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Influence of Nano Fertilizers on Growth and Yield of Maize

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Abstract

The field experiment entitled 'Influence of nano fertilizers on growth and yield of maize' was carried out during *Kharif* - 2021 and 2022 at L - block, GKVK, Bengaluru. There were 11 treatments laid out in Randomized Complete Block Design. replicated thrice. The treatments consisted of T_1 - (No nitrogen), T_2 - 100 per cent RDF as per PoP (UASB), T_3 - 50 per cent RDN + foliar spray of nano - N at 30 and 50 DAS, T_4 - 50 per cent RDNP + foliar spray of nano - NP at 30 and 50 DAS, T_5 - Foliar spray of only nano - N at 30, 50 and 70 DAS, T_6 - Foliar spray of only nano - NP at 30, 50 and 70 DAS, T_7 - 25 per cent RDN + foliar spray of nano - N at 30, 50 and 70 DAS, T_8 - 25 per cent RDNP + foliar spray of nano - NP at 30, 50 and 70 DAS, T_9 - 100 per cent RDN + NDVI based nano - N spray, T_{10} - 100 per cent RDN + NDVI based nano - NP spray and T_{11} - 100 per cent RDN + NDVI based conventional urea spray. The crop was raised by following the package of practices (150 : 75 : 40 kg NPK ha^{-1}). For all the treatments recommended dose of potassium was applied uniformly. The results indicated that application of 100 per cent RDN + NDVI based nano - N spray recorded higher plant height (223.8 cm), leaf area at 90 DAS (10238 cm^2 $plant^{-1}$), Greens Seeker reading at 50 and 70 DAS after spray (0.59 and 0.73 respectively), cob length and cob girth (20.8 cm and 5.55 cm) and higher kernel and stover yield (7751 and 8955 kg ha^{-1} respectively) over other treatments and was par with 100 per cent RDN+NDVI based conventional urea spray and 100 per cent RDN as per package of practices.

Keywords : Conventional urea, Green seeker, Nano-N, Nano-NP

Maize (*Zea mays* L.) is the third most important food crop after rice and wheat, and plays a significant role in both the Indian and global agricultural economies. It serves as a vital source of food and fodder. Maize grains are used for human consumption, feed for poultry and livestock. Globally it is being cultivated in an area of 214 million hectares with a production of 1444 million tonnes and productivity of 6.74 t ha^{-1} (2022). The USA stands as main producers of maize followed by China, Brazil, Argentina and India. In India, it occupies an area of 9.95 m ha with production of 34.61 million tonnes and the productivity of 3.38 t ha^{-1}, which is less than half of the world productivity. In Karnataka it occupies an area of 1.5 9 million hectares, with the production of 5.22 million tonnes and productivity of 3.20 t ha^{-1} (Anonymous, 2022).

Synthetic fertilizers greatly impact the world's food security and without which, there would be only half of the amount of food production that we are producing now. About 35-40 per cent of the crop productivity depends upon fertilizer (Rameshaiah., *et al*., 2015). These applied fertilizers are also

subjected to various types of losses such as leaching, volatilization, denitrification, fixation etc. which reduces their efficiency. Based on recent fertilizer use efficiency studies it is identified that the efficiency of fertilizer nitrogen is only 30-40 per cent in rice and 50-60 per cent in other cereals, while the efficiencies of fertilizer phosphorus, potassium are 15-20 per cent, 45-70 per cent in most of the crops (Rakshit, 2012)

Latest technologies such as controlled release technique and targeted delivery of agrochemicals (fertilizers and pesticides) for plant nutrition and pest control, increase food safety and security. Nano fertilizers or nano-encapsulated nutrients have the properties to release nutrients effectively on-demand that regulate plant growth and enhance target activity (Derosa *et al*., 2010). The nano-coated materials enhance the penetration via stomata with a size exclusion limit above 10 nm (Perez, 2017). In addition to this, nano-carriers transport the nutrients in the right place and right time acts as the right source, reducing the extra amount of active chemicals deposited into the plant system and increasing nutrient use efficiency. Nano-fertilizers have a high surface area, sorption capacity and controlled-release kinetics to targeted sites and have been considered the smart delivery system (Rameshaiah *et al*., 2015).

