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Effect of nano NPK and straight fertilizers on yield, economics and agronomic indices in baby corn (*Zea mays* L.)

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Abstract
A field experiment was conducted in sandy clay loam soil at Campus Farm, M.S. Swaminathan School of Agriculture, R. Sitapur, CUTM, Paralakhemundi to study the fertilizer use efficiency of nano NPK and straight fertilizers with and without organic sources on baby corn (*Zea mays* L.) during winter of 2018-19. The experiment was laid out in randomized complete block design with three replications and 12 treatments. The treatments comprise of nano NPK, straight fertilizers and organics (vermicompost and *azotobacter*) applied as alone and combinations. The baby corn and green forage yield was significantly influenced by use of nutrient management treatments. Application of 125 % recommended fertilizer dose (RFD) as straight fertilizer through urea, single super phosphate and muriate of potash registered the maximum gross return (Rs. 412498.00/ha), net return (Rs.266528.00/ha) and B:C ratio (2.83). It was followed by application of 100 % RFD (SF) and 75% RFD (SF) + 25% recommended dose of nitrogen through vermicompost + *Azotobacter*. Amongst 12 treatment variables, the least performance was exhibited under control for all the parameters. Amongst different nutrients management treatments, the maximum partial factor productivity, agronomic efficiency and apparent nutrient recovery was recorded by application of nano NPK alone while nutrient use efficiency was the highest in 75 recommended fertilizer dose (Nano NPK) + 50 % (SF).

Keywords: Nano NPK, straight fertilizer, organic nutrient, yield and economics, agronomic indices, baby corn

Introduction
Maize is an exhaustive crop after sugar cane requiring both organic and in organic source of nutrients to perform better growth and yield potentials. To fulfill the need of nutrients, farmers are practicing indiscriminate use of inorganic fertilizers to replenish the nutrient removed by crops. It affects the soil health, human wellbeing and reduces factor productivity. The use of high analysis fertilizers like urea, diammonium phosphate and muriate of potash have been found to have lower fertilizer efficiency ranging from 20 to 50 % for nitrogen and10-25 % for phosphorus and 70-80 % potassium owing to leaching losses besides volatilization and denitrification losses (Chinnamuthu *et al*., 2009) [2].

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. In fertilizer management, soil nutrient depletion is one of the constraints in productivity of maize. It is quite imperative to combine fertilizer with manure of different qualities, in different rates and modes of application. Most of the agricultural soils in India have low native fertility. Successful and sustained crop production on these soils requires regular nutrient inputs through chemical fertilizers and/or organic manures to replenish soil nutrient reserves depleted by crop removal and other losses. Chemical fertilizers, the source of plant nutrients is considered as major contributor to enhance crop production and maintain soil productivity. But due to more leaching losses, nanostructured fertilizers can increase the nutrient use efficiency through mechanisms of targeted delivery and slow or controlled release. They precisely release the active ingredients to maintain soil health and environmental quality. Nano-fertilizers also improve crop productivity by enhancing the rate of seed germination, seedling growth, photosynthetic activity and nitrogen metabolism along with carbohydrate and protein synthesis (Solanki, 2015) [12].

The information regarding the potentiality of nano-particles as alternative to regularly used inorganic fertilizers on baby corn is meager.

Hence, inorganic fertilizer alone with different levels, the integration of nano NPK with straight fertilizers with and without vermi compost and bio fertilizers as non-symbiotic N fixer *Azotobacter* are tested find out the suitable one for use.

Materials and Methods

The field experiment was conducted during *rabi* season of 2018-2019 at M. S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha, India. The soil of the experimental plot was sandy clay loam in texture, slightly alkaline in reaction (7.40), low in organic carbon (0.30%), available nitrogen (263.4 kg/ha) and potassium (168.0 kg/ha) but medium in available phosphorus (15.2 kg/ha). The experiment was laid out in complete randomized block design with three replications and twelve treatments *viz.* 100% recommended fertilizer dose (RFD) i. e. 150-75-75 kg of N –P_2 O_5- K_2O/ha through straight fertilizers (SF), 100% RFD through nano NPK(1-1-1 kg of N –P_2 O_5- K_2O/ha @ (25 kg /ha), 50% RFD (Nano NPK) + 50% RFD (SF), 75%RFD (Nano NPK) + 25% RFD (SF), 125% RFD through SF, 125% RFD (Nano NPK), 75%RFD (Nano NPK) + 50% RFD (SF), 75% RFD (SF) +25% recommended dose of nitrogen (RDN) through vermi compost (VC), 75%RFD (Nano NPK) + 25% RDN (VC), 75% (SF) +25% RDN (VC) + *Azotobacter (*CUTM consortia) @5kg/ha, 75% RFD (Nano NPK) + 25% RDN (VC) + *Azotobacter* (CUTM consortia) @5kg/ha and absolute control (No chemical and organic nutrients).

