Mysore J. Agric. Sci., 57 (2) : 286-293 (2023)

Effect of Nano Phosphorus Fertilizers on Growth and Yield of Maize (*Zea mays* L.) in Central Dry Zone of Karnataka

C. M. RASHMI AND S. S. PRAKASH
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : rashucm132@gmail.com

AUTHORS CONTRIBUTION

C. M. RASHMI :
Research carried out, wrote manuscript and data analysis;
S. S. PRAKASH :
Planning of research work, corrected the manuscript and provided facilities to conduct research

Corresponding Author :
C. M. RASHMI
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065

Received : August 2022
Accepted : January 2023

ABSTRACT

A field experiment was conducted during *Kharif* 2021 in farmer's field at Halavarthy village of Davanagere district, Karnataka, which comes under Central Dry Zone of Karnataka (Zone 4), using RCBD with eleven treatments and three replications to evaluate the impact of three different nano phosphorus fertilizers on the productivity of maize. Treatments included T_1: Absolute control, T_2: 100 per cent recommended package of practice (RPP), T_3 to T_5: 75 per cent RDP (75% recommended dose of P) through SSP + 5 per cent RDP through NP1(hydroxyapatite nano fertilizer), NP2 (nano rock phosphate) and NP3 (hydroxyapatite nanoparticles coated with CMC), T_6 to T_8 : 75 per cent RDP + 1 per cent RDP through foliar spray of NP1, NP2 and NP3, T_9 to T_{11}: 75 per cent RDP + 5 per cent RDP through soil application of NP1, NP2 and NP3 and 1 per cent RDP through foliar spray of NP1, NP2 and NP3, respectively. Results revealed that application of phosphorus in nano form had significant effect on growth and yield of maize. Treatment with 75 per cent RDP through SSP + 5 per cent RDP through soil application of NP1 + 1 per cent RDP through foliar spray of NP1 recorded significantly higher plant height, number of leaves plant^{-1}, chlorophyll content, dry matter accumulation, cob length (19.01 cm), number of rows cob^{-1} (16.27), number of kernels row^{-1} (35.27), test weight (33.20 g), stover yield (82.23 q ha^{-1}) and kernel yield (73.59 q ha^{-1}) over absolute control and were better when compared to T_2 (100 % RPP).

Keywords : Hydroxyapatite nanoparticles, Nano rock phosphate, Coated hydroxyapatite nanoparticles, Carboxy methyl cellulose, Maize productivity, Yield attributes

PHOSPHORUS (P) along with other nutrient elements plays a central role in achieving food and nutritional security of ever growing population of the world. In the absence of any one of the essential nutrients makes it impossible to achieve this goal. Among the essential nutrients, potential reserve of P resource is dwindling in the world, if exhausted it spell a dooms day on crop production. On the other hand, only 15 to 20 per cent of the applied P being utilized by crop. The low P use efficiency in crop production reported may be attributed to the faster rate of conversion of applied P into non available forms as a result of its reaction with soil chemical constituents (Ca, Fe or Al). The efforts are underway to make use of such fixed P by using PSB or mobilizing using VAM. Even under such circumstances the P use efficiency still remains low. With recent advances happened in material science in the synthesis of nano materials/ products for variety of uses, the fertilizer industry too started using the nano technology for the synthesis of nano fertilizers, which have many advantages over conventional nutrient carrier fertilizer materials in crop production. Employing nanotechnology in synthesis and formulations of nano fertilizers and their subsequent use is regarded as a breakthrough in achieving higher nutrient use efficiency with minimum environmental risk. Nano P fertilizers are those which contain conventional P fertilizers or rock phosphate or hydroxyapatite encapsulated in nanomaterials or coated with a thin protective nano scale polymeric film or delivered as nanoemulsions or nanoparticles. Nano fertilizers release nutrients into the soil gradually in a sustained manner. The controlled release of nutrient may reduce the loss of nutrient from soil. Nano coatings on fertilizer particles can hold the material more strongly when sprayed on the plant due to the higher surface tension. Nano material increases the plant uptake efficiency of nutrients and reduce the adverse impacts of conventional fertilizer application thus, enhances the growth and yield of crops. Thus, realizing the importance of nano fertilizers in crop nutrition, an experiment was conducted with the objective to study the 'Effect of synthesized nano phosphorus fertilizers on growth and yield of maize'