Foliar application of nano fertilizers is being researched in India to see if they might boost nutrient production and improve plant nutrition when compared to regular fertilizers. The usage of nano fertilizers extends the time and rate of element release in the plant system, allowing it to match plant nutritional requirements. The plant can absorb the maximum amount of nutrients, resulting in an increase in crop yield.

Green Seeker is an integrated optical sensor and application system that measures crop nitrogen status and variably applies the crop's nitrogen requirements. Yield potential for a crop is identified using a vegetative index known as NDVI (normalized difference vegetative index) and an environmental factor. These sensors use visible and near-infrared (NIR) spectral response from plant canopies to detect N stress. Chlorophyll contained in the palisade layer of the leaf absorbs 70 to 90 per cent of all incident light in the red wavelength band. Reflectance of the NIR electromagnetic spectrum (720-1300 nm) depends upon mesophyll cells which scatter and reflect as much as 60 per cent of all incident NIR radiation (Puneet, 2011) and (Gurunath Raddy, 2022). Nitrogen (N) is then recommended based on yield potential and the responsiveness of the crop to additional nitrogen. Considering the above mentioned facts the present study is planned to investigate the effect of nano fertilizers on growth and yield of maize.

Material and Methods

A field experiment on influence of nano fertilizers on growth and yield of maize (*Zea mays* L.) was conducted during *kharif*-2021 and 2022 at Integrated Farming System demonstration block (L-block), Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. The site of experimentation was in Agro Climatic Zone V (Eastern Dry Zone) of Karnataka, located in 12º 51' N Latitude and 77º 35' E Longitude at an altitude of 930 m above mean sea level (MSL). The soil of the experimental site is red sandy loam with coarse sand (32.50%), fine sand (31.70%), Silt (6.70%) and Clay (29.10%) as soil components. The soil reaction was neutral (6.18) with an EC of 0.22 dS m^{-1}, medium in available nitrogen (292 kg ha^{-1}), available phosphorus (52.7 kg ha^{-1}) and available potassium (188.5 kg ha^{-1}). There were 11 treatments laid in Randomized Complete Block Design and replicated three times. The treatments were T_1 - (Nonitrogen), T_2 - Nitrogen management as per the PoP (UASB), T_3 - 50 per cent RDN + foliar spray of nano nitrogen at 30 and 50 DAS, T_4 - 50 per cent RDNP + foliar spray of nano NP at 30 and 50 DAS, T_5 - only foliar spray of nano nitrogen at 30, 50 and 70 DAS, T_6 - only foliar spray of nano NP at 30, 50 and 70 DAS, T_7- 25 per cent RDN + foliar spray of nano nitrogen at 30, 50 and 70 DAS T_8 : 25 per cent RDNP + foliar spray of nano NP at 30, 50 and 70 DAS, T_9 : 100 per cent RDN+ NDVI based nano-nitrogen spray,T_{10} : 100 per cent RDN + NDVI based nano - NP spray and T_{11} : 100 per cent RDN + NDVI based conventional urea spray. The crop was raised using a standard package of

practices for all other aspects. For all the treatments, the recommended dose of potassium was applied commonly. High yielding, disease tolerant, stay green single cross maize hybrid MAH - 14 - 5 suitable for all seasons was selected for the study.

