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Effect of foliar application of Nano urea and hydrogel on growth and yield of summer maize (*Zea mays* L.)

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Abstract
The field experiment was carried out during the summer season in two successive years of 2022 and 2023 at Krishi Vidnyan Kendra, Gandheli, Chhatrapati Sambhajinagar, Maharashtra. The experiment was laid out in Split Plot Design along with two factors *viz.*, three Nano urea spray (60 Kg N Basal + 30 Kg N 30 DAS + 30 Kg N 45 DAS (Soil applied), 60 Kg N Basal + 30 Kg N 30 DAS(Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS, 60 Kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS) as main plot and (1.5 Kg soil applied Hydrogel,2.5 Kg soil applied Hydrogel,3.5 Kg soil applied Hydrogel,4.5 Kg soil applied Hydrogel) as sub-plot factor treatment along with one control treatment and their combination of 15 treatments replicated thrice. Treatments were randomly arranged in each replication, divided into forty-five plots. Results revealed that the productivity of maize was influenced by Nano urea spray and hydrogel application. On statistical analysis of both the year experiment, it was clearly evaluated that among application of 60 Kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS produced higher growth and yield attributes. Further, in case of hydrogel application of4.5 Kg soil applied Hydrogel (H5) produced higher growth and yield attributes. Therefore, the 60 Kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS with foliar application of application of 4.5 Kg soil applied Hydrogel may be adopted by corn growers to harness the maize production and profitability under the ecological parameters of Maharashtra.

Keywords: Growth, hydrogel, Nano urea spray, phenophases, summer maize, yield

Introduction
Maize (*Zea mays* L.) belongs to family *Poaceae* and it is world third important cereal crop after rice and wheat and is widely cultivated across the world (Sandhu *et al.*, 2007) [10]. The word "maize" is derived from the Spanish word. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is only food cereal crop that can be grown in different seasons and ecologies. Globally it is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 per cent (782 m.ton) in the global grain production. In Maharashtra, area and production of maize is about 1.15 m ha and 3.44 m tonnes respectively with productivity of 3000 kg/ha. The productivity of maize in Marathwada is low (1983 kg/ha) as compared to Maharashtra (Anonymous, 2022) [2]. There are many reasons for the low productivity of maize in Marathwada and Maharashtra *viz.*, Hybrids and varietal selection, nutrient management, weed management, irrigation or water management etc. since maize is voracious feeder and exhaustive crop and required heavy nutrient doses especially of nitrogen, nutrient management is one of the most important for increasing the productivity of crop. The use of nitrogen fertilizers results in higher biomass and protein yield and increases the concentration of protein in the plant tissue. As the protein concentration of corn grain increases, zein makes up an increasing proportion of the protein (Sai *et al.*, 1992) [8]. Nitrogen fertilization also has problem of losses in soil application due to denitrification, volatilization, leaching, fixation and immobilization. To reduce the N losses and improve crop N uptake, it is suggested to increase the utilization efficiency of applied fertilizer.

Nano fertilizers are a novel concept in agricultural nutrient management, and while it is still in its early stages, there is a big push in agriculture for long-term crop development, with Nano-nitrogen playing a significant role. Hydrogel (Super absorbent polymer) is a water retaining, cross-linked hydrophilic, biodegradable amorphous polymer which can absorb and retain water at least 400 times of its original weight and make at least 95 per cent of stored water available for crop absorption (Johnson and Veltkamp, 1985) [14]. When polymer is mixed with the soil, it forms an amorphous gelatinous mass on hydration and is capable of absorption and desorption over long period of time, hence acts as a slow-release source of water in soil. The hydrogel particles may be taken as "miniature water reservoir" in the soil and water will be removed from these reservoirs upon the root demand through osmotic pressure difference. The irrigation requirement of rabi maize is much more (6-7 irrigations) which increases cost of production. Its cultivation may be made more profitable by decreasing the demand of water and the frequency of irrigation.

