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Organic nano NPK formulations for enhancing soil post-harvest nutrient status of bhindi

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Abstract
The present investigation was conducted to study the effect of soil and foliar application of organic nano fertilizer on post-harvest soil nutrient status. The field experiment was carried out during the year 2017-18 at College of Agriculture, vellayani. Fertilizer samples were analysed and particle size of granular organic nano NPK and liquid organic nano NPK were 89.26 nm and 67.30 nm respectively. The soil samples were collected at the final harvest of the crop for calculating nutrient status of the post-harvest soil. From the result it was indicated that among the different treatment combinations, application of FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) + Foliar application of nano. NPK. (0.4%) was found to be beneficial in recording higher nutrient status of the post-harvest soil.

Keywords: Organic nano NPK and bhindi

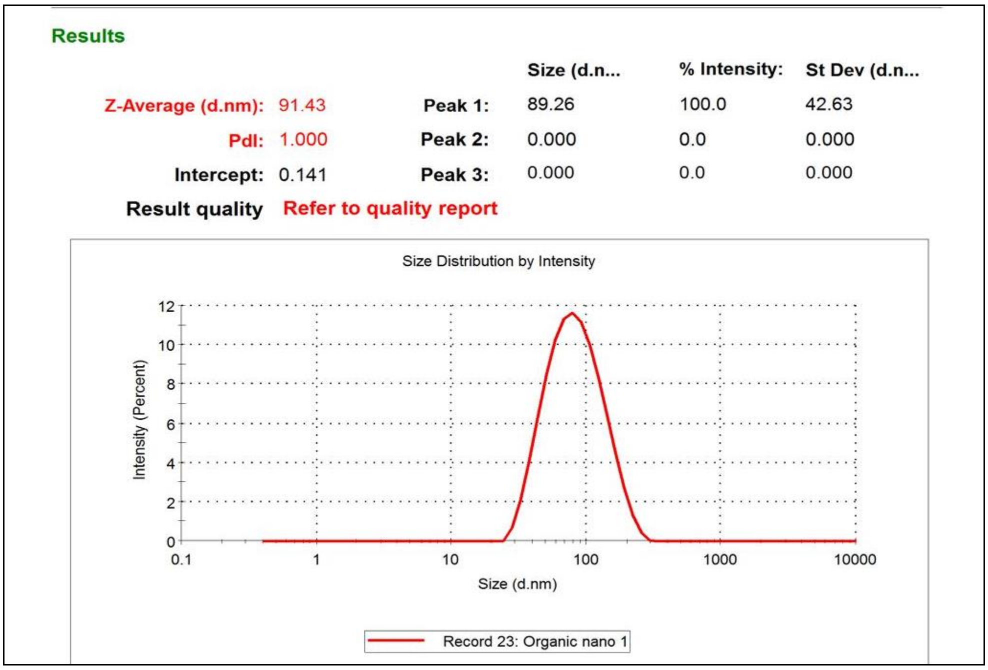
Introduction
The term “nano” refers to dimensions on the order of magnitude of 10–9 m (one billionth of a metre or one millionth of a milli metre). Using approaches inspired by nature, scientists are now able to self-assemble atoms into structures with controlled properties (Moraru *et al.*, 2003) [3]. Nanoparticles (nano-scale particles = NSPs) are atomic or molecular aggregates with at least one dimension between 1 and 100nm (Ball 2002; Roco 2003) [1, 6], that can drastically modify their physico-chemical properties compared to the bulk material (Nel *et al.*, 2006) [4]. Nanofertilizers are synthesized in order to regulate the release of nutrients depending on the requirements of the crops and it is also reported that nanofertilizers are more efficient than ordinary fertilizer
(Liu *et al.*, 2006) [2]. Nanofertilizers more particulary multi nutrient mixtures have received more attention.
Nano-fertilizers make nutrients more available to nano scale plant pores resulting in enhanced nutrient uptake and its use efficiency. Greatest advantage of nano-fertilizers over conventional fertilizers is that their requirement is in small quantity and thus easy to handle and transport. Therefore, nanotechnology has a high potential for achieving sustainable agriculture especially in developing countries.