Green Seeker is an optical sensor that emits and measures reflected light at two different wave lengths *viz.,* one in the visible spectrum (660 nm) and another one in the near-infrared spectrum (770 nm). Measured spectral reflectance is expressed as spectral vegetation indices such as NDVI. NDVI values range from 0 to 1.0 If NDVI values are below 0.3 (15-30 DAS) applied 25 kg ha^{-1} nitrogen, if values are in between 0.3 to 0.5 (45- 60 DAS) applied 25 kg ha^{-1} nitrogen, if it is not in the range no nitrogen was applied and values are more than 0.7 no need to apply additional nitrogen (Puneet, 2011). If NDVI value less than 0.3 (15-30 DAS). Instead of 25 kg ha^{-1} of nitrogen, we applied one spray of nano nitrogen. The growth observations were recorded at different growth stages *i.e.*, at 30, 60, 90 DAS and at harvest.

Results and Discussion

The data relevant to plant height of maize at different growth stages as influenced by nitrogen management practices through nano fertilizers are depicted in Table 1. The data clearly shows that plant height steadily increases with increase in age of the plant irrespective of treatments imposed. The extent of increase was higher between 30 to 60 DAS and lesser during later stages.

At 30 DAS, the plant height of hybrid maize was not significantly influenced by nitrogen management through nano fertilizer. Where as, at 60 DAS, significantly higher plant height (202.0 cm) was noticed under 100 per cent RDN + NDVI based nano-nitrogen spray, this was on par with 100 per cent RDN as per PoP, 100 per cent RDN + NDVI based conventional urea spray and 100 per cent RDN + NDVI based nano nitrogen and phosphorus spray (197.9, 194.0 and 190.5 cm respectively). While, significantly lower plant height was observed in T_1 control (135.6 cm). At 90 DAS and at harvest, significantly higher plant height was recorded with the treatment receiving 100 per cent RDN + NDVI based nitrogen management through nano nitrogen spray (217.5 and 223.8 cm) compared to other treatments and followed by 100 per cent RDN + NDVI based conventional urea spray, 100 per cent RDN+ NDVI based nano nitrogen and phosphorus spray and 100 per cent RDN as per PoP (212.4, 210.4 and 209.1 and 218.4, 216.3 and 215.1 cm, respectively) which are on par with each other. No nitrogen treatment resulted in significantly lower plant height (147.6 and 154.3 cm, respectively). Initially higher plant height was noticed with application of 100 per cent RDN as per PoP. However, during later stages, the application of nano nitrogen through foliar spraying led to enhanced plant height might be due to spraying of nano nitrogen based on NDVI value synchronized with the crop demand, resulted in higher nutrient uptake and increased cell division and growth (Raddy *et al*., 2022). Nano particles can move more easily within the plant and facilitating for better distribution of nutrients which helped in growth of new cells there by increased plant height (Asha Kiran, 2022). Similar results were noticed by Samui *et al*, (2022) and Prakasha *et al*, (2020).

The data pertaining to leaf area at different growth stages of hybrid maize as influenced by nitrogen management through nano fertilizer on pooled basis is interpreted in Table 2.

At 30 DAS, Leaf area did not differ significantly between the treatments as influenced by nitrogen management through nano fertilizer in maize. At 60 DAS, application of 100 per cent RDN along with NDVI based nano nitrogen spray significantly recorded higher leaf area (8594 cm^2 $plant^{-1}$) which was on par with application of 100 per cent RDN as per PoP, 100 per cent RDN + NDVI based conventional urea spray and 100 per cent RDN+ NDVI based nano nitrogen and phosphorus spray (8403, 8239 and 8133 cm^2 $plant^{-1}$, respectively). Where as, significantly lower leaf area was noticed with no nitrogen treatment (5635 cm^2 $plant^{-1}$). At 90 DAS and at harvest, significantly higher leaf area (10238 and 9916 cm^2 $plant^{-1}$) was noticed in plot

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TABLE 1

Plant height (cm) of maize at 30, 60 and 90 DAS and at harvest as influenced by nitrogen management through nano fertilizers

