EFFECT OF NITROGEN MANAGEMENT THROUGH NANO FERTILIZERS ON GROWTH, YIELD ATTRIBUTES AND YIELD OF MAIZE (*Zea mays* L.)

Abstract

A field experiment on "Effect of nitrogen management through nano fertilizers on growth, yield attributes and yield of maize (*Zea mays* L.)" was carried out during *Kharif*2022-23 at Integrated Farming System demonstration unit, L-block, GKVK, Bengaluru, consisting 11 treatmentsreplicated thrice and laid out in Randomized Complete Block Design. The treatments consisted of T_1-(No nitrogen), T_2-Nitrogen management as per package of practices (UASB), T_3-50%RDN+foliar spray of nano-N at 30 and 50 DAS, T_4-50%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%RDN+foliar spray of nano-N at 30, 50 and 70 DAS, T_8-25%RDNP+foliar spray of nano-NP at 30, 50 and 70 DAS, T_9-100% RDN+NDVI based nano-N spray, T_{10}-100% RDN+NDVI based nano-NP spray and T_{11}-100% RDN+NDVI based conventional urea spray. The resultsrevealed that application of 100%RDN+NDVI based nano-N spray recorded higher plant height (229.3 cm), number of leaves at 90 DAS (15.76), dry matter production (354.9 g plant^{-1}), GreenSeeker readingat 30, 50 and at 70 DAS after spray (0.43, 0.58 and 0.73, respectively), cob length, cob girth and cob weight (20.5 cm, 5.49 cm and 201.9 g plant^{-1}, respectively) and higher kernel and stover yield (7729 and 8948 kg ha^{-1}, respectively)over other treatments and on it was par with 100% RDN+NDVI based conventional urea spray and 100% RDN + NDVI based nano NP spray.

Key words: Conventional urea, Foliar spray, GreenSeeker, Nano-nitrogen

INTRODUCTION

Maize (*Zea mays*) is one of the important cereal crops with wide adaptability to various agro-climatic conditions in the world.It holds the top position with respect to production in the world. In India, it ranks third after rice and wheat. The maize is being called "Queen of cereals" due to its higher production potential. Maize grains are used for human consumption, feed for poultry and livestock. In India it is cultivated an area of 9.95 million hectare with production of 34.61million tonnes and productivity of 3.38t ha^{-1}. In Karnataka it occupies an area of 1.59 million hectares, with the production of 5.22 million tonnes and productivity of 3.20 t ha^{-1}(Anon., (2).

Maize is an exhaustive crop and requires a balanced supply of the entire 3 major nutrient (N, P and K). The hybrids of maize are very responsive to external supply of nutrients. Application rate of nutrient depends on soil nutrient status.Conventional fertilizers greatly impact the global food security and without which, there would be only half of the amount of food production that we are producing now. About 35-40% of the crop productivity depends upon fertilizer(Rameshaiah., *et al*. (21). These applied conventional fertilizers are subjected to various types of losses such as leaching, volatilization, denitrification, and 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% in rice and 50-60% in other cereals, while the efficiencies of fertilizer phosphorus, potassium are 15-20%, 45-70% in most of the crops (Rakshit, (20).

Latest technologies such as controlled release technique and targeted delivery of agrochemicals (fertilizers and pesticides) for plant nutrition and pest control and thus, increase food safety and security. Nano fertilizers. have theproperties to release nutrients effectively on-demand that regulate plant growth andenhance target activity (Derosa*et al*., (7). The nano-coated materials enhance thepenetration via stomata with a size exclusion limit above 10 nm (Perez, (15). Inaddition to this, nano-carriers transport the nutrients in the right place and right timeacts as the right source, reducing the extra amount of active chemicals deposited intothe plant system and increasing nutrient use efficiency. Nanofertilizers have a highsurfacearea,sorptioncapacityandcontrolledreleasekineticstotargetedsitesandhavebeenconsidered thesmartdeliverysystem

Foliar application of nano fertilizers is being researched in India to see if theymight boost

nutrient production and improve plant nutrition when compared to regularfertilizers. The usage of nano fertilizers extends the time and rate of element release intheplantsystem,allowingittomatchplantnutritionalrequirements.Asaresponse,theplant can absorb the maximum amount of nutrients, resulting in an increase in cropyield.