The sources used for applying N, P and K were urea, single super phosphate and muriate of potash, respectively. The organic sources of nutrients were vermicompost (organic manure) and biofertilizers (*Azotobacter spp*). The chemical analysis of vermicompost showed that it contained 1.42 % N, 0.61 % P_2O_5 and 1.03 % K_2O on oven dry weight. Nano NPK was collected from Tropical Argo System Pvt ltd, Chennai. Nano NPK contains multiple organic acids (protein-lactose gluconates) based chelated major nutrients 4:4:4 of N, P_2O_5 and K_2O, respectively along with amino acids (6%), organic carbon (10%) with organic micronutrients in traces and vitamins. Vermicompost @ 2.6 t/ha was added at sowing as per the plan of work in respective treatments and mixed well in soil. The fertilizer dose of 150:75:75: N: P_20_5: K_20 kg/ha was applied to the baby corn crop. As basal application, 50 % N, full P_20_5 and half dose of K_20 were applied just before the sowing. The basal dose of fertilizers was well mixed with soil before sowing. The bio fertilizer was applied to the specific treatments at sowing. The inorganic nutrients were supplied in the form of urea, single super phosphate and muriate of potash. For nano fertilizer, 50 % nano NPK was applied as basal. Remaining 50% nitrogen and potassium for inorganic NPK fertilizer and rest 50 % nano N PK were top dressed as per the treatments after final hoeing and weeding followed by earthling up. Irrigation was applied at regular intervals in baby corn as per need. All recommended package and practices were uniformly followed in all the treatments.

Agronomic indices for nutrient use efficiency was calculated by following formula mentioned below as suggested by Dobermann and Fairhurst, 2000.

Agronomic indices for nutrient use efficiency was calculated by following formula mentioned below:

Agronomic indices	Calculation
Agronomic efficiency	AE = (kg yield increase kg-1 nutrient applied) = (Y-Y0)/F
Nutrient utilization efficiency	NUE = grain yield (fertilized plot) - grain yield(control)/Rate of nutrient applied
Apparent recovery efficiency	ARE = (kg increase in uptake kg-1 applied) = (U-U0)/F
Partial factor productivity	PFP = (kg yield kg-1 nutrient applied) = Y/F

Y – Yield from treated plot
Y_0 – Yield from control plot
U – Nutrient uptake in treated plot
U_0 – Nutrient uptake in control plot
F – Fertilizer rate

Gross return was calculated by multiplying the total baby corn and green forage yield with prevalent market prices of the items and then presented on hectare basis as per treatments. The selling price of baby corn and green fodder was Rs.100/kg and Rs. 1000/t, respectively.

Net return was computed by deducting the total cost of cultivation from the gross returns as per treatments. Benefit: cost ratio was calculated by dividing gross returns with the cost of cultivation for each treatment given below.

$$\text{Benefit: cost ratio} = \frac{\text{Gross return (Rs /ha)}}{\text{Cost of cultivation (Rs /ha)}}$$

Results and discussion

Baby corn yield

The result on effect of nano NPK and straight fertilizers with and without organic sources on baby corn yield are presented in table 4.7. Significantly the highest baby corn yield (3.93 t/ha) was registered by the application of 125 % RFD through straight fertilizer. The next best result was obtained with 100 % RFD through straight fertilizer (3.05 t/ha) and 75% RFD through Nano NPK + 50% RDF through straight fertilizer (2.93 t/ha) being was statistically on par. The baby corn yield recorded with 75% RFD (SF) + 25% RDN through VC (2.71), 50% RFD (Nano)+ 50% RFD through SF (2.55) and 75 % RFD (Nano)+ 25% RDN (VC) + Azotobacter (2.55) were at par and significantly different from rest of the treatments. On the other hand, absolute control treatment produced significantly the lowest green cob yield (0.96 t/ha).

Increase in yield is ascribed to their direct influence on dry matter production in leaf and stem at successive stages by virtue of increased photosynthetic efficiency. The profound influence of nutrient application on biological yield seems to be on account of its positive influence on vegetative growth which reflected reproductive growth (sink). Combined use of chemical fertilizer and organic sources has been resulted in higher productivity and providing stable crop yields for sustainable crop production through organic manure and balanced use of chemical fertilizers. Similar result in improving the baby corn yield is in agreement with Jaime and Viola (2011) [5].