Treatment	30 DAS			60 DAS			90 DAS			At harvest		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	32.49	33.68	33.08	134.2	137.1	135.6	146.5	148.7	147.6	153.2	155.4	154.3
T_2	36.61	38.05	37.33	196.3	199.5	197.9	207.8	210.5	209.1	214.1	216.1	215.1
T_3	34.26	34.87	34.57	179.5	182.3	180.9	194.3	196.5	195.4	200.7	202.6	201.6
T_4	34.75	35.37	35.06	182.3	185.5	183.9	197.8	200.2	199.0	204.0	206.0	205.0
T_5	29.42	29.09	29.25	154.8	157.6	156.2	168.1	170.8	169.5	174.4	176.4	175.4
T_6	30.16	31.04	30.60	155.8	158.4	157.1	169.0	171.7	170.4	175.3	177.2	176.3
T_7	32.75	33.21	32.98	166.7	169.5	168.1	180.7	183.5	182.1	187.1	189.0	188.0
T_8	33.06	34.51	33.79	169.5	172.3	170.9	183.7	186.5	185.1	190.1	192.0	191.1
T_9	35.87	37.10	36.49	200.3	203.7	202.0	216.4	218.6	217.5	222.9	224.7	223.8
T_{10}	35.06	35.83	35.44	189.1	191.9	190.5	209.0	211.8	210.4	215.3	217.3	216.3
T_{11}	35.05	35.79	35.42	192.5	195.4	194.0	211.0	213.8	212.4	217.4	219.3	218.4
F test	NS	NS	NS	*	*	*	*	*	*	*	*	*
S.Em.±	1.54	1.74	1.62	4.2	4.6	4.4	4.6	4.8	4.7	5.8	5.9	5.9
CD at 5%	-	-	-	12.3	13.4	12.8	13.4	14.1	13.7	17.1	17.4	17.3

TABLE 2

Leaf area (cm2 plant-1) of maize at 30, 60 and 90 DAS and at harvest as influenced by nitrogen management through nano fertilizer

Treatment	30 DAS			60 DAS			90 DAS			At harvest		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	1843	1855	1849	5510	5760	5635	7041	7058	7049	6718	6746	6732
T_2	2067	2099	2083	8386	8420	8403	9926	9991	9959	9603	9635	9619
T_3	1988	2011	1999	7664	7697	7681	9298	9377	9338	9003	9035	9019
T_4	2010	2034	2022	7785	7817	7801	9465	9544	9504	9142	9174	9158
T_5	1845	1864	1854	6609	6640	6625	8032	8110	8071	7709	7741	7725
T_6	1866	1900	1883	6653	6684	6669	8077	8116	8097	7754	7786	7770
T_7	1946	1975	1961	7118	7149	7134	8643	8721	8682	8320	8352	8336
T_8	1947	2011	1979	7238	7270	7254	8787	8866	8826	8482	8514	8498
T_9	2046	2079	2063	8587	8602	8594	10187	10289	10238	9900	9932	9916
T_{10}	2019	2043	2031	8110	8157	8133	9944	10057	10000	9621	9652	9636
T_{11}	2022	2049	2035	8222	8255	8239	10020	10155	10087	9697	9728	9712
F test	NS	NS	NS	*	*	*	*	*	*	*	*	*
S.Em.±	56	57	55	152	178	161	170	173	171	163	157	160
CD at 5%	-	-	-	447	522	480	509	517	512	477	460	468

which received 100 per cent RDN along with NDVI based nano nitrogen spray. However, it was on par with treatment receiving 100 per cent RDN + NDVI based conventional urea, 100 per cent RDN + NDVI based nano DAP and 100 per cent RDN as per the PoP (10087, 10000 and 9959 cm^2 $plant^{-1}$ and 9712, 9636 and 9619 cm^2 $plant^{-1}$, respectively). In no nitrogen treatment significantly, lower leaf area (7049 and 6732 cm^2 $plant^{-1}$) was observed.