Material and Methods

The experiment was laid out in field at Mahatma Gandhi Mission, Krishi Vidnyan Kendra, Gandheli, Chhatrapati Sambhajinagar, Maharashtra during summer season of 2022 and 2023.The topography of experimental plot was fairly levelled. The soil was medium black in colour, high retentive of moisture, deep and fairly well drained. Geographically Krishi Vidnyan Kendra, Gandheli, Chhatrapati Sambhajinagar is situated at 19.92° north latitude north latitude and 75.350 east longitude and at 513 m altitudes above sea level and has a semi-arid climate. The mean maximum and minimum temperatures during the cropping period varied from 410C to 270C and 230C to110C during 2022 and 410C to 260C and 230C to 110C during 2023 respectively. The mean relative humidity during morning and evening hours ranged between 61to 83 and 64 to 39 per cent and 62 to 87 and 64 to 39 percent during 2022 and 2023 respectively. The maximum rainfall of 7.0 mm was recorded during summer 2022 in 7thmeteorological week. There was 02 rainy days during entire crop duration in summer 2022 while in 2023, there was no rainfall recorded during period of investigation. The maximum and minimum wind speed of 4.3 to 2.1 Km/hr and 4.2 to 2.1 Km/hr was recorded during 2022 and 2023 respectively during the entire life span of the crop. The climatic condition during crop growth period was sufficient except temperature. This climate favoured form normal growth of the crop of summer maize. The experiment was laid out in Split plot design. The gross and netplot size were 4.5 m x 4.0 m and 4.0 m x 3.0 m, respectively. The experimental field was laid out after preparatory cultivation before sowinginSplit plotdesignconsisting45plots. The field was ploughed twice 15 days before sowing followed by harrowing. Well-decomposed farm yard manure at the rate of 12.5 t/ha was applied uniformly over the field before last ploughing. Bold and healthy seeds were hand dibbled into the soil @ one seed per hill at a depth of 3-5 cm. Bond NMH 007 is a hybrid maize variety. It is suitable for both Kharif and Rabi seasons and typically matures in 105-110 days. Prophylactic measures were taken up against stem borer (Spodoptera litura) and Fall- armyworm by spraying a combination of chlorpyriphos + cypermethrin at 1.5 ml/l and monocrotophos at 1ml/l, using low volume knapsack sprayer. Harvesting of maize crop when husk has turned yellow and grains are hard enough having less than 30 percent moisture. Five plants from the net plot were randomly selected and used for recording observations on growth parameters periodically (50, 75 DAS and at harvest).In order to record the observation on various growth characters at different growth stages, 5 plants were selected randomly from each net plot. These selected plants were labelled for recording biometric observation and harvested separately for assessing per plant yield attributes. The experiment was laid out in split plot design. All the pre and post-harvest observation recorded during different periods with respect to various growth, yield parameter, yields and laboratory studies, were subjected to statistical analysis by adopting the method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984) [5]. The significance of comparison was tested. The significant difference values were computed for 5 percent probability of error. Wherever the variance ratio (F value) was found significant, critical difference (CD) values were computed for the comparison among the treatment means.

Results and Discussion

Growth is an irreversible process of plant phenomenon in which there is an increase in size, space or dry weight or volume plant growth characters were evaluated in term of plant height, number of leaves, stem girth, leaf area index, dry matter accumulation, crop growth rate at different growth stages presented Table 1. Data related to days taken to achieve five (Isttassel, 50% tassel, Ist silking, 50% silking and maturity) phenophases of maize cultivars as affected by Nano urea spray and hydrogel application have been presented in Table 2. Data pertaining to yield attributing characters of maize i.e. number of cobs per plant, cob length, cob girth, number of grains per row, number of grains row per cob, number of grains per cob, weight of per cob, weight of grain per cob and 100 grain weight (seed index) as affected by Nano urea spray and hydrogel application have been presented in Table 3.

Effect of Nano urea spray on Growth and phenophases

At harvest significantly higher plant height was recorded with N3: 60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS, which was on par with N2: 60 kg N Basal + 30 kg N 30 DAS (Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS except N1: 60 kg N Basal + 30 kg N 30 DAS + 30 kg N 45 DAS (Soil applied). This might be attributed due to increase in cell growth as influenced by the nitrogen availability and these results were agreement with the findings of (Samui *et al.* 2022) [9]. Nano urea spray along with application of hydrogel improves plant height vigorously and ultimately better stand of crop. Foliar fertilization or foliar feeding entails the application of nutrients via spraying to plant leaves and stems and their absorption at those sites (Chavan *et al.*, 2023) [4]. Significantly increase no of leaves due to application of N3: 60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS, which was on par with N2: 60 kg N Basal + 30 kg N 30 DAS (Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS except N1: 60 kg N Basal + 30 kg N 30 DAS + 30 kg N 45 DAS (Soil applied). This might be due to with higher fertilizer dose, availability of nutrients especially nitrogen has increased which promoted growth of plants in terms of height and leaves due to rapid cell division and cell elongation. Number of green leaves is also an important parameter which influences the yield and quality of maize. The advantages of foliar fertilizers seaweed help to vigorous growth and development of cell were more noticeable to growing conditions restricting the incorporation of nutrients from the soil. This effect is likely due to the enhanced absorption of Nano urea by plants, leading to a more readily available source of nitrogen for chlorophyll synthesis.

