptake and crop performance under effective moisture conservation practices.

Among the fertility levels, F₇ (75% RDF + one foliar spray each of nano urea and nano zinc @ 5 ml L⁻¹ at 35 DAS) recorded the highest uptake of all nutrients during both years of experimentation. Nitrogen uptake under F₇ was 115.56 and 117.33 kg ha⁻¹ in grain and 49.00 and 50.91 kg ha⁻¹ in straw during 2024 and 2025, respectively. The corresponding phosphorus uptake was 36.79 and 37.81 kg ha⁻¹ in grain and 30.33 and 31.35 kg ha⁻¹ in straw, while potassium uptake was 35.28 and 35.95 kg ha⁻¹ in grain and 155.32 and 157.84 kg ha⁻¹ in straw during the respective years. Zinc uptake under F₇ was also maximum, recording 206.31 and 210.30 g ha⁻¹ in grain and 285.50 and 288.64 g ha⁻¹ in straw during 2024 and 2025, respectively. The lowest uptake of all nutrients was recorded under F₁ (control), with nitrogen uptake of 61.68 and 63.70 kg ha⁻¹ in grain and 30.83 and 32.79 kg ha⁻¹ in straw; phosphorus uptake of 17.16 and 18.20 kg ha⁻¹ in grain and 19.66 and 20.69 kg ha⁻¹ in straw; potassium uptake of 19.84 and 20.51 kg ha⁻¹ in grain and 113.14 and 115.66 kg ha⁻¹ in straw; and zinc uptake of 131.68 and 135.67 g ha⁻¹ in grain and 220.77 and 224.09 g ha⁻¹ in straw during 2024 and 2025, respectively. similar finding reported by Lindsay, W. L., & Norvell, W. (1978) ^[9], Chapman, D. H., & Parker, F. (1961) ^[4], Jackson, M. L. (1973) ^[7].

Economics

The economic analysis presented in Table 7 revealed that moisture conservation practices and fertility levels had a marked influence on the profitability of hybrid maize cultivation during both 2024 and 2025. Variations in gross returns, net returns, cost of cultivation and benefit-cost ratio were primarily associated with differences in crop productivity and input-use efficiency under various treatments.

Among the moisture conservation practices, Hydrogel application @ 5 kg ha⁻¹ (M₄) recorded the highest gross returns of ₹99,851 and ₹1,14,184 ha⁻¹ during 2024 and 2025, respectively. The treatment also resulted in the highest net returns of ₹61,110 and ₹73,203 ha⁻¹ and the maximum B ratio of 2.51 and 2.78 during the respective years. However, M₄ incurred the highest cost of cultivation, amounting to ₹40,223 and ₹40,982 ha⁻¹ during 2024 and 2025, respectively, due to the additional expenditure involved in hydrogel application. In contrast, Minimum tillage (M₂) recorded the lowest gross returns (₹88,733 and ₹99,945 ha⁻¹), net returns (₹52,511 and ₹62,713 ha⁻¹) and B ratio (2.41 and 2.68) during 2024 and 2025, respectively, although it registered the lowest cost of cultivation (₹36,722 and ₹37,232 ha⁻¹). The higher profitability under hydrogel application may be attributed to improved soil moisture retention, enhanced nutrient uptake, better growth and higher grain yield, which compensated for the additional cost of the treatment. Similar findings have been reported by several researchers who observed increased economic returns under improved moisture conservation practices due to enhanced crop productivity.