In this investigation, initially (up to 30 DAS) higher leaf area was noticed with application of 100 per cent RDN as per PoP, during later stages (up to 90 DAS) leaf area was higher with foliar spray of NDVI based nano nitrogen then gradually decreased at harvest. The decrease in leaf area at harvest due to senescence of lower leaves. Higher leaf area was noticed in 100 per cent RDN + NDVI based nano nitrogen, this was might be due to foliar application of nitrogen in nano form having sufficient nitrogen molecule and higher surface area of nano particle favors more absorption of nitrogen. Adequate supply of nitrogen based on NDVI value at right concentration could helped in production of greater number of leaves due to reduced competition between the plant for nutrients and finally it helped in higher leaf area. To maintain the higher leaf area there should be a greater number of leaves which in turn depends on plant height (Krishna Desai and Mudalagiriyappa, 2022). Results are in line with the findings of Ajithkumar *et al*., (2021) and Mallikarjuna (2021).

The data on Green Seeker readings before and 7 days after spray of nano fertilizers at 30 and 50 DAS as influenced by nitrogen management through nano fertilizers as depicted in Fig. 1. The Green Seeker reading of maize leaf (NDVI values) significantly varied before and after spray of nano fertilizer at 30 DAS. Before spray of nano fertilizer, significantly higher Green Seeker reading (0.42) was observed with 100 per cent RDN as per PoP compared to other treatments and lower Green Seeker reading was noticed under no nitrogen treatment (0.26).

Significantly higher Green Seeker reading was observed seven days after spray of nano fertilizer at 30 DAS in 100 per cent RDN along with NDVI based nano nitrogen spray (0.46), while it was on par with T_{10} - 100 per cent RDN + NDVI based nano - NP spray, T_{11} - 100 per cent RDN + NDVI based conventional urea spray, T_3 - 50 per cent RDN + foliar spray of nano-N at 30 & 50 DAS and T_4 - 50 per cent

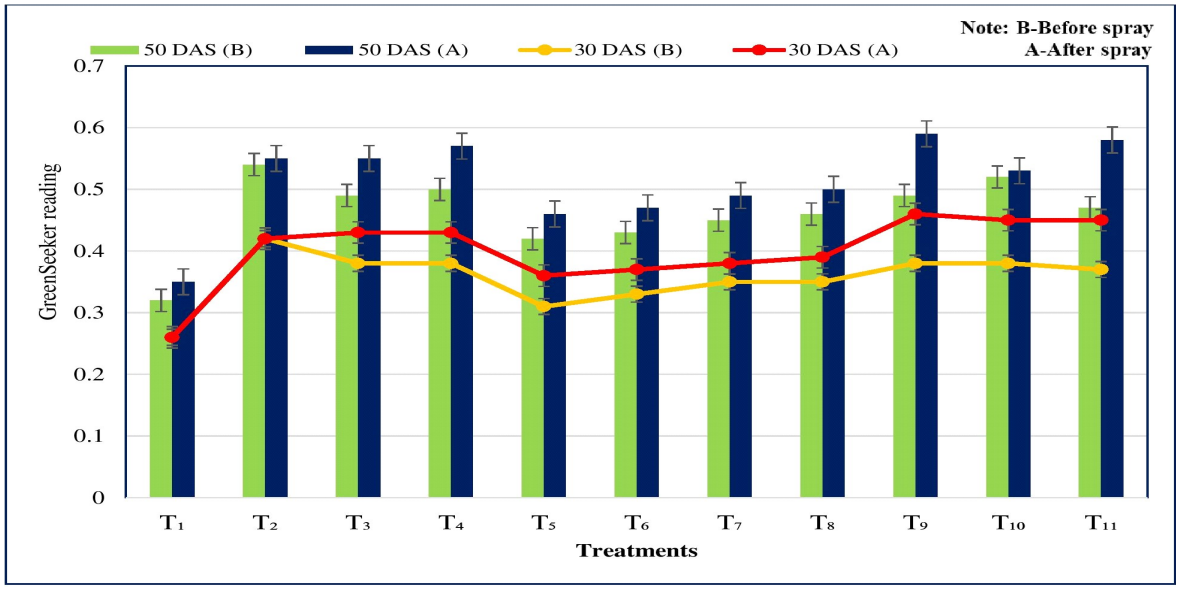

Fig. 1 : Green Seeker readings (NDVI) before and after spray of nano fertilizers at different growths stages as influenced by nitrogen management through nano fertilizers in maize