Material and Methods

A field experiment was conducted during *Kharif* 2021 in farmer's field at Halavarthy village of Davanagere district, Karnataka, which comes under Agro Climatic Zone-4, Central Dry Zone of Karnataka. It lies between 76°08' E longitude and 14°39' N latitude with an altitude of 690 ± 04 m above mean sea level. The experiment consisted of eleven treatment combinations *viz.,* T_1: Absolute control, T_2: 100 per cent recommended package of practice (RPP), T_3 to T_5: 75 per cent RDP (75% recommended dose of P) through SSP + 5 per cent RDP through NP1 (hydroxyapatite nano fertilizer), NP2 (nano rock phosphate) and NP3 (hydroxyapatite nanoparticles coated with CMC) respectively, T_6 to T_8: 75 per cent RDP through SSP + 1 per cent RDP through foliar spray of NP1,NP2 and NP3 respectively, T_9 to T_{11}: 75 per cent RDP through SSP + 5 per cent RDP through soil application of NP1, NP2 and NP3 + 1 per cent RDP through foliar spray of NP1, NP2 and NP3, respectively.

Synthesis of Nano Phosphorus Fertilizers

Three types of nano phosphorus fertilizers *viz.,* hydroxyapatite nanoparticles (NP1), nano rock phosphate (NP2) and hydroxyapatite nanoparticles coated with carboxy methyl cellulose (NP3) were synthesized in laboratory as per the standard protocol. Hydroxyapatite nanoparticles were synthesized using chemical synthesis method as described by Mateus *et al.* (2007) using aqueous solution of calcium hydroxide (1M) and orthophosphoric acid (85%). Rock phosphate nano fertilizer was prepared by ball-milling the rock phosphate till it reaches nano size. Nano hydroxyapatite particles were coated with CMC as per the method described by Liu and Lal (2014) using nano hydroxyapatite and carboxy methyl cellulose powder and the prepared material was characterized using XRD, SEM, EDS and FTIR. The phosphorus (P) content in these synthesized NP1, NP2 and NP3 was 15.82, 9.48 and 15.03 per cent, respectively.

Initial Physico-chemical Properties of the Soil at Experimental Site

The texture of soil was sandy loam with 72.18 per cent sand, 9.86 per cent silt and 17.96 per cent clay. The soil was nearly neutral (pH: 6.97) in reaction, low in organic carbon content (4.34 g kg^{-1}) and normal with respect to salt content (0.124 ds m^{-1}). The available nitrogen content was low (183.56 kg ha^{-1}), phosphorus was medium (27.29 kg P_2O_5 ha^{-1}) and potassium was medium (373.16 kg K_2O ha^{-1}) and medium in micro nutrients.

Collection of Growth and Yield Parameters

Five plants from each treatment in all three replications were labelled to collect growth and yield attributes of maize. Growth observations were taken at 30, 60, 90 DAS and at harvest. Plant height was measured from base of plant to the base of fully opened top most leaf and expressed in centimetre. Number of leaves per plant was recorded by counting fully opened leaves, the relative chlorophyll content of maize leaves was measured by placing chlorophyll meter at 20 to 25 cm above on one side of the mid rib of the leaf blade, midway between the leaf base and leaf tip between 8 to 9 AM in morning or between 5 to 6 PM in evening hours. Cob length was measured from base to tip of cob, from all the five cobs collected from tagged plants. Number of rows per cob and number of kernels per row were recorded by counting them manually. Test weight was recorded by weighing hundred grains from each treatment and expressed in grams.

Results and Discussion

Growth Parameters

Data on growth parameters of maize presented in Tables 1 and 2 indicated that nano phosphorus fertilizers application either through soil and or foliar spray recorded significantly higher growth parameters of maize *viz.,* plant height, number of leaves per plant, chlorophyll meter reading and dry matter production than absolute control. At 30 DAS, significantly higher plant height of 33.55 cm was recorded in T_2 (100% RPP) than absolute control but was on par with all other treatments that received phosphorus through conventional and nano sources (T_3 to T_{11}) 20 per cent less than normal recommended P dose. Significantly maximum number of leaves per plant (7.27), chlorophyll meter reading (461.23) and dry matter production (11.13 g plant^{-1}) were recorded in the T_9 treatment that received 75 per cent RDP through SSP + 5 per cent RDP - NP1+ FS of 1 per cent RDP - NP1 over absolute control (T_1) but it was on par with the treatments T_2 to T_{11}.