It is apparent from the data (Table 2) that the different Nano urea spray to the maize exerted significant influence on the number of days taken to important phenophases of maize. Among the different spray of Nano urea, 60 kg N Basal + 30 kg N 30 DAS + 30 kg N 45 DAS (Soil applied) took highest number of days for I sttasseling (54), 50% tasseling (57), Ist silking (60), 50% silking (60) and maturity (91) during 2022 followed by 60 kg N Basal + 30 kg N 30 DAS (Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS was noticed to be statistically at par at Istsilking and 50% silking. Similar results were obtained during 2023 and pooled analysis. Increase in days taken was due to application of nitrogenous fertilizers through solid and liquid form to summer maize help to develop and enhance growth with suitable environment and resulted positive. Foliar applications of Nano-urea, especially when combined with soil-based nitrogen, can lead to earlier tasseling and silking, potentially shortening the vegetative growth period. These findings were in accordance with (Santoshi *et al.* 2024) [11].

Effect of Nano urea spray on yield

Among the different spray of Nano urea, application of 60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS is resulted in achieving significantly superior maize grain yield during both the years i.e. 6.81 t/ha in 2022, 6.74 t/ha in 2023 and 6.78 t/ha in pooled mean analysis. Growth and yield attributing characters *viz*. higher plant height, number of cobs, number of grains/cobs, cob weight, seed index and were the main characters which were responsible for higher grain yield of application of 60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS. The grain yield was significantly influenced due to Nano urea spray as well as hydrogel application (H) treatments. The increase in yield attributes might have been owing to better utilization of resources under improved N supply, as it is an integral part of proteins the building blocks of plant (Singh *et al.*, 2000) [12]. The improvement in all these yield attributes might have been due to favourable effect of nitrogen on physiological parameters resulting in the increase of photosynthetic efficiency and subsequent translocation of photosynthates into reproductive organ. These results are in conformity with the findings of (Mehta and Bharat 2019) and (Burondkar *et al.*, 2018) [3, 7].

Effect of hydrogel application on growth and phenophases

With respect to hydrogel application rate of 4.5 kg soil applied Hydrogel recorded significantly higher dry weight than other foliar spray during both the years and pooled mean analysis. However, 3.5 kg soil applied Hydrogel (H4) recorded statistically at par with 4.5 kg soil applied Hydrogel (H5) different growth intervals during both the years and pooled mean analysis. However, lowest plant dry matter was obtained by treatments application with control plot (H1) and 1.5 kg soil applied Hydrogel (H1) both the year of investigation and pooled mean. Hydrogel application in maize can significantly increase plant weight (both fresh and dry) by improving water availability and potentially nutrient uptake. Studies show that maize plants grown in hydrogel-amended soils, especially in drought-prone areas, exhibit higher plant weight compared to control groups. The extent of this increase depends on the hydrogel type, concentration and soil properties. Similar results are found to (Akhter *et al.*, 2004) [1]. Hydrogel application can positively impact SPAD values, especially under drought stress conditions. Hydrogels, by increasing soil moisture retention, can help maintain higher chlorophyll levels in plants, leading to increased SPAD readings. However, the specific effect of hydrogel on SPAD can vary depending on factors like hydrogel concentration, plant species and the presence of other stressors. The benefits are likely due to the hydrogel application in summer maize ability to improve water and nutrient retention in the soil, which allows for enhanced plant growth and development, including stem thickening. Similar results were also reported by (Yazdani *et al.* 2007) [13]. Hydrogel application significantly influenced the days taken to different phenophases of maize. During the year 2022, the maximum days taken to Ist tasselling (53), 50% tasselling (56), Ist silking (58), 50% silking (58) and maturity (90) were recorded under no application of hydrogel i.e. control treatment which was significantly superior among all rest of the hydrogel application except it was followed by application of 1.5 kg soil applied Hydrogel. Similar results were also obtained in pooled analysis. Early maturity, silking and tasseling in maize are crucial stages where hydrogels can significantly impact yield, particularly under water stress conditions. Tasselling, the emergence of the male flower and silking, the emergence of the female flower, are sensitive to water stress, leading to substantial yield reductions if water availability is insufficient during these stages. Similar results confirmed with (Yazdani *et al.*, 2007) [13].