Material and methods

A field experiment was conducted during *kharif*2022-23 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). There were 11 treatments laid inRandomized Complete Block Design and replicated three times. The treatments were T_1- (No-nitrogen), T_2- Nitrogen management as per the PoP (UASB), T_3- 50% RDN + foliar spray of nano nitrogen at30 and 50 DAS, T_4- 50% RDNP+ foliar spray of nano NP at 30 and 50 DAS, T_5-only foliar spray of nano nitrogen at 30, 50 and70DAS, T_6-only foliar spray of nano NP at 30, 50 and70DAS,T_7- 25%RDN + foliar spray of nano nitrogen at 30, 50 and 70 DAS T_8-25%RDNP + foliar spray of nano NP at 30,50 and 70 DAS, T_9-100% RDN+ NDVI based nano-nitrogen spray,T_{10}-100%RDN+ NDVI based nano-NP spray and T_{11}-100% 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 suitablefor all seasons was selected for the study.

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}). The experimental data obtained at different growth stages was compiled and subjected to statistical analysis by adopting Fischer's method of analysis of variancetechnique as outlined by Gomez and Gomez (9).The level of significance used in 'F' test was p = 0.05.The critical difference (CD) value was given in the table at 0.05 per cent level of significance.

GreenSeeker is an optical sensor technology used in agriculture to assess and manage

crop health, particularly with regard to nitrogen management. It works by emitting and measuring the reflection of light at two specific wavelengths one in the visible spectrum (660 nm) and other inthe near-infrared spectrum (770 nm). Measured spectral reflectance is expressed as spectral vegetationindices such as Normalized Difference Vegetation Index (NDVI). NDVI is a valuableindicator of crop health and more specifically, the nitrogen status of the crop canopy. NDVI valuestypically range from 0 to 1higher value indicating healthier and nitrogen rich vegetation. For instance,if NDVI values are below 0.3 between 15-30 DAS, application of 25 kg ha^{-1}nitrogen is recommended, if values are below 0.5 between 45-60 DAS, application of 25 kg ha^{-1}nitrogen is recommended. When NDVI values reach more than 0.7 between 70 DAS - silking, noadditional nitrogen application. (Puneet, (18) and Gurunath Raddy, (10).

Results and Discussion

Growth attributes: Phenotypic character of plants is vital in realizing the crops potentialoutput. The data pertaining to plant height, number of leaves and dry matter production at various growth stages under the influence of nitrogen management practices using nano fertilizers is presented in Table 1.

At 30 DAS, there were no significant differences in plant height between the treatments. Whereas, at 60, 90 DAS and at harvest,application of 100% RDN + NDVI based foliar spray of nano nitrogen recorded significantly higher plant height (200.3, 216.4 and 222.9 cm, respectively) and it was on par with 100% RDN + NDVI based conventional urea spray(196.3, 211.0 and 217.4 cm, respectively), 100% RDN + NDVI based nano NP spray (192.5, 209.0 and 215.3 cm respectively) and nitrogen management as per package of practice (189.1, 207.8 and 212.1 cm respectively). Whereas, treatment with no nitrogen treatment recorded significantly lower plant height at 60, 90 DAS and at harvest (134.2,146.5 and 152.9 cm, respectively). Initially, a greater plant height was observed with nitrogen management as package of practices. Nevertheless, in the later stages, 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 both from root as well from leaves in turn increased cell division and growth (Raddy *et al*., (19). 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, (3). Similar results were noticed by Samui *et al*, (22) and Prakasha *et al*, (16).

Table 1: Plant height and number of leaves of maize as influenced by nitrogenmanagementthroughnano fertilizers