At 60 DAS, 90 DAS and at harvest, plant height (195.18, 202.72 and 203.98 cm, respectively), number of leaves per plant (13.66, 15.03 and 13.10, respectively), chlorophyll meter reading (496.33, 364.00 and 139.17, respectively) and dry matter production (101.57, 147.64 and 162.72 g plant^{-1}, respectively) were significantly higher in treatment T_9 that received 75 per cent RDP through SSP + 5 per cent RDP - NP1+ FS of 1 per cent RDP - NP1 over absolute control (T_1). However, it was on par with

Table 1

Effect of nano P fertilizers on plant height (cm), number of leaves plant^{-1} of maize at different growth stages

Treatments	Plant height (cm)				Number of leaves plant^{-1}			
	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	At Harvest
T_1 : Control	22.55	122.73	125.93	127.19	5.78	8.37	8.87	7.40
T_2 : 100 % RPP	33.55	188.54	194.40	195.66	6.44	12.27	12.87	11.27
T_3 : 75 % RDP + 5 % RDP - NP1	31.85	193.57	198.77	198.36	6.98	12.77	13.83	11.90
T_4 : 75 % RDP + 5 % RDP - NP2	31.39	190.52	196.72	197.32	6.78	12.88	13.80	11.83
T_5 : 75 % RDP + 5 % RDP -NP3	31.71	192.38	195.91	197.51	6.97	12.73	13.67	11.73
T_6 : 75 % RDP + FS of 1 % RDP - NP1	30.93	189.58	196.45	197.71	6.66	12.91	13.80	11.77
T_7 : 75 % RDP + FS of 1 % RDP –NP2	31.08	188.60	195.13	196.39	6.48	12.60	13.53	11.50
T_8 : 75 % RDP + FS of 1 % RDP –NP3	30.30	189.63	195.83	197.09	6.58	12.34	13.60	11.60
T_9 : T_3 + FS of 1 % RDP - NP1	32.78	195.18	202.72	203.98	7.27	13.66	15.03	13.10
T_{10}: T_4 + FS of 1 % RDP – NP2	31.45	193.70	201.23	202.49	7.05	13.13	14.93	12.67
T_{11}: T_5 + FS of 1 % RDP – NP3	31.45	194.66	201.92	203.18	7.03	13.53	15.00	13.07
S.Em ±	1.39	7.80	9.28	10.49	0.34	0.52	0.76	0.64
CD @ 5%	4.11	23.03	27.38	30.96	NS	1.54	2.24	1.89

T1 : Control
T2 : 100 % RPP
T3 : 75 % RDP + 5 % RDP - NP1
T4 : 75 % RDP + 5 % RDP - NP2
T5 : 75 % RDP + 5 % RDP -NP3
T6 : 75 % RDP + FS of 1 % RDP - NP1
T7 : 75 % RDP + FS of 1 % RDP –NP2
T8 : 75 % RDP + FS of 1 % RDP –NP3
T9 : T3 + FS of 1 % RDP - NP1
T10: T4 + FS of 1 % RDP – NP2
T11: T5 + FS of 1 % RDP – NP3

TABLE 2

Effect of nano P fertilizers on chlorophyll meter reading and dry matter production (g plant^{-1}) of maize plant at different growth stages