Effect of hydrogel application on yield

With respect to hydrogel application, it is quite clear from the Table 3, that the mean grain yield was varied between 6.02 t/ha in control treatment to 6.20 t/ha in application of 4.5 kg soil applied Hydrogel. Maize crop nourished and treated through hydrogel application and recorded significantly higher grain yield 6.20, 6.19 and 6.20 t/ha during 2022, 2023 and on pooled mean analysis, respectively and it was significantly differed from the other treatments except application of 3.5 kg soil applied Hydrogel and application of 2.5 kg soil applied Hydrogel was noticed on par with the application of 4.5 kg soil applied Hydrogel during both the year of experimentation and pooled mean analysis. The lowest grain yields 6.08, 5.97 and 6.02 t/ha were recorded due to no hydrogel application i.e. control treatment during 2022, 2023 and pooled mean analysis, respectively. It was due to no application hydrogel treatment, plant its failure to contribute maximum growth and yield ultimately. Yield is a complex character which involves the interaction of several intrinsic and external factors. It largely depends upon the production and mobilization of carbohydrates, uptake of water and nutrients from the soil in addition to several environmental factors to which crop is exposed during the growing period (Kumar *et al.*, 2015) [6].

Conclusions

From the experimental finding it is therefore, being concluded that for more productive cultivation among different spray of Nano urea with application of 60 Kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS is more beneficial among rest of the two Nano urea spray. The application of hydrogel with rate 4.5 Kg soil applied Hydrogel was more productive (6.20 t/ha) among rest of the hydrogel application as it supplies adequate moisture in most critical stages of summer maize and stimulate yield compare to other rate of application of hydrogel. Therefore, the different spray of Nano urea with application of 60 Kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS with application of 4.5 Kg soil applied Hydrogel may be adopted by summer maize growers to harness the maize production and profitability under the ecological parameters of Maharashtra.

Table 1: Effect of Nano urea spray and hydrogel application on growth attributes in summer maize on pooled mean basis

Treatments	Growth attributes of summer maize						
	At harvest				100 DAS		
	Plant height (cm)	No of leaves/ plant	Stem girth (cm)	Plant dry weight (g)	SPAD value	Leaf area	Leaf area Index
A. Nano urea spray							
N_1	208.31	10.23	4.21	208.05	35.65	3966.67	197.18
N_2	217.83	10.72	4.57	216.26	38.16	4569.80	210.61
N_3	226.24	11.25	4.88	225.28	40.52	4800.53	219.44
S.Em (±)	0.020	0.012	0.001	0.001	0.004	7.981	0.034
CD @ 5 %	0.080	0.046	0.004	0.003	0.008	31.339	0.135
B. Hydrogel Application							
H_1	216.50	10.71	4.41	213.89	37.70	4434.67	208.18
H_2	217.03	10.4	4.48	216.62	37.82	4476.78	208.69
H_3	217.42	10.73	4.55	217.05	38.02	4442.56	208.96
H_4	217.70	10.74	4.61	217.40	38.24	4457.00	209.18
H_5	218.65	10.76	4.69	217.69	38.75	4417.33	210.38
S.Em (±)	0.026	0.029	0.001	0.002	0.004	6.948	0.047
CD @ 5 %	0.077	0.086	0.004	0.005	0.008	20.281	0.138
C. Interaction (A x B)							
S.Em (±)	0.079	0.088	0.004	0.005	0.012	20.845	0.142
CD @ 5 %	0.231	0.258	0.011	0.015	0.025	60.842	0.415
Mean	217.46	10.73	4.55	216.53	38.11	4417.33	209.08

N_1:60 kg N Basal + 30 kg N 30 DAS + 30 kg N 45 DAS (Soil applied),N_2:60 kg N Basal + 30 kg N 30 DAS(Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS, N_3:60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS, H_1:Control, H_2:1.5 kg soil applied Hydrogel,H_3:2.5 kg soil applied Hydrogel,H_4:3.5 kg soil applied Hydrogel,H_5:4.5 kg soil applied Hydrogel

Table 2: Phenophases studies of summer maize as influenced by Nano urea spray and hydrogel application on pooled mean basis.