Materials and Methods
Okra [*Abelmoschus esculentus* (L.) Moench] is one of the warm season vegetables having high nutritive value as well as foreign exchange potential. Varsha uphar is the most acceptable and widely cultivated. variety. in. India. A field experiment was conducted with bhindi crop (Varsha Uphar) in sandy clay loam soil at College of Agriculture, Vellayani during 2017-18 by using Lattice Design with sixteen treatments including control plot with three replications. Initial soil analysis revealed that the soil of the experimental field was with pH = 5.48, EC of 0.106 dS m^{-1} and organic carbon 0.97%. The available N, P and K of the experiment soil was 175, 54 and 100.8 kg ha^{-1} respectively. The treatments are as follows :
T_1: Soil application of nano NPK (12.5 kg ha^{-1}),
T_2: FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}),
T_3: Soil application of nano NPK (25 kg ha^{-1}),
T_4: FYM (12 t ha^{-1}) + Soil application of nano NPK (25 kg ha^{-1}),
T_5: Soil application of nano NPK (50 kg ha^{-1}),
T_6: FYM (12 t ha^{-1}) + Soil application of nano NPK (50 kg ha^{-1}),
T_7: Foliar application of nano NPK (0.2%),
T_8: FYM (12 t ha^{-1}) + foliar application of nano NPK (0.2%),
T_9: Foliar application of nano NPK (0.4%),
T_{10}:.FYM (12 t ha^{-1}) + Foliar application of nano NPK (0.4%),
T_{11}: Soilapplication of nano NPK (12.5 kg ha^{-1}) + foliar application of nano NPK (0.4%),

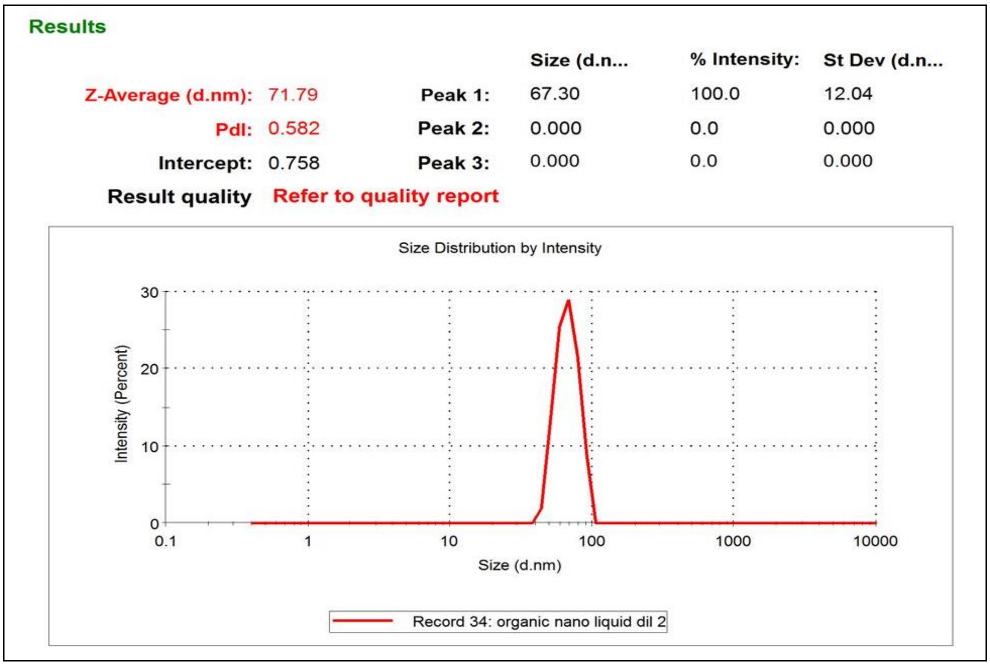
T_{12}:.FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) + foliar application of nano. NPK. (0.4%),
T_{13}: Soil application of nano NPK (25 kg ha^{-1}) + foliar application of nano NPK (0.2%),
T_{14}: FYM (12 t ha^{-1}) + Soil application of nano NPK (25 kg ha^{-1}) + Foliar application of nano NPK (0.2%),
T_{15}: KAU POP (FYM 12 t ha^{-1} NPK 110:35:70 kg ha^{-1}) and
T_{16}: Absolute control.

Granular organic nano NPK formulation have applied as basal dose. Foliar application of liquid organic nano NPK formulations were applied at 15 days interval. The data collected from the experiment were subjected to statistical analysis as per standard procedures using R package.

Particle size analysis of Organic nano NPK (Granular)



Particle size analysis of Organic nano NPK (Liquid)



Using zeta sizer analyser, size of organic nano NPK fertilizers were recorded. Size of granular organic nano NPK was 89.26 nm and liquid nano NPK was 67.30 nm.

B.) Effect of treatments on soil properties

(i) pH, EC and Organic carbon: Among the different treatments, the treatment which received with FYM (12 t ha^{-1}) + Soil application of nano NPK (25 kg ha^{-1}) + Foliar application of nano NPK (0.2%) shows the highest pH. A higher initial pH due to the application of nano fertilizer could be related to the alkaline nature of zeolite (Rajonee *et al.*, 2017) [5]. Application of different treatment combination significantly alters the EC and organic carbon (Table 1.) value of the post- harvest soil. OC of the soil is increased over the control plot.