Treatments	Chlorophyll meter reading				Dry matter production (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	90 DAS	At Harvest
T_1: Control	368.43	413.42	295.33	103.60	8.33	48.00	69.66	79.24
T_2: 100 % RPP	424.06	452.54	331.07	125.27	9.85	90.67	129.24	145.83
T_3: 75 % RDP + 5 % RDP - NP1	445.07	477.94	342.23	132.00	10.85	97.82	137.27	156.54
T_4: 75 % RDP + 5 % RDP - NP2	442.75	470.38	340.17	130.23	10.46	95.30	135.20	154.10
T_5: 75 % RDP + 5 % RDP -NP3	445.29	471.96	341.90	131.53	10.65	96.80	135.23	155.19
T_6: 75 % RDP + FS of 1 % RDP - NP1	442.59	478.52	341.13	131.48	10.04	96.55	134.53	154.77
T_7: 75 % RDP + FS of 1 % RDP –NP2	440.18	474.45	340.23	130.27	10.00	94.27	133.33	153.30
T_8: 75 % RDP + FS of 1 % RDP –NP3	441.90	476.22	340.07	131.23	10.02	95.70	133.43	154.20
T_9: T_3 + FS of 1 % RDP - NP1	461.23	496.33	364.00	139.17	11.13	101.57	147.64	162.72
T_{10}: T_4 + FS of 1 % RDP – NP2	459.01	490.00	361.33	136.67	10.93	100.47	144.23	159.83
T_{11}: T_5 + FS of 1 % RDP – NP3	460.03	494.00	363.33	138.29	10.97	101.02	146.67	160.13
S.Em ±	13.47	14.93	12.35	6.07	0.47	3.86	6.39	5.97
CD @ 5%	39.75	44.05	36.45	17.92	1.40	11.40	18.85	17.61

T1 : Control
T2 : 100 % RPP
T3 : 75 % RDP + 5 % RDP - NP1
T4 : 75 % RDP + 5 % RDP - NP2
T5 : 75 % RDP + 5 % RDP -NP3
T6 : 75 % RDP + FS of 1 % RDP - NP1
T7 : 75 % RDP + FS of 1 % RDP –NP2
T8 : 75 % RDP + FS of 1 % RDP –NP3
T9 : T3 + FS of 1 % RDP - NP1
T10: T4 + FS of 1 % RDP – NP2
T11: T5 + FS of 1 % RDP – NP3

the treatment that received 100 per cent RPP (T_2). and with all other treatments that received 75 per cent RDP through SSP along with soil and/or foliar applied nano phosphorus treatments (T_3 to T_{11}).

The results indicated that soil and / or foliar application of nano phosphorus fertilizer enhanced the growth parameters of maize compared to control and produced better and at par growth parameters with 100 per cent RPP applied treatment (Tables 1 and 2). The better and / or at par growth parameters observed in maize with the application of nano phosphorus fertilizers even at 20 per cent reduced level might be attributed to slow and continued release of P, which coincided with crop nutrient demand (Manikandan and Subramanian, 2015 in maize; Rajendran *et al.*, 2017 and Babubhai, 2018 in maize). The enhanced and continued P availability from these nano sources at distinct physiological phases, might have increased metabolic processes in plants (protein formation, photosynthesis, cell division, cell respiration and energy storage, *etc*.) thereby increased the below ground (root growth) and above ground biomass (plant height, number of leaves and dry matter production). Besides, application of P in nano form allows better dissolution and faster absorption and assimilation by the plants compared to P supplied through conventional fertilizers. Liu and Lal (2014) also confirmed that biomass productions were enhanced by 18.2 per cent (above ground) and 41.2 per cent (below ground) in nano hydroxyapatite treated plants compared to di calcium phosphate applied soybean plants and application of nano hydroxyapatite (nHA) increased the growth rate and seed yield by 32.6 per cent and 20.4 per cent, respectively compared to regular P treated soybean plants and these results are in agreement with the research findings of Beeresha and Jayadeva (2020) in maize; Sohair *et al.* (2018) in Egyptian cotton; Harish and Gowda (2017) in groundnut; Rajendran *et al*. (2017) in greengram and Soliman *et al*. (2016) in Baobab. In comparison with mere soil application or foliar application of nano hydroxyapatite fertilizer, combined soil and foliar application of hydroxyapatite nano fertilizer (NP1) recorded higher plant height, number of leaves per plant, chlorophyll meter reading and dry matter accumulation at all growth stages of maize plants might be due to quicker absorption of applied nutrients in nano form because nano coatings on fertilizers hold nutrient more strongly on plant surface due to its high surface tension, smaller size and higher surface area and thus it get easily pene trated into plant leaves and contributed to increased growth parameters.

Yield Parameters

The data on yield attributes *viz.,* cob length, number of rows per cob, number of kernels per row and test weight of maize as influenced by the application of P through conventional and nano phosphorus fertilizers are presented in Table 3.