Green forage yield

Green forage was yield of baby corn was significantly influenced by the nano NPK and straight fertilizers with and

without organic sources. Maximum green forage yield (20 t/ha) was obtained in 125 % RFD through SF (20 t/ha) closely followed by 100 % RFD through SF (19.63 t/ha) and 50% RFD through Nano NPK + 50% RDF through straight fertilizer (19.52 t/ha) which were statistically on par with each other. The next order with respect to green forage yield were 75% RFD (SF) + 25% RDN (VC) + *Azotobacter* (18.46 t /ha), 75% RFD (Nano) + 50 % through SF (18.40 t/ha) and 75% RFD (SF) + 25% RDN through VC (18.27 t/ha) which were significantly more than rest of the treatments. Minimum green fodder yield (9.32 t/ha) was obtained in control.

Among all the treatments, application of nano NPK alone was resulted less while compared to the straight fertilizers at all the yield and yield attributes. The conjugated use of organic manure and inorganic fertilizer resulted in balanced use of chemical fertilizers. Hence, increased the absorption and translocation of nutrients from source to sink thus reflected the productivity and yield and resulted in stable crop yields for sustainable crop production chemical fertilizers. Similar result was observed by Gosavi (2009) [4], Rakesh Kumar *et al*, 2015 [10] and Auwal *et al*. (2017) [1].

Relative economics

The treatment wise economics of cultivation was worked out with the help of operating cost of individual treatment and the cost of production. The data so obtained have been presented in the Table 1. Application of 125 % RFD through straight fertilizer fetched maximum gross return (Rs. 412498.00 /ha) and net return (Rs. 266528.00/ha). It was closely followed by 100 % RFD through SF providing the gross return (Rs. 325046.00/ha) and net return Rs. 182000.00/ha) and 75% RFD through nano NPK+ 50% RFD through SF giving the corresponding values of (Rs. 311103.00/ha) and Rs. 171467.00 /ha), respectively. However, loss was obtained under 100 % RFD through nano NPK and control treatment.

This was possible due to the significant increase in baby corn and Stover yield of baby corn and cost of fertilizers incurred at different treatments. This is attributed to higher cob yield with these levels, ultimately reflected into higher gross return net return. These results are in partially conformity with those reported by Zende, 2007 [13], Ajaz *et al*., 2013 and Rakesh Kumar *et al*, 2015 [10].

Benefit: Cost ratio

The mean data on benefit cost ratio presented in Table 1 indicated that 125 % RFD through straight fertilizer recorded maximum B:C ratio (2.83) followed by 100 % RFD through straight fertilizer (2.27) and 75% RFD through nano NPK+ 50% RFD through straight fertilizers (2.23). The absolute control plot gave minimum B:C ratio to the tune of 0.84. which might be due to variation in cost of cultivation and net returns. Similar findings were also observed by Ajaz *et al.*, 2013 and Rakes Kumar *et al*., 2015 [10].

Agronomic indices

The results on the effect of nano NPK and straight fertilizers with and without organic sources on agronomic indices *viz*., partial factor productivity (PFP), agronomic efficiency (AE), nutrient utilization efficiency (NUE) and apparent nutrient recovery (ANR) are presented in Table 1.

Partial factor productivity

Application of of nano NPK and straight fertilizers with and without organic sources had favorable effect on the partial factor productivity in baby corn (Table 2).The highest PFP (535.06 kg /kg) was recorded with 100% recommended fertilizer dose through nano NPK closely followed by 125% recommended fertilizer dose through nano NPK which recorded a PFP of 508.36 kg/ kg. The lowest PFP value of 9.63 kg/ kg was recorded with 75% RFD through nano NPK+ 25% RDN through vermicompost + *Azotobacter*.

Agronomic indices reflect the nutrient use efficiency of the crops the increase in PFP signifies that crop response to added fertilizer is more due to low initial available nutrient status of soil. Increase in fertilizer dose resulted in decrease in PFP. This result confirms to the findings obtained by Sharma and Banik, 2014 [11].

Agronomic efficiency

Agronomic efficiency of nutrients was observed to vary widely with nano NPK and straight fertilizers with and without organic sources (Table 2). The treatment, 125% recommended fertilizer dose through nano NPK recorded the maximum AE of 169.16 kg/ kg. It was followed by 100% recommended fertilizer dose through nano NPK (110.68 kg/kg) and 75% RFD through nano NPK+ 50% RFD through straight fertilizers (15.81 kg/kg). The conjugated application of75% RFD through nano NPK+ 25% RFD through straight fertilizers gave the lowest AE (2.94 kg/kg). Agronomic efficiency provides the information regarding the effect of applied fertilizer on production and quantifies productivity due to added nutrients. Higher values of AE imply that further enhancement in nutrient input will not give the positive crop response (Dobermann, 2007) [3].