Among the fertility levels, F₇ (75% RDF + one foliar spray each of nano urea and nano zinc @ 5 ml L⁻¹ at 35 DAS) recorded the highest gross returns of ₹1,04,061 and ₹1,16,905 ha⁻¹ during 2024 and 2025, respectively. The treatment also produced the maximum net returns of ₹64,706 and ₹77,040 ha⁻¹ and the highest B ratio of 2.64 and 2.93 during the respective years. Although the cost of cultivation under F₇ (₹39,355 and ₹39,866 ha⁻¹) was slightly higher than some other fertility treatments, the substantial increase in crop yield and returns resulted in greater profitability. On the other hand, the control treatment F₁ recorded the lowest gross returns (₹75,891 and ₹86,765 ha⁻¹), net returns (₹36,546

and ₹46,887 ha⁻¹) and B ratio (1.92 and 2.17) during 2024 and 2025, respectively, despite having one of the highest cultivation costs (₹39,356 and ₹39,878 ha⁻¹). Similar results have been reported by Uma *et al.* (2019) ^[19], Bala *et al.* (2019) ^[3], Ajithkumar *et al.* (2021) ^[2], Rajesh *et al.* (2021), Deepak Sathyan (2022) ^[5], Mahesh *et al.* (2022) ^[10], who observed higher economic returns and profitability with nano fertilizer application in maize and other cereal crops.

The superior economic performance of F₇ may be attributed to the

efficient utilization of nutrients through the combined application of 75% RDF and foliar sprays of nano urea and nano zinc. Nano fertilizers improve nutrient-use efficiency, reduce nutrient losses and ensure better nutrient availability during critical growth stages, leading to enhanced growth, yield and nutrient uptake. The reduction in basal fertilizer requirement coupled with increased productivity contributed significantly to higher net returns and benefit-cost ratio.

Table 1: Effect of moisture conservation practices and fertility levels on plant height (60, 90 DAS) on hybrid maize

Treatments	Plant height (cm)			
	60 DAS		90 DAS	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ - (Conventional tillage two harrowing)	164.53	166.05	182.42	184.34
M ₂ - Minimum tillage (one cross ploughing)	158.97	160.65	177.48	178.52
M ₃ - Organic crop residue @4 tons per ha	168.86	169.98	187.81	189.04
M ₄ - Hydrogel @ 5kg/ha	170.80	171.64	190.18	192.19
SE (d)	3.07	3.09	3.47	3.50
CD at 5%	7.66	7.72	8.67	8.73
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	155.63	156.63	158.52	160.55
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35, 50 DAS)	164.65	165.89	186.41	187.27
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35, 50 DAS)	165.75	166.96	187.01	188.54
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35, 50 DAS)	166.68	167.99	187.57	189.59
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	167.78	169.02	189.10	190.64
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	168.81	170.54	190.38	191.93
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	171.23	172.50	192.32	193.61
SE(d)	2.85	2.08	3.17	3.20
CD at 5%	5.76	5.80	6.40	6.45

Table 2: Effect of moisture conservation practices and fertility levels on No. of leaves plant⁻¹(60, 90 DAS) on hybrid maize

Treatments	No. of leaves plant ⁻¹			
	60 DAS		90 DAS	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ - (Conventional tillage two harrowing)	12.95	14.24	15.32	15.51
M ₂ - Minimum tillage (one cross ploughing)	12.43	13.45	14.71	14.81
M ₃ - Organic crop residue @4 tons per ha	13.40	14.57	15.57	15.83
M ₄ - Hydrogel @ 5kg/ha	13.68	14.90	15.82	16.14
SE (d)	0.24	0.27	0.28	0.29
CD at 5%	0.61	0.67	0.72	0.73
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	11.85	12.85	13.42	13.55
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35, 50 DAS)	13.04	13.64	15.30	15.47
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35, 50 DAS)	13.15	13.75	15.39	15.57
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35, 50 DAS)	13.25	13.85	15.50	15.67
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	13.35	13.95	15.60	15.77
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	13.45	15.05	15.70	15.88
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	13.72	16.95	16.60	17.10
SE(d)	0.22	0.24	0.26	0.26
CD at 5%	0.45	0.49	0.53	0.54

Table 3: Effect of moisture conservation practices and fertility levels on nutrient uptake on hybrid maize

Treatments	N Uptake (kg ha ⁻¹) in grain		N Uptake (kg ha ⁻¹) in straw	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ (Conventional tillage two harrowing)	101.40	102.42	40.53	42.28
M ₂ Minimum tillage (one cross ploughing)	96.78	97.73	37.19	39.31
M ₃ - Organic crop residue @4 tons per ha	107.88	108.90	45.50	47.66
M ₄ Hydrogel @ 5kg/ha	113.60	114.61	48.37	50.11
SE (d)	2.13	2.15	1.49	1.60
CD at 5%	5.32	5.36	3.72	4.01