Table 1: Effect of treatments on pH, EC and organic carbon content in the soil

Treatments	pH	EC (dS m^{-1})	OC (%)
T1	6.19 ef	0.009 def	1.433 c
T2	6.55 abc	0.008 fg	1.370 c
T3	6.61 ab	0.010 cdef	1.380 c
T4	6.27 ef	0.023 a	1.587 ab
T5	6.62 ab	0.009 ef	1.460 bc
T6	6.48 bcd	0.006 g	1.480 bc
T7	6.53 abc	0.009 ef	1.343 cd
T8	6.28 def	0.010 cdef	1.223 d
T9	6.35 cde	0.012 bcd	1.433 c
T10	6.60 ab	0.011 bcde	1.587 ab
T11	6.30 def	0.012 bc	1.457 bc
T12	6.70 a	0.013 b	1.650 a
T13	6.57 ab	0.010 cde	1.433 c
T14	6.53 abc	0.009 ef	1.403 c
T15	6.11 f	0.012 bc	1.070 e
T16	5.47 g	0.006 g	0.990 e

Effect of treatments on post-harvest soil nutrient status of N, P and K (Kg ha^{-1})

The significance of applied treatment combination on the post-harvest nutrient status of the soil was evidenced in the present study (Table. 2). The plots which received FYM (12 t ha^{-1}) + Soil application of nano NPK (25 kg ha^{-1}) shows the highest available nitrogen content in the soil. Application of FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) + foliar application of nano. NPK. (0.4%) resulted in highest available phosphorous present in the soil. Higher available potassium content is noticed with treatment received with Soil application of nano NPK (25 kg ha^{-1}) + foliar application of nano NPK (0.2%). TiO_2 nanoparticles (NPs) on the growth of soybean plants and their root associated soil microbes and found that plant growth was significantly lower with the application of TiO_2 compared to Fe_3O_4 NPs. It indicated that the type of NPs can affect plant growth and nutrient content in an agriculturally important crop species and the charge of these particles can influences the colonization of the root system by nitrogen-fixing bacteria. Valadkhan *et al.* (2015) [8] reported that improvement in the yield components was due to the enhanced photosynthetic and other metabolic activities, which resulted in the production of more dry matter and greater nutrient uptake.

Table 2: Effect of treatments on post-harvest soil nutrient status (kg ha^{-1})

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T1	146.36 fg	76.41 g	135.03 ef
T2	167.29 cde	90.29 c	167.18 d
T3	179.75 abc	85.99 def	180.40 cd
T4	188.13 a	83.72 ef	175.31 cd
T5	179.77 abc	85.92 def	190.96 c
T6	167.31 cde	87.98 cd	174.57 cd
T7	154.60 ef	85.26 def	125.28 f
T8	163.00 de	83.51 f	143.23 e
T9	175.66 abcd	86.43 cdef	170.61 d
T10	188.09 a	101.08 b	180.03 cd
T11	167.40 cde	74.53 g	172.28 d
T12	179.77 abc	112.72 a	209.63 b
T13	184.00 ab	99.23 b	231.19 a
T14	171.46 bcd	82.74 f	227.79 a
T15	154.75 ef	87.83 cde	170.58 d
T16	137.91 g	60.10 h	123.46 f

Effect of treatments on post-harvest soil nutrient status of secondary nutrients (mg kg^{-1})

Availability of secondary nutrients after harvest (Table 3.) shows that treatment received with FYM (12 t ha^{-1}) + Foliar application of nano NPK (0.4%) shows highest available calcium (426.66 mg kg^{-1}) which was on par with (T_2, T_4, T_5, T_6, T_7, T_9, T_{12} and T_{14}) and the lowest available Ca was reported on absolute control (206.66 mg kg^{-1}). Available magnesium status of the soil was maximum with the treatment received with FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) which was on par with (T_5, T_7, T_{12} and T_{14}) and the least available magnesium was recorded in the absolute control (64.00 mg kg^{-1}). Treatment which received with FYM (12 t ha^{-1}) + Soil application of nano NPK (25 kg ha^{-1}) + Foliar application of nano NPK (0.2%) shows the highest available sulphur status of the soil and the lowest available sulphur was reported in the absolute control plot (3.81 mg kg^{-1}). Subramanian and Tarafdar (2011) [7] revealed that ^{15}N studies were taken using maize as a model system have revealed that N use efficiency from nano-fertilizer was 82 per cent and the conventional fertilizer (urea) registered 42 per cent with a net higher nitrogen use efficiency of 40 per cent which is hardly achievable in the conventional systems. This suggests that nano-fertilizers may be used as a strategy to regulate the smart release of nutrients that commensurate with crop requirement.