The experimental data indicated that, significantly higher cob length of 19.01 cm was recorded in T_9 treatment compared to control (11.45 cm) and was on par with all other treatments. Least number of rows cob^{-1} (10.73) was recorded in control which was increased significantly to 16.67 with the application of 75 per cent RDP through SSP + 5 per cent RDP - NP1 + FS of 1 per cent RDP - NP1 (T_9 treatment) and the treatment T_9 was on par with all the treatments that received P either through conventional and or along with nano sources (T_2 to T_{11}). Similarly, the number of kernels cob^{-1} (35.27) were significantly higher in the treatment T_9 (T_3+ 1% RDP - NP1 through foliar spray) which was on par with all other treatments except control (21.53). Compared to control, test weight was significantly increased in all the treatments which received P either through conventional or nano sources.

Compared to control, application of 75 per cent RDP through SSP along with 5 per cent RDP through soil application of hydroxyapatite nano fertilizer (NP1) + 1 per cent RDP through foliar application of NP1 recorded higher values of yield attributes of maize than that was recorded with 100 per cent RPP applied treatment. The observed increase in yield parameters with the application of nano P fertilizers along with

TABLE 3

Yield attributes of maize as influenced by the application of nano P fertilizers

Treatments	Cob length (cm)	No of rows Cob^{-1}	No of kernels Row^{-1}	Test Weight (g)
T_1 : Control	11.45	10.73	21.53	26.14
T_2 : 100 % RPP	16.53	13.78	31.22	30.15
T_3 : 75 % RDP + 5 % RDP - NP1	17.67	14.67	33.53	31.83
T_4 : 75 % RDP + 5 % RDP - NP2	17.50	14.00	33.47	31.42
T_5 : 75 % RDP + 5 % RDP -NP3	17.53	14.33	33.47	31.76
T_6 : 75 % RDP + FS of 1 % RDP - NP1	17.50	14.33	33.53	31.64
T_7 : 75 % RDP + FS of 1 % RDP –NP2	17.20	14.06	33.20	31.63
T_8 : 75 % RDP + FS of 1 % RDP –NP3	17.63	14.00	33.53	31.09
T_9 : T_3 + FS of 1 % RDP - NP1	19.01	16.27	35.27	33.20
T_{10}: T_4 + FS of 1 % RDP – NP2	18.10	15.33	34.47	32.25
T_{11}: T_5 + FS of 1 % RDP – NP3	19.00	15.73	35.00	33.07
S.Em ±	0.86	0.86	1.53	1.15
CD @ 5%	2.53	2.54	4.52	3.41

conventional P fertilizers might be attributed to improvement in growth parameters. The improvement in growth parameters was due to synchronized supply of P (15.82%) and Ca (32%) contained in NP1 and also due to the slow and continued release of P from nano sources throughout the crop period and calcium present in these synthesized materials played a vital role in meristem growth, cell elongation and nutrient uptake like nitrogen which enhanced the vegetative growth and ultimately lead to more number of leaves. The increase in number of leaves enhances the amount of photosynthetic material and contributed to increased root biomass in turn increases nutrient content, uptake, growth and yield attributes of maize. Through several research papers, it was confirmed that supply of nutrients in nano form had positive effect on growth parameters, yield parameters and yield of crops because nano fertilizers influence the physiology of plants by positively increasing the root biomass to efficiently absorb the nutrients from the rhizosphere in turn, contributed to increased growth and yield attributes.

Kernel and Stover Yield

The kernel and stover yield of maize (Fig.1) varied significantly with the application of P from conventional and nano sources. Significantly higher kernel yield of 73.59 q ha^{-1} was recorded in T_9 treatment compared to control (55.56 q ha^{-1}), T_2 (62.78 q ha^{-1}), T_7 (65.63 q ha^{-1}) and T_8 (65.59 q ha^{-1}) treatments and was at par with all other remaining treatments tried.

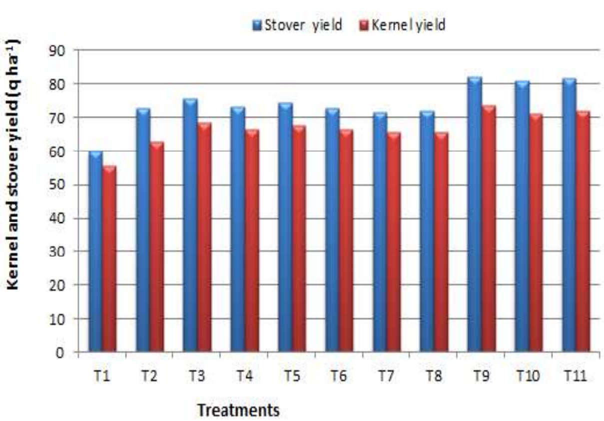

Fig.1 : Stover and kernel yield (q ha^{-1}) of maize as influenced by the application of nano P fertilizers