(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	61.68	63.70	30.83	32.79
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35,50 DAS)	109.38	111.43	41.97	43.96
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35,50 DAS)	110.35	112.38	43.25	45.13
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35,50 DAS)	111.36	113.39	44.04	46.01
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	112.54	114.57	45.19	47.06
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	113.55	115.65	46.02	48.03
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	115.56	117.33	49.00	50.91
SE(d)	1.79	1.82	1.91	2.06
CD at 5%	3.62	3.68	3.86	4.17

Table 4: Effect of moisture conservation practices and fertility levels on nutrient uptake on hybrid maize

Treatments	P Uptake (kg ha ⁻¹) in grain		P Uptake (kg ha ⁻¹) in straw	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ (Conventional tillage two harrowing)	30.80	31.84	25.42	26.48
M ₂ Minimum tillage (one cross ploughing)	28.78	29.82	23.46	24.47
M ₃ - Organic crop residue @4 tons per ha	32.48	33.52	27.63	28.66
M ₄ Hydrogel @ 5kg/ha	34.49	35.53	29.53	30.57
SE (d)	0.6	0.66	0.48	0.50
CD at 5%	1.61	1.66	1.21	1.25
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	17.16	18.20	19.66	20.69
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35,50 DAS)	31.35	32.40	24.99	26.02
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35,50 DAS)	32.42	33.47	26.05	27.09
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35,50 DAS)	33.49	34.54	27.13	28.16
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	34.58	35.62	28.18	29.23
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	35.68	36.72	29.23	30.29
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	36.79	37.81	30.33	31.35
SE(d)	0.54	0.56	0.50	0.56
CD at 5%	1.09	1.13	1.02	1.12

Table 5: Effect of moisture conservation practices and fertility levels on nutrient uptake on hybrid maize

Treatments	K Uptake (kg ha ⁻¹) in grain		K Uptake (kg ha ⁻¹) in straw	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ (Conventional tillage two harrowing)	30.81	31.84	143.82	146.34
M ₂ Minimum tillage (one cross ploughing)	29.53	30.20	139.42	141.94
M ₃ - Organic crop residue @4 tons per ha	31.91	32.58	149.36	151.88
M ₄ Hydrogel @ 5kg/ha	33.00	33.67	154.91	157.43
SE (d)	0.62	0.63	2.83	2.87
CD at 5%	1.55	1.58	7.06	7.17
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	19.84	20.51	113.14	115.66
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35,50 DAS)	31.21	31.88	149.84	152.36
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35,50 DAS)	31.98	32.65	150.86	153.38
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35,50 DAS)	32.77	33.43	151.91	154.43
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	33.65	34.32	152.96	155.48
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	34.46	35.13	154.11	156.63
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	35.28	35.95	155.32	157.84
SE(d)	0.53	0.54	2.51	2.56
CD at 5%	1.08	1.10	5.07	5.16

Table 6: Effect of moisture conservation practices and fertility levels on nutrient uptake on hybrid maize

Treatments	Zn Uptake (g ha ⁻¹) in grain		Zn Uptake (g ha ⁻¹) in straw	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ (Conventional tillage two harrowing)	192.05	196.03	272.54	275.88
M ₂ Minimum tillage (one cross ploughing)	185.57	189.56	266.01	269.34
M ₃ - Organic crop residue @4 tons per ha	197.64	201.63	278.24	281.46
M ₄ Hydrogel @ 5kg/ha	198.63	202.62	279.17	282.50
SE (d)	3.81	3.88	5.16	5.24
CD at 5%	9.51	9.68	N/A	N/A
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	131.68	135.67	220.77	224.09
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35,50 DAS)	201.08	205.07	280.15	283.48