Treatments	Plant height (cm)				Number of leaves per plant			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	32.49	134.2	146.5	152.9	6.29	9.81	10.67	10.01
T_2	36.61	189.1	207.8	212.1	7.06	13.23	15.13	13.50
T_3	34.26	179.5	194.3	200.7	6.62	12.46	14.15	12.72
T_4	34.75	182.3	197.8	204.0	6.72	12.66	14.40	12.91
T_5	29.42	154.8	168.1	174.4	5.72	10.75	12.24	10.96
T_6	30.16	155.8	169.0	175.3	5.86	10.82	12.31	11.04
T_7	32.75	166.7	180.7	187.1	6.35	11.57	13.16	11.81
T_8	33.06	169.5	183.7	190.1	6.40	11.77	13.38	12.01
T_9	35.87	200.3	216.4	222.9	6.92	13.77	15.76	14.06
T_{10}	35.06	192.5	209.0	215.3	6.77	13.37	15.22	13.64
T_{11}	35.05	196.3	211.0	217.4	6.77	13.65	15.37	13.93
F test	NS	*	*	*	NS	*	*	*
S.Em±	1.54	4.2	4.6	5.8	0.29	0.30	0.33	0.31
CD at 5%	-	12.3	13.4	17.1	-	0.87	0.98	0.90

NS – Non-significant *-Significant

Number of leaves per plant didn't varied significantly at different growth stages of maize as influences by nitrogen management through nano fertilizers. Whereas, at 60, 90 DAS and at harvest, significantly more number of leaves per plant (13.77, 15.76 and 14.06, respectively) were recorded with application of 100% RDN + NDVI based foliar spray of nano nitrogen and it was on par with 100% RDN + NDVI based conventional urea spray (13.65, 15.37 and 13.93, respectively), 100% RDN + NDVI based nano DAP spray (13.37, 15.22 and 13.64, respectively) and nitrogen management as per package of practice (13.23, 15.13 and 13.50, respectively). Whereas, no nitrogen treatment recorded significantly lesser number of leaves per plant at 60, 90 DAS and at harvest (9.81, 10.67 and 10.01, respectively).

In case of dry matter production per plant significantly higher total dry matter production was observed under treatment received with 100% RDN + NDVI based foliar spray of nano nitrogen (100.5, 300.7 and 354.9 g plant^{-1}, respectively) at 60, 90 and at harvest and it was it was on par with 100% RDN + NDVI based conventional urea spray (97.4, 292.5 and 346.5 g plant^{-1}, respectively), 100% RDN + NDVI based nano DAP spray (95.8, 290.5and 344.6 g plant^{-1}, respectively) and nitrogen management as per package of practice (95.2, 288.6 and 341.2 g plant^{-1}, respectively). Whereas, control treatment recorded significantly lesser number of leaves per plant at 60, 90 DAS and at harvest (64.2, 197.7 and 228.7 g plant^{-1}, respectively) presented in Table 2.

Table 2: Total dry matter production and days to 50% tasseling of maize as influenced by nitrogenmanagement throughnano fertilizers

Treatments	Dry matter production (g plant^{-1})				Days to 50% tasseling
	30 DAS	60 DAS	90 DAS	At harvest	
T_1	15.5	64.2	197.7	228.7	61.6
T_2	17.9	95.2	288.6	341.2	61.5
T_3	16.8	89.8	270.5	320.7	59.8
T_4	17.1	91.3	276.3	327.6	59.9
T_5	15.1	77.1	235.8	280.0	60.3
T_6	15.2	77.7	237.1	281.5	60.3
T_7	16.2	83.2	253.8	301.2	58.6
T_8	16.3	84.7	258.1	306.3	58.7
T_9	17.6	100.5	300.7	354.9	59.1
T_{10}	17.2	96.8	290.5	344.6	59.6
T_{11}	17.2	97.4	292.5	346.5	59.8
F test	NS	*	*	*	NS
S.Em±	0.64	2.14	5.52	6.53	1.27
CD at 5%	-	6.28	16.20	19.15	-

NS – Non-significant *-Significant

Initially (up to 30 DAS) higher dry matter accumulation was observed in nitrogen management as per package of practice treatment due to adequate quantity of nutrient available for crop growth and establishment. During later stages both soil application and NDVI based foliar spray of nano nitrogen improved dry matter production in plant which is mainly due to spraying of nano nitrogen based on NDVI value synchronized with the crop demand, nano particles easily enter plant epidermis due to higher surface area of the particles resulted in higher nutrient uptake and enhanced the photosynthetic activity in turn production of more photosynthates resulted in higher plant height and leaf area and reflected on higher dry matter production. These results are in conformity withWang *et al*. (24), Chandana *et al*. (4) and Choudhary *et al*. (6).