In case of stover yield also, significantly highest value (82.23 q ha^{-1}) was recorded in T_9 treatment than all other treatments except T_{10} (80.89 q ha^{-1}), T_{11} (81.73 q ha^{-1}) and T_3 (75.61 q ha^{-1}) and lowest stover yield value (59.92 q ha^{-1}) was recorded in control.

Compared to control, application of 75 per cent RDP through SSP along with 5 per cent RDP through soil application of hydroxyapatite nano fertilizer (NP1) and / or 1 per cent RDP through foliar application of NP1 recorded higher maize yield than that was recorded with 100 per cent RPP applied treatment. So, the yield obtained with soil and / or foliar application of nano P fertilizers along with conventional P sources is equivalent or more than that was obtained with 100 per cent RPP applied treatment. The yield attributes and yield of maize were gradually increased in all the treatments where 25 per cent RDP from conventional sources was substituted with nano P fertilizers in different proportions (5% RDP as soil application and / or 1% RDP as foliar spray) So, application of 5 per cent RDP through soil application nano P fertilizers and / or 1 per cent RDP through foliar spray of nano P fertilizers can replace 20 per cent RDP through conventional P source (SSP). Hence, 25 per cent RDP through conventional sources can be substituted with 5 per cent RDP through nano P fertilizers which saves nearly 25 per cent conventional P sources.

The higher yield in nano phosphorus fertilizers applied treatments might be attributed to the increased cob length, number of rows per cob, number of kernels per cob and test weight. The improvement in yield and yield parameters was due to the improvement in growth parameters (Table 1 and 2). The improvement in growth parameters was due to synchronized supply of P and Ca contained in NP1. Through several research papers, it was confirmed that supply of nutrients in nano form had positive effect on growth and yield parameters because nano fertilizers influence the physiology of plants by positively increasing the root biomass to efficiently absorb the nutrients from the rhizosphere soil (Rajendran *et al.,* 2017). Adhikari *et al.* (2014) also confirmed that application of nano phosphorus fertilizer had enhanced the maize grain yield by 44.68 per cent and stover yield by 13.17 per cent over the control. These results were corroborated with findings of Ekinci *et al*. (2014) in cucumber; Liu and Lal (2014) in soybean; Abdel-Aziz *et al.* (2016) in wheat; Harish and Gowda (2017) in groundnut; Babubhai (2018) in maize and Khanm *et al.* (2018) in tomato and Rathnayaka *et al.* (2018) in rice.

Application of 75 per cent recommended dose of phosphorus (RDP) through conventional P fertilizer (SSP) along with soil application of 5 per cent RDP through hydroxyapatite nanoparticles (NP1) and 1 per cent of foliar application of RDP through NP1 recorded highest growth parameters, yield attributes and yield of maize plant compared to 100 per cent RDP applied through conventional fertilizer treatment. This results in saving of nearly 25 per cent of P fertilizer application through conventional sources. From this study, it is confirmed that application of phosphorus in nano form will increases the use efficiency of P, in turn contributed to higher growth and yield of maize.

TABLE 4

Effect of Nano P fertilizers on stover and kernel yield (q ha^{-1}) of maize

Treatments	Stover yield	Kernel yield
T_1: Control	59.92	55.56
T_2: 100% RPP	72.73	62.78
T_3: 75% RDP+5 % RDP - NP1	75.61	68.56
T_4: 75% RDP+5 % RDP - NP2	73.35	66.43
T_5: 75% RDP+5 % RDP - NP3	74.29	67.41
T_6: 75% RDP+ FS of 1 % RDP - NP1	72.98	66.52
T_7: 75% RDP+FS of 1% RDP –NP2	71.53	65.63
T_8: 75% RDP+FS of 1% RDP –NP3	72.17	65.59
T_9: T_3 + FS of 1% RDP - NP1	82.23	73.59
T_{10}: T_4+FS of 1% RDP – NP2	80.89	71.11
T_{11}: T_5+FS of 1% RDP – NP3	81.73	71.96
S.Em ±	2.33	2.56
CD @ 5%	6.88	7.57

Acknowledgement : The first author is thankful to the Karnataka Science and Technology Promotion Society (KSTePs), Department of Science and Technology, Government of Karnataka for funding Ph.D. fellowship to conduct the research work.