Table 3: Effect of treatments on post-harvest soil nutrient status of secondary nutrients

Treatments	Available Ca (mg kg^{-1})	Available Mg (mg kg^{-1})	Available S (mg kg^{-1})
T1	340.00 cd	94.00 bcd	7.31 def
T2	416.66 ab	132.00 a	10.85 d
T3	363.33 bcd	92.00 bcde	19.99 c
T4	386.66 abc	94.00 bcd	6.67 def
T5	390.00 abc	114.00 abc	9.83 de
T6	370.00 abcd	90.00 bcde	9.49 de
T7	366.66 abcd	118.00 ab	6.31 ef
T8	320.00 d	84.00 de	10.65 de
T9	370.00 abcd	100.00 bcd	6.47 def
T10	426.66 a	89.33 cde	21.87 bc
T11	360.00 bcd	98.00 bcd	10.87 d
T12	413.33 ab	114.00 abc	20.15 c
T13	350.00 cd	88.00 cde	25.52 b
T14	390.00 abc	114.00 abc	31.59 a
T15	323.33 d	86.00 cde	6.84 def
T16	206.66 e	64.00 e	3.81 f

Effect of treatments on post-harvest available micro nutrients of bhindi field (mg kg^{-1})

The plots which received Soil application of nano NPK (50 kg ha^{-1}) recorded the highest available copper (2.955 mg kg^{-1}) content in the soil and the lowest available copper content received in the absolute control plot (1.562 mg kg^{-1}). Application of FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) recorded the highest available iron (18.45 mg kg^{-1}) content in the soil and the lowest was recorded in the treatment which received with absolute control plot (12.31 mg kg^{-1}). The maximum available manganese (28.65 mg kg^{-1}) and zinc (8.196 mg kg^{-1}) content in the soil was reported in the treatment FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) + foliar application of nano. NPK. (0.4%).

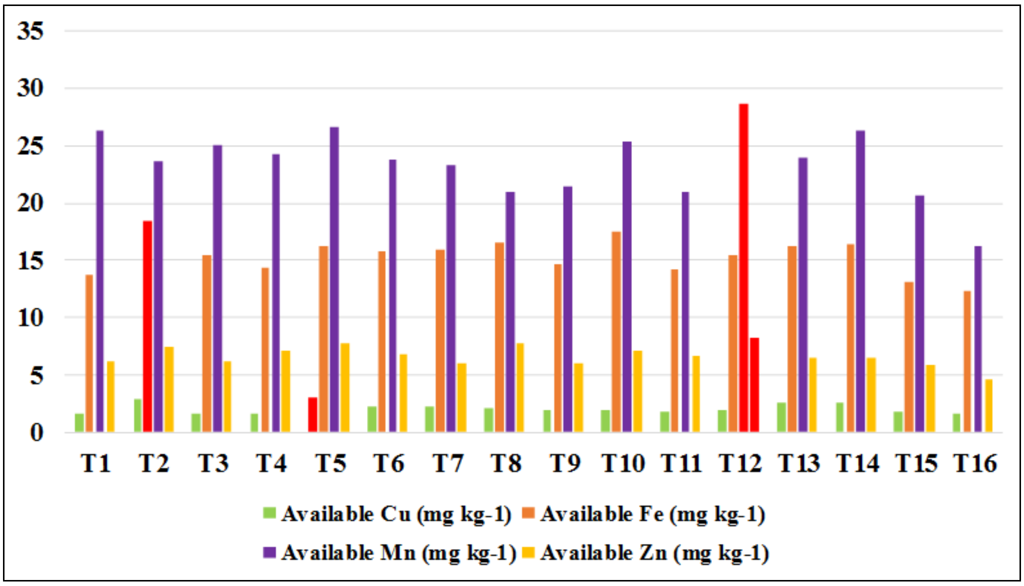


Fig 1: Effect of treatments on available micro nutrients of bhindi field (mg kg^{-1})

Conclusion

From the study it was concluded that among the different treatment combinations, application of FYM (12 t ha^{-1}) + Soil application of nano NPK (12.5 kg ha^{-1}) + foliar application of nano. NPK. (0.4%) was found to be beneficial in recording higher nutrient status of the post-harvest soil. Nanofertilizers can serve as an efficient nutrient delivery system which reduces the quantity of nutrient required and increase the effectiveness of applied nutrients as well as nutrients in the labile pool.

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