There was no significant difference between the treatments in case of days to 50 per cent tasseling. But, numerically lesser daysto attained 50 per cent tasseling with application of 25% RDN + nano nitrogen spray 30, 50 and 70 DAS(58.6 days) followed by 25%RDNP + foliar spray of nano DAP at 30, 50 and 70 DAS (58.7). While higher number of days required to attain 50 per cent tasseling in no nitrogen treatment (61.6) and nitrogen management as per PoP (61.2).

GreenSeeker reading

The data regarding GreenSeeker readings before and 7 days after spray of nano fertilizers at 30, 50 and 70 DAS asinfluenced by nitrogen management through nano fertilizers depicted in figure 1. The NDVIvalue of maize leaf (GreenSeeker reading) significantly varied before and 7 days after spray of nano fertilizer at 30 DAS. Before spray of nano fertilizer, significantly higher GreenSeeker reading (0.42) was observed with 100% RDN as per PoP compared to other treatments and lower GreenSeeker reading was noticed under no nitrogen treatment (0.25).Significantly higher GreenSeeker reading was observed seven days after spray of nano fertilizer at 30 DAS in 100%RDN along with NDVI based nano nitrogen spray (0.43) Whereas, lower GreenSeeker value observed in no nitrogen treatment (0.26).

At 50 DAS before spray, GreenSeeker readings varied significantly during before and after spray of nano fertilizer. Application of nitrogen management as per PoP recorded significantly higher GreenSeeker reading (0.53), followed by 100% RDN + NDVI based nano-N spray (0.52). Whereas significantly lower GreenSeeker reading was observed in no nitrogen

treatment (0.31).After spray of nano fertilizer at 50 DAS, GreenSeeker readings varied significantly Application of 100% RDN + NDVI based nano DAP spray recorded higher GreenSeeker reading (0.60), followed by 100% RDN + NDVI based nano nitrogen spray, 100% RDN + NDVI based conventional ureaspray(0.58, and 0.57, respectively). Whereas, lower NDVI value was observed with no nitrogen treatment (0.34).

At 70 DAS. Before spray of nano fertilizer, significantly higher NDVI reading (0.70) was noticed in 100% RDN+NDVI based nano DAP spray compared to other treatments and lower GreenSeeker reading was noticed in no nitrogen treatment (0.41). Seven days after spray of nano fertilizer at 70 DAS, GreenSeeker reading varied significantly. Plant supplied with application of 100% RDN along with NDVI based nano nitrogen spray recorded higher GreenSeeker reading (0.74), followed by 100% RDN + NDVI based conventional urea spray, 100% RDN +NDVI based foliar spray (0.70 and 0.72, respectively).