Treatments	Day taken (days)				
	I tasseling	50% tasseling	I silking	50% silking	Maturity
A. Nano urea spray					
N_1	56	57	61	62	94
N_2	54	55	60	60	92
N_3	51	53	57	57	88
S.Em (±)	0.069	0.069	0.052	0.052	0.044
CD @ 5 %	0.271	0.271	0.204	0.204	0.128
B. Hydrogel Application					
H_1	55	56	61	61	92
H_2	54	55	60	60	91
H_3	53	55	60	60	91
H_4	53	55	59	59	91
H_5	52	54	59	59	91
S.Em (±)	0.049	0.049	0.044	0.044	0.131
CD @ 5 %	0.144	0.144	0.128	0.128	0.384
C. Interaction (A x B)					
S.Em (±)	0.148	0.148	0.131	0.131	0.131
CD @ 5 %	0.431	0.431	0.384	0.384	0.384
Mean	53	55	60	60	91

N_1:60 kg N Basal + 30 kg N 30 DAS + 30 kg N 45 DAS (Soil applied),N_2:60 kg N Basal + 30 kg N 30 DAS(Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS, N_3:60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS, H_1:Control, H_2:1.5 kg soil applied Hydrogel,H_3:2.5 kg soil applied Hydrogel,H_4: 3.5 kg soil applied Hydrogel,H_5:4.5 kg soil applied

Table 3: Effect on yield attributes of summer maize as influenced by Nano urea spray and hydrogel application on pooled mean basis

Treatments	Yield attributes of summer maize								
	No. of cob/plant	Cob length	Cob girth	Number of grain/cob	Number of grain row/cob	Cob weight (g)	No. grain/ cob	Grain weight /cob	Seed index (g)
A. Nano urea spray									
N_1	1.73	19.56	19.88	397.00	13.85	139.12	397.00	58.49	31.08
N_2	1.91	19.85	20.00	483.30	15.18	142.77	483.30	61.63	32.17
N_3	1.97	20.65	20.23	564.73	16.49	152.81	564.73	63.55	32.80
S.Em (±)	0.015	0.054	0.031	0.333	0.005	0.043	0.333	0.034	0.001
CD @ 5 %	0.045	0.240	0.098	1.307	0.019	0.168	1.307	0.133	0.005
B. Hydrogel application									

H_1	1.75	19.99	19.42	455.17	14.55	144.82	455.17	60.81	31.56
H_2	1.87	20.02	20.01	470.61	14.81	144.65	470.61	61.24	31.84
H_3	1.76	20.01	19.65	482.83	15.23	144.85	482.83	61.37	32.08
H_4	1.89	20.55	19.98	492.78	15.52	144.95	492.78	61.27	32.25
H_5	1.95	21.01	20.15	507.00	15.75	145.22	507.00	61.45	32.34
S.Em (±)	0.012	0.075	0.065	0.363	0.006	0.041	0.363	0.044	0.001
CD @ 5 %	0.036	0.215	0.105	1.059	0.017	0.118	1.059	0.129	0.004
C. Interaction (A x B)									
S.Em (±)	0.039	0.225	0.0215	1.088	0.018	0.122	1.088	0.132	0.004
CD @ 5 %	0.106	0.654	0.456	3.176	0.052	0.355	3.176	0.386	0.013
Mean	1.89	20.30	20.23	481.68	15.17	144.90	61.22	61.68	32.02

N_1:60 kg N Basal + 30 kg N 30 DAS + 30 kg N 45 DAS (Soil applied),N_2:60 kg N Basal + 30 kg N 30 DAS(Soil applied) + (4 ml/L) spray of Nano Urea 45 DAS, N_3:60 kg N Basal + (4 ml/L) spray of Nano Urea 30 DAS + (4 ml/L) spray of Nano Urea 45 DAS, H_1:Control, H_2:1.5 kg soil applied Hydrogel,H_3:2.5 kg soil applied Hydrogel,H_4:3.5 kg soil applied Hydrogel,H_5:4.5 kg soil applied Hydrogel

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