F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35,50 DAS)	202.13	206.12	281.20	284.53
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35,50 DAS)	203.36	207.35	282.43	285.76
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	204.42	208.41	283.49	286.82
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	205.34	209.33	284.40	287.74
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	206.31	210.30	285.50	288.64
SE(d)	3.31	3.38	4.82	4.84
CD at 5%	6.68	6.82	9.73	9.76

Table 7: Effect of moisture conservation practices and fertility levels on Economics (₹ ha⁻¹) on hybrid maize

Treatments	Gross Returns (₹ ha ⁻¹)		Cost of Cultivation (₹ ha ⁻¹)	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ (Conventional tillage two harrowing)	93623	105506	38659	39169
M ₂ Minimum tillage (one cross ploughing)	88733	99945	36722	37232
M ₃ - Organic crop residue @4 tons per ha	96873	109176	39722	40231
M ₄ -Hydrogel @ 5kg/ha	99851	114184	40223	40982
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	75891	86765	39356	39878
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35, 50 DAS)	89878	103776	37737	38429
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35, 50 DAS)	94540	106147	38627	39137
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35, 50 DAS)	96415	108999	39130	39845
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	100165	112642	38648	39158
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	102438	115185	38968	39512
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	104061	116905	39355	39866

Table 8: Effect of moisture conservation practices and fertility levels on Economics (₹ ha⁻¹) on hybrid maize

Treatments	Net Returns (₹ ha ⁻¹)		B:C Ratio	
	2024	2025	2024	2025
(A)Moisture Conservation Practices (Main plot)				
M ₁ (Conventional tillage two harrowing)	55649	66337	2.42	2.69
M ₂ Minimum tillage (one cross ploughing)	52511	62713	2.41	2.68
M ₃ - Organic crop residue @4 tons per ha	57151	68945	2.44	2.71
M ₄ -Hydrogel @ 5kg/ha	61110	73203	2.51	2.78
(B) Fertility levels (sub plot)				
F ₁ - Control (RDF 120:60:40)	36546	46887	1.92	2.17
F ₂ - 50% RDF +2 spray each of nano urea and nano zinc @3ml/ltr each (35, 50 DAS)	54402	65348	2.43	2.70
F ₃ - 50% RDF +2 spray each of nano urea and nano zinc @4ml/ltr each (35, 50 DAS)	56283	67010	2.44	2.71
F ₄ - 50% RDF +2 spray each of nano urea and nano zinc @5ml/ltr each (35, 50 DAS)	57924	69154	2.46	2.73
F ₅ - 75% RDF +1 spray each of nano urea and nano zinc @3ml/ltr each (35 DAS)	61666	73484	2.59	2.87
F ₆ - 75% RDF +1 spray each of nano urea and nano zinc @4ml/ltr each (35 DAS)	63835	75673	2.62	2.91
F ₇ - 75% RDF +1 spray each of nano urea and nano zinc @5ml/ltr each (35 DAS)	64706	77040	2.64	2.93

Conclusion

The study concluded that hydrogel application @ 5 kg ha⁻¹ (M₄) significantly enhanced plant height, number of leaves, nutrient uptake (N, P, K and Zn), and economic returns of hybrid maize compared to other moisture conservation practices. Among fertility levels, 75% RDF along with one foliar spray each of nano urea and nano zinc @ 5 ml L⁻¹ at 35 DAS (F₇) recorded the highest growth attributes, nutrient uptake, gross returns, net returns and benefit-cost ratio during both years of experimentation. Therefore, the combination of hydrogel application and 75% RDF supplemented with nano urea and nano zinc spray can be recommended as an efficient and economically viable strategy for improving productivity, nutrient-use efficiency and profitability of hybrid maize.