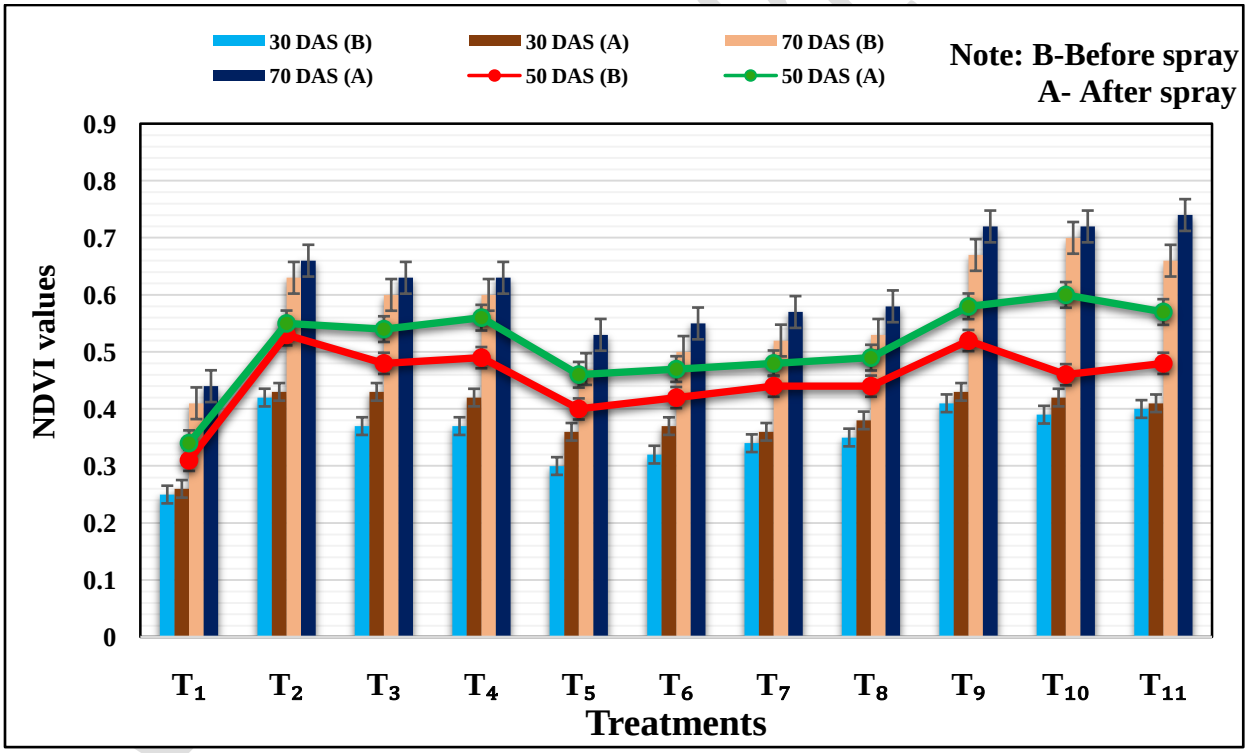

Fig.1: NDVI values (GreenSeeker readings) before and seven days after spray of nano fertilizers at different growths stages as influenced by nitrogen management through nano fertilizers in maize

Increased in GreenSeeker reading (NDVI value) after nano nitrogen and phosphorus spray at all the stages mainly due to smaller particles size and increased surface area of nano fertilizer easily

enter the epidermis of plant leaves resulted in higher nutrient absorption through leaves along with roots, in turn increased the chlorophyll content these higher the NDVI value indicating that higher biomass production. Krishna Desaiand Mudalagiriyappa(11), Mallikarjuna (13) and Gurunath Raddy (10).

Yield attributes

The datarespect to number of cobs plant^{-1}, cob length and cob weight plant^{-1}as affected by nitrogen managementpractices through nano fertilizers in maizeon arementioned in Table3.

Significantly higher number of cobs per plant, cob length, cob girth and cob weight per plant wererecorded in plant supplied with 100%RDN + NDVI based nano nitrogen spray (1.30 plant^{-1}, 20.5 cm, 5.49 cm and 201.9 g plant^{-1}, respectively), It was found on par with application 100%RDN +NDVI based conventional urea spray(1.27 plant^{-1}, 19.5 cm, 5.31 cm and 196.5 g plant^{-1}, respectively), 100 % RDN +NDVI based nano DAP spray (1.25 plant^{-1}, 19.3 cm, 5.21 cm and 192.0 g plant^{-1}, respectively)and 100% RDN as per the package of practices (1.23, 19.0 cm, 5.00 cm and 188.6 g plant^{-1}, respectively). Whereas, significantly lesser number of cobs per plant,cob length, cob girth and cob weight per plant wererecorded with treatment of no nitrogen treatment (1.04 plant^{-1}, 12.9 cm, 4.03 cm and 118.7 g plant^{-1}).This was due to the fact thatnanofertilizers stimulate the enzymes activityby integrating with the creation of chlorophyll in most plants, this led to acceleration in the synthesis of growth hormones, results in a heightened production of carbohydrates within plants (Afshar*et al*. (1) andParmarsnehalbhai, (14).

Maize kernel yield differed significantly among the treatments. Application of 100% RDN along with NDVI based nano nitrogen spray recorded significantly higher kernel yield (7772 kg ha^{-1}),which was on par with application of100% RDN + NDVI based conventional urea spray, 100% RDN + NDVI based nano DAP spray and 100% RDN as per the package of practices(7563, 7481 and 7281 kg ha^{-1} respectively). Control treatment recorded significantly lower kernel yield (3585 kg ha^{-1}) compared to other treatments.