REFERENCES

ABDEL-AZIZ, H. M. M., HASANEEN, M. N. A. AND OMER, A. M., 2016, Nano chitosan-NPK fertilizer enhances the growth and productivity of wheat plants grown in sandy soil. *Spanish J. Agric. Res.,* **14** (1) : 902 - 1000.

ADHIKARI, T., KUNDU, S., MEENA, V. AND RAO, A. S., 2014, Utilization of nano rock phosphate by maize (*Zea mays* L.) crop in a vertisol of central India. *J. Agric. Sci. Technol. A*, **4** : 384 - 394.

BABUBHAI, B. D., 2018, Evaluation of potassic nano fertilizer under incubation trial and its effect on growth, yield and nutrient uptake by maize *(Zea mays* L.*)* crop. *M.Sc (Agri.) Thesis,* Junagadh Agril. University, Junagadh.

BEERESHA, K. J. AND JAYADEVA, H. M., 2020, Effect of nano-potassium fertilizer on yield and economics of maize (*Zea mays* L.). *Mysore J. Agric. Sci.,* **54** (1) : 28 - 34.

EKINCI, M., DURSUN, A., YILDIRIM, E. AND PARLAKOVA, F., 2014, Effects of nanotechnology liquid fertilizers on the plant growth and yield of cucumber (*Cucumis Sativus* L.). *Acta Sci. Pol., Hortorum Cultus.,* **13** (3) : 135 - 141.

HARISH, M. S. AND GOWDA, R., 2017, Effect of nano scale zinc oxide on plant growth, seed yield and quality in groundnut. *Mysore J. Agric. Sci.,* **51** (3) : 637 - 643.

KHANM, H., VAISHNAVI, B. A. AND SHANKAR, A. G., 2018, Raise of nano-fertilizer era: Effect of nano scale zinc oxide particles on the germination, growth and yield of tomato (*Solanum lycopersicum*). *Int. J. Curr. Microbiol. App. Sci.,* **7** (5) : 1861 - 1871.

LIU, R. AND LAL, R., 2014, Synthetic apatite nano particles as a phosphorus fertilizer for soybean (*Glycine max*). *Scientific Reports.,* **4** : 5686.

Manikandan, A. and Subramanian, K. S., 2015, Evaluation of zeolite based nitrogen nano-fertilizers on maize growth, yield and quality on inceptisols and alfisols. *Int. J. Plant Soil Sci.,* **9** (4) : 1 - 9.

Mateus, A. Y. P., Barrias, C. C., Ribeiro, C., Ferraz, M. P. and Monteiro, F. J., 2007, Comparative study of nano hydroxyapatite microspheres for medical applications. *J. Biomed. Mater. Res*., **86**: 483-493.

Rajendran, M., Selvaraj, R. C. A. and Sundaram, V. B., 2017, Evaluation of nanostructured slow release fertilizer on soil fertility, yield and nutritional profile of *Vigna radiata*. *Recent Patents on Nanotechnol.*, **11** (1) : 1 - 13.

Rathnayaka, R. M. N. N., Mahendran S., Iqbal Y. B. and Rifnas, L. M., 2018, Influence of urea and nano-nitrogen fertilizers on the growth and yield of rice (*Oryza sativa* L.) cultivar 'Bg 250'. *Int. J. Res. Pub.,* **5** (2) : 1 - 9.

Sohair, E. D. E., Abdall, A. A., Amany, M. A. and Houda, A. R., 2018, Effect of nitrogen, phosphorus and potassium nano fertilizers with different application times, methods and rates on some growth parameters of Egyptian cotton (*Gossypium barbadense* L.). *Biosci. Res.*, **1 5**(2) : 549 - 564.

Soliman, A., Hassan, M., Abou-Elella, F., Ahmed, A. H. and El-Feky, S., 2016, Effect of nano and molecular phosphorus fertilizers on growth and chemical composition of baobab (*Adansonia digitata* L.). *J. Plant Sci.,* **11** (5) : 52 - 60.