RDNP + foliar spray of nano-NP at 30 and 50 DAS (0.45, 0.45, 0.43 and 0.43 respectively). Lower Green Seeker value observed in no nitrogen treatment (0.26).

At 50 DAS before spray, Green Seeker readings varied significantly during before and after spray of nano fertilizer. Application of 100 per cent RDN as per PoP (0.54) recorded significantly higher Green Seeker reading, followed by, T_{10} - 100 per cent RDN + NDVI based nano-NP spray (0.52). Where as significantly lower Green Seeker value observed in no nitrogen treatment (0.32).

After spray of nano fertilizer at 50 DAS, Green Seeker value varied significantly between different treatments. In 100 per cent RDN along with NDVI based nano nitrogen spray recorded significantly higher Green Seeker reading (0.59), followed by T_{11} - 100 per cent RDN + NDVI based conventional urea spray, T_4 - 50 per cent RDNP + foliar spray of nano-NP at 30 and 50 DAS and T_3 - 50 per cent RDN + foliar spray of nano-N at 30 and 50 DAS (0.58, 0.57 and 0.55, respectively). And lower Green Seeker value observed in no nitrogen treatment (0.35).

The Green Seeker reading of maize leaf (NDVI values) significantly varied at before and after first spray of nano fertilizer at 70 DAS. Before spray of nano fertilizer, significantly higher Green Seeker reading (0.68) was found in 100 per cent RDN + NDVI based nano nitrogen spray compared to other treatments and lower Green Seeker reading was found in no nitrogen treatment (0.26).

After spray of nano fertilizer at 70 DAS, Green Seeker value varied significantly between different treatments. Plant supplied with 100 per cent RDN along with NDVI based nano nitrogen spray recorded significantly higher Green Seeker reading (0.73), followed by T_{11} - 100 per cent RDN + NDVI based conventional urea spray, T_{10} - 100 per cent RDN + NDVI based foliar spray of nano-NP (0.71 and 0.69). And significantly lower Green Seeker value observed in no nitrogen treatment (0.44).

TABLE 3

Green Seeker reading before and after spray at 70 DAS as influenced by nitrogen management through nano fertilizer in maize

Treatment	Before spray			After spray		
	2021	2022	Pooled	2021	2022	Pooled
T_1	0.41	0.43	0.42	0.44	0.44	0.44
T_2	0.63	0.63	0.63	0.66	0.68	0.67
T_3	0.60	0.62	0.61	0.63	0.63	0.63
T_4	0.60	0.63	0.62	0.63	0.65	0.64
T_5	0.47	0.49	0.48	0.53	0.55	0.54
T_6	0.50	0.51	0.50	0.55	0.57	0.56
T_7	0.52	0.54	0.53	0.57	0.59	0.58
T_8	0.53	0.55	0.54	0.58	0.60	0.59
T_9	0.67	0.69	0.68	0.72	0.75	0.73
T_{10}	0.57	0.58	0.57	0.68	0.70	0.69
T_{11}	0.66	0.68	0.67	0.70	0.72	0.71
F test	*	*	*	*	*	*
S.Em.±	0.01	0.01	0.01	0.01	0.01	0.01
CD at 5%	0.03	0.04	0.03	0.03	0.04	0.04

Increase in green Seeker reading (NDVI value) after nano nitrogen and phosphorus spray at all the stages was mainly due to smaller particle size and increased surface area of nano fertilizers which easily enter the epidermis of plant leaves resulted in higher nutrient absorption through leaves in turn increased the chlorophyll content which resulted in higher growth parameters *viz.,* plant height, number of leaves and leaf area, which in turn increased crop canopy cover and biomass production. Higher the NDVI value indicating that higher biomass production. The findings are consistent with findings of Pruthviraj (2022), Mallikarjuna (2021) and Gurunath Raddy (2022).