Similarly, same trend was observed in stover yield, in which significantly higher stover yield (8948 kg ha^{-1}) was noticed in plot which received 100% RDN along with NDVI based nano

Table 3: Number of cobs, cob length, cob girth and cob weight per plant of maize as affected by nitrogen management through nano fertilizers

Treatment	No. of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	Cob weight plant^{-1}	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
T_1	1.04	12.9	4.03	118.7	3585	4779	0.42
T_2	1.25	19.2	5.00	188.6	7273	8769	0.45
T_3	1.19	17.3	4.75	175.3	6414	7918	0.44
T_4	1.21	17.7	4.88	179.7	6505	7984	0.44
T_5	1.12	14.9	4.41	150.3	4644	5949	0.43
T_6	1.14	15.3	4.57	153.7	4845	6260	0.43
T_7	1.16	16.6	4.62	166.9	5604	6693	0.45
T_8	1.18	17.0	4.73	169.2	5796	6868	0.45
T_9	1.30	20.5	5.49	201.9	7729	8948	0.46
T_{10}	1.25	19.3	5.21	192.0	7463	8869	0.45
T_{11}	1.27	19.5	5.31	196.5	7548	8845	0.45
F test	*	*	*	*	*	*	NS
S.Em±	0.02	0.41	0.15	4.99	142	133	0.01
CD at 5%	0.06	1.20	0.45	14.63	418	390	-

NS – Non-significant *-Significant

nitrogen spray. However, it was on par with treatment received 100% RDN + NDVI based conventional urea, 100% RDN + NDVI based nano DAP and nitrogen management as per the PoP (8868, 8845 and 8769 kg ha^{-1}, respectively). might be duetoimprovement in yieldattributingparameters and it is governed by the factors which have direct or indirect impact. Thefactors which have direct influence on the grain yield are the yield components and itsaccumulation into various plant parts have an indirect influence on grainyield through theyield 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 ofTrinh *et al*. (23), Gheysari*et al*. (8), Lamptey *et al*. (12), Chen *et al*. (5) andWang*et al*. (24).Harvest Index indicates the percentage of dry matter partitionedand accumulated inthe economic portion. In the current investigation, harvest index didn't show any significantdifferencedueto nitrogen

management through nano fertilizers.

Conclusion

Higher growth, yield attributes, kernel and stover yield in the cultivation of maize can be achieved with application of 100% RDN along with NDVI based nano nitrogen spray. On the basis of results obtained under present investigation and possible reasons for their unevenness having discussedand the following conclusions were drawn. Maize kernel yield (7772 kg ha^{-1}) and stover yield (8948 kg ha^{-1}) were significantlyhigher with the application of 100% RDN along with NDVI based foliar spray of nano nitrogen which was followed by 100% RDN along with NDVI based foliar spray of conventional urea (7548 and 8845 kg ha^{-1}). GreenSeeker based nano nitrogen spray will help to increase nitrogen use efficiency and save the nitrogen in maize.

References

1. Afshar I, Akbar R, and Minoo S. Comparison of the effects ofspraying different amounts of nano zinc oxide and zinc oxide. International Journal of Advanced Biological and Biomedical Research, 2014;2(4): 318-325.
2. Anonymous, Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Govt of India, 2022.
3. Asha Kiran K. Studies on influence of nano nitrogen and phosphorus on growth and yield of maize (*Zea mays* L.).M.Sc.Thesis, submitted to University of Agricultural Sciences,Bengalore 2022,
4. Chandana P, Latha KR, Chinnamuthu CR, Malarvizhi P and Lakshmanan A. Impact of foliar application of nanonitrogen,zincandcopper onyieldand nutrient uptakeofRice.International Journal of Plant & Soil Science, 2021;33(24): 276-282.
5. Chen H, Chen S, Zheng S, Shen X and liu D. Regulationeffectsof adding nitrogen on physiological properties and yield of rapeseed after waterloggingduringseedling. Soil, 2017;49:519–526.
6. Choudhary P, Singh D, Kaushik MK, Sharma SS, Jain HK, Saharan V, Singh DP, Sharma RK and Chouhan D. Production, productivity andquality of maize (*Zea mays* L.) as affected by foliar application of zincbased nano fertilizeranddifferent fertility levels.The Pharma Innovation Journal, 2022;11(2): 1878-1882.