References

- Aikins SHM, Afuakwa JJ, Owusu-Akuoko O. Effect of four different tillage practices on maize performance under rain fed conditions. *Agriculture and Biology Journal of North America*. 2012;3(1):25-30.
- Ajithkumar K, Kumar Y, Savitha AS, Ajayakumar M, Narayanaswamy C, Bhat SN. Effect of IFFCO nanofertilizer on growth, grain yield and managing turicum leaf blight disease in maize. *International Journal of Plant and Soil Science*. 2021;33(16):19-28.
- Bala R, Kalia A, Dhaliwal SS. Evaluation of efficacy of ZnO nanoparticles as remedial zinc nano fertilizer for rice. *Journal of Soil Science and Plant Nutrition*. 2019;19:379-389.
- Chapman DH, Parker F. Determination of NPK. In: *Methods of analysis for soils, plants and water*. 1st ed. California: University of California, Agriculture Division; 1961. p. 150-179.
- Sathyan D. Effect of nano nutrients on pea growth and yield (*Pisum sativum* L.). *Journal of Pharmaceutical Innovation*. 2022;11(9):1895-1898.
- Food and Agriculture Organization of the United Nations. *FAO statistical database*. Rome: Food and Agriculture Organization of the United Nations; 2023.
- Jackson ML. *Soil chemical analysis-advanced course: a manual of methods useful for instruction and research in soil chemistry, physical chemistry of soils, soil fertility, and soil genesis*. Madison: Author; 1973.
- Kayode J, Ademiluyi B. Effect of tillage methods on weed control and maize performance in Southwestern Nigeria location. *Journal of Sustainable Agriculture*. 2004;23(3):39-45.

9. Lindsay WL, Norvell W. Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal*. 1978;42(3):421-428.
10. Mahesh RH, Dayal A, Nasakar J, Sharan EA. Effect of particle size and concentration of zinc oxide nanoparticles on growth, yield and yield attributing traits of maize (*Zea mays* L.). *International Journal of Novel Research and Development*. 2022;7.
11. Mahil EIT, Kumar BA. Foliar application of nanofertilizers in agricultural crops: a review. *Journal of Farm Sciences*. 2019;32(3):239-249.
12. Memon SQ, Mirjat MS, Mughal AQ, Amjad N. Effect of conventional and non-conventional tillage practices on maize production. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*. 2013;29(2):155-163.
13. Nair D, Baral KR, Abalos D, Strobel BW, Petersen SO. Nitrate leaching and nitrous oxide emissions from maize after grass-clover on a coarse sandy soil: mitigation potentials of 3,4-dimethylpyrazole phosphate (DMPP). *Journal of Environmental Management*. 2020;260:110165. doi:10.1016/j.jenvman.2020.110165.
14. Ranum P, Peña-Rosas JP, Garcia-Casal MN. Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*. 2014;1312(1):105-112.
15. Verma R, Dwivedi GK, Singh JP, Singh AP, Tamta N, Kumar A. Characterization of synthesized zinc oxide nanoparticles and their effect on growth, productivity and zinc use efficiency of wheat and field pea in the Indian Himalayan foothills. *Current Science*. 2023;124.
16. Samui S, Sagar L, Sankar T, Manohar A, Adhikary R, Maitra S, *et al.* Growth and productivity of rabi maize as influenced by foliar application of urea and nano-urea. *Crop Research*. 2022;57(3):136-140. doi:10.31830/2454-1761.2022.019.
17. Satdev VJ, Chavda BN, Saini LK. Effect of nano ZnO on growth and yield of sweet corn under South Gujarat condition. *International Journal of Conservation Science*. 2020;8(1):63-65.
18. Song R, Wu CS, Mu JM, Xu K. Effect of subsoiling on root growth of maize. *Journal of Jilin Agricultural University*. 2000;22(4):73-80.
19. Uma V, Jayadeva HM, Rehaman HA, Kadalli GG, Umashankar N. Influence of nano zinc oxide on yield and economics of maize (*Zea mays* L.). *Mysore Journal of Agricultural Sciences*. 2019;53(4):44-48.
20. United States Department of Agriculture, Agricultural Research Service. Corn. Washington, DC: United States Department of Agriculture.
21. Wasaya A, Tahir M, Tanveer A, Yaseen M. Response of maize to tillage and nitrogen management. *The Journal of Animal & Plant Sciences*. 2012;22(2):452-456.