The results relevant to number of cobs plant^{-1} as affected by nitrogen management practices through nano fertilizers in maize on pooled basis are mentioned in Table 4

Significantly higher number of cobs per plant was observed in plant supplied with 100 per cent RDN + NDVI based nano nitrogen spray (1.32 plant^{-1}). It was found on par with T_{11} - 100 per cent RDN + NDVI based conventional urea spray, T_{10} - 100 per cent RDN + NDVI based nano nitrogen and phosphorus spray and 100 per cent RDN as per the package of practices (1.28, 1.27 and 1.27 plant^{-1}, respectively). Significantly lesser number of cobs per plant was observed in without nitrogen treatment (1.06 plant^{-1}).

Application of 100 per cent RDN+ NDVI based nano nitrogen spray noticed significantly higher cob length (20.8 cm) and cob girth (5.52 cm) were found on par with T_{11} - 100 per cent RDN +NDVI based conventional urea spray (19.8 cm and 5.34 cm), T_{10} - 100 per cent RDN + NDVI based nano nitrogen and phosphorus spray (19.5 cm and 5.26 cm) and 100 per cent RDN as per the package of practices (19.4 cm and 5.05 cm). No nitrogen treatment recorded significantly lower cob length and cob girth (13.2cm and 4.09 cm, respectively).

Kernel yield varied significantly among the treatments. Application of 100 per cent RDN along

TABLE 4

Number of cobs, cob length and cob girth of maize as affected by nitrogen management through nano fertilizers

Treatment	No. of cobs plant-1			Cob length (cm)			Cob girth (cm)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	1.04	1.09	1.06	12.9	13.5	13.2	4.03	4.15	4.09
T_2	1.25	1.28	1.27	19.2	19.6	19.4	5.00	5.10	5.05
T_3	1.19	1.21	1.20	17.3	17.5	17.4	4.75	4.83	4.79
T_4	1.21	1.23	1.22	17.7	18.0	17.8	4.88	4.95	4.92
T_5	1.12	1.14	1.13	14.9	15.1	15.0	4.41	4.53	4.47
T_6	1.14	1.16	1.15	15.3	16.0	15.7	4.57	4.70	4.64
T_7	1.16	1.18	1.17	16.6	16.9	16.7	4.62	4.77	4.70
T_8	1.18	1.20	1.19	17.0	17.5	17.3	4.73	4.88	4.81
T_9	1.30	1.33	1.32	20.5	21.1	20.8	5.49	5.55	5.52
T_{10}	1.25	1.28	1.27	19.3	19.6	19.5	5.21	5.31	5.26
T_{11}	1.27	1.29	1.28	19.5	20.0	19.8	5.31	5.38	5.34
F test	*	*	*	*	*	*	*	*	*
S.Em.±	0.02	0.03	0.02	0.41	0.47	0.44	0.15	0.16	0.15
CD at 5%	0.06	0.08	0.06	1.20	1.39	1.29	0.45	0.47	0.45

T_1 : Control; No nitrogen

T_2 : Nitrogen management as per PoP

T_{11} : 100 % RDN + NDVI based conventional urea spray

T_9 : 100% RDN + NDVI based nano nitrogen spray

Plate 1 : comparison of different treatment as influenced by nitrogen management through nano fertilizers in maize

TABLE 5

Kernel yield, stover yield and harvest index of maize as influenced by nitrogen through nano fertilizers in maize