7. Derosa MR, Monreal C, Schnitzer M, Walsh R and Sultan Y. Nanotechnologyin fertilizers. Nature Nanotechnology, 2010;5:91.
8. Gheysari M, Mirlatifi SM, Homaee M, Asadi ME andHoogenboom G. Nitrate leaching in a silage maize field under differentirrigationand nitrogen fertilizer rates.Agricultural water management. 2009;96: 946–954.
9. Gomez KA. and Gomez AA. Statistical Procedure for Agricultural Research –An International Rice Research Institute, A Wiley Inter science, John Wiley and SonsIncNewYork, USA. 1984.
10. Gurunath Raddy, Investigation on sensor based irrigation and nitrogen management in maize (*Zea mays* L.).Ph.D. Thesis, submitted to University of Agricultural Sciences, Bengalore 2022,
11. Krishna Desai and Mudalagiriyappa, Next generation technology for nutrient and water management inmaize(*Zea mays* L.). Mysore Journal of Agricultural Sciences, 2022;56 (1):1- 13.
12. Lamptey S, Li L, Xie J, Zhang R, Yeboah S. and Antille DL. Photosynthetic response of maize to nitrogen fertilization in the semiarid westernloessplateau of China. Crop Sciences, 2017; 57: 2739–2752.
13. Mallikarjuna PR. Effect of nano nitrogen and nano zinc nutrition on nutrientuptake, growth and yield of irrigated maize during summer in the southern transition zoneofKarnataka. M.Sc. (Agri.)Thesis, University of Agricultural Sciences,Shivmogga, 2021.
14. Parmar Snehalbhai J. Effect of ZnO nanoparticles on germination,growth and yield of Groundnut (*Arachis hypogea* L.). Ph.D. (Agri.) Thesis,Submittedto Anand Agriculture University, Anand. 2016,
15. Perez DE. Luque A. Interaction of nano materials with plants:whatdo weneedforrealapplicationsin agriculture. Frontiers in Environmental Science, 2017;5: 12.
16. Prakasha G, Mudalagiriyappa, Somashekar KS. And Goudra S. Anovelapproachforincreasingproductivityunderprecisionnitrogenmanagementinmaize(*Zea mays*L.)throughcropsensors.Journal of Pharmacognosy and Phytochemistry, 2020;9(5):

97-103.

17. Pruthviraj N, Geetha KN, Prakash SS, Jayadeva HM, Pushpa K. and Shankar AG. Impact of different methods of nano fertilizers applicationon soil chemical properties and fertility status in sunflower growing soils. Mysore Journal of Agricultural Sciences, 2022;56 (1): 275-284.

18. Puneet S. Nitrogen management in rice using chlorophyll meter and GreenSeekeropticalsensor.M.Sc.(Agri.)Thesis,Punjab Agriculture University, Ludhiana, 2011.

19. Raddy G, Jayadeva, HM, Hanumantappa DC, Lalitha BS, Kadalli GG and Ramachandrappa CT, Effectofsensorbased irrigationandnutrientmanagementongrowth,yield attributes and yieldofbabycorn(*Zea mays*L.). Mysore Journal of Agricultural Sciences,2022;56 (4): 155-166.

20. Rakshit. Customized fertilizers: Marker in fertilizerrevolution". International Journal of Agriculture Environment and Biotechnology, 2012;51: 67-75.

21. Rameshaiah GN, Pallavi J. and Shabnam S. Nanofertilizers andnanosensors-Anattemptfordevelopingsmartagriculture.International journal of engineering research and general science, 2015;3: 314-320.

22. Samui S, Sagar L, Sankar T, Manohar A, Rahul A, Sagar M and Subhashisa P. Growth and productivity of rabi maize as influenced by foliarapplicationofureaand nano-urea. Crop Research, 2022;57(3): 136-140.

23. Trinh QK, Pham S. and Christian W. Improving of maize yield andprofitability through site-specific nutrient management (SSNM) and planting density.OMONRICE, 2008;16:88-92.

24. Wang X, Miao Y, Dong R, Chen Z, Guan Y, Yuexuezhi, Fang Z and David M. Developingactivecanopysensor-basedprecisionnitrogenmanagementstrategies formaizeinNortheast China. Sustainability, 2019;11:706