Treatment	Kernel yield (kg ha-1)			Stover yield (kg ha-1)			Harvest index		
	2021	2022	2021	2021	2021	2022	2021	2022	Pooled
T_1	3585	3704	3644	4779	4828	4804	0.428	0.433	0.430
T_2	7273	7287	7280	8769	8790	8780	0.452	0.452	0.452
T_3	6414	6553	6483	7918	7963	7941	0.447	0.451	0.449
T_4	6505	6635	6570	7984	8003	7993	0.449	0.454	0.451
T_5	4644	4795	4719	5949	6035	5992	0.439	0.443	0.441
T_6	4845	4929	4887	6260	6358	6309	0.436	0.437	0.436
T_7	5604	5726	5665	6693	6709	6701	0.456	0.460	0.458
T_8	5796	5918	5857	6868	6889	6879	0.457	0.462	0.460
T_9	7729	7772	7751	8948	8963	8955	0.461	0.462	0.461
T_{10}	7463	7482	7472	8869	8826	8848	0.450	0.451	0.451
T_{11}	7548	7563	7556	8845	8861	8853	0.451	0.452	0.451
F test	*	*	*	*	*	*	NS	NS	NS
S.Em.±	143	147	142	133	140	131	0.010	0.011	0.010
CD at 5%	419	432	417	390	411	384	-	-	-

with NDVI based nano nitrogen spray recorded significantly higher kernel yield (7751 kg ha^{-1}), which was on par with application of 100 per cent RDN + NDVI based conventional urea spray, 100 % RDN + NDVI based nano DAP spray (7556 & 7472 kg ha^{-1}, respectively). Control treatment recorded significantly lower kernel yield (3644 kg ha^{-1}) compared to other treatments.

Similarly, same trend was observed in stover yield, in which significantly higher stover yield (8955 kg ha^{-1}) was noticed in plot which received 100 per cent RDN along with NDVI based nano nitrogen spray. However, it was on par with treatment received 100 per cent RDN + NDVI based conventional urea, 100 per cent RDN + NDVI based nano DAP and 100 per cent RDN as per the PoP (8853, 8848 and 8780 kg ha^{-1}, respectively). In no nitrogen treatment significantly, lower stover yield (4804 kg ha^{-1}) was observed.

The increasing in the kernel yield of maize was mainly due to improvement in yield attributing parameters and it is governed by the factors which have direct or indirect impact. The factors which have direct influence on the grain yield are the yield components and its accumulation into various plant parts have an indirect influence on grain yield through the yield components, which in turn depends on different growth components *viz*., plant height, leaf area and chlorophyll content in leaf. These results are in corroborative with findings of Trinh *et al*. (2008), Gheysari *et al*. (2009), Lamptey *et al.* (2017), Chen *et al*. (2017) and Wang *et al*. (2019). And also, synergetic effect of nutrient applied to the soil and foliar spray of nano fertilizer which enhanced the nitrogen uptake resulting in higher kernel yield by Chandana *et al*. (2021).

Harvest Index indicates the percentage of dry matter partitioned and accumulated in the economic portion. In the current investigation, harvest index didn't show any significant difference due to nitrogen management through nano fertilizers.

Higher growth, yield attributes, kernel and stover yield in the cultivation of maize can be achieved with application of 100 per cent RDN along with NDVI based nano nitrogen spray. On the basis of results obtained under present investigation and possible reasons for their unevenness having discussed, the following conclusions were drawn. Maize kernel yield (7751 kg ha^{-1}) and stover yield (8955 kg ha^{-1}) were significantly higher with the application of 100 per cent RDN along with NDVI based foliar spray of nano nitrogen which was followed by 100 per cent RDN along with NDVI based foliar spray of conventional urea (7556 and 8861 kg ha^{-1}). Green Seeker based nano nitrogen spray will help to increase nitrogen use efficiency and save the nitrogen in maize.

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