Nutrient utilization efficiency (NUE)

NUE denotes the increase in yield per unit uptake of nutrients by the above ground parts of the plant thus, indicates the ability of the crop to transform the nutrients removed from the applied source into economic yield. Nutrient utilization efficiency of nutrients widely differed with nano NPK and straight fertilizers with and without organic sources (Table 2). Maximum NUE was registered by application of 75% RFD through nano NPK+ 50% RFD through straight fertilizers (16.68 kg/kg) closely followed by 125 % RFD through straight fertilizer (14.62 kg/kg) and 50% RFD through nano NPK+ 50% RFD through straight fertilizers (12.99 kg/kg). The lowest NUE (5.28 kg/kg) was recorded under 100% RFD through nano NPK.

This might be due to the fact that nano-fertilizers have large surface area and particle size, less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano-fertilizer which leads to more penetration and uptake of the nutrient and thus results in high nutrient use efficiency (Liscano *et al*., 2000) [9]. Below 100 nm nano-fertilizers makes plant use fertilizers more efficiently, reduces pollution, environmentally friendly, dissolve in water more effectively thus increase its metabolic activities (Joseph and Morrison, 2006). Similar findings were given by Kumar *et al*. (2014) [8] and Jhanzab *et al*. (2015) [6].

Apparent nutrient recovery (ANR)

The wide variation was observed in the apparent nutrient recovery (ANR) in response to use of nano NPK and straight fertilizers with and without organic sources (Table 2). Application of 100% RFD through nano NPK registered the

highest ANR (20.98 kg/kg) which was closely followed by 125% RFD through nano NPK (18.41 kg/kg) and 75% RFD through nano NPK+ 25% RFD through SF (1.43 kg/kg). The lowest ANR (0.61kg/kg) was recorded under 75% RFD through straight fertilizers+ 25% RDN through vermin compost. Apparent nutrient recovery is the difference in nutrient uptake of the plant between the fertilized and unfertilized crop in relation to the quantity of nutrient applied. Increase in apparent nutrient recovery obtained with recommended dose of fertilizer through inorganic sources is due to more quantity of nutrient taken up by the crop as against the quantity applied.

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Table 1: Effect of simple and nano NPK with and without organic sources on Fertilizer use efficiency

Treatments	Nutrient added NPK (kg/ha)	Baby corn Yield (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	Total NPK uptake (kg/ha)	PFP (kg/kg)	AE (kg/kg)	NUE (kg/kg)	ANR (kg/kg)
100 % RFD through simple fertilizer (SF)	244.99	3054	114.45	17.08	115.61	247.13	12.47	8.53	12.79	0.67
100% RFD (Nano NPK)	2.27	1215	57.87	8.47	64.99	131.33	535.06	110.68	5.28	20.98
50% RFD (Nano NPK) + 50% RFD (SF)	123.64	2552	92.93	14.15	98.97	206.04	20.64	12.85	12.99	0.99
75 %RFD (Nano NPK) + 25 % RFD (SF)	62.95	1865	77.03	11.53	85.01	173.57	29.63	2.94	10.03	1.43
125% RFD (SF)	306.24	3925	131.40	20.45	134.40	286.26	12.82	9.67	14.62	0.66
125% RFD (Nano NPK)	2.84	1444	59.96	9.14	66.87	135.97	508.36	169.16	9.19	18.41
75% RFD (Nano NPK) + 50 % RFD (SF)	124.2	2927	88.94	14.57	97.93	201.45	23.57	15.81	16.68	0.95
75% RFD (SF)+ 25% RDN (VC)	264.29	2715	111.07	17.97	116.80	245.84	10.27	6.63	10.80	0.61
75 % RFD (Nano NPK) + 25% RDN (VC)	82.25	1504	75.26	10.86	82.60	168.71	18.29	6.58	6.36	1.03
75% RFD (SF)+ 25% RDN (VC) + *Azotobacter*	264.29	2546	111.90	17.95	117.63	247.47	9.63	5.99	9.66	0.62
75 % RFD (Nano NPK) + 25% RDN (VC) + *Azotobacter*	82.25	1777	76.24	10.97	81.85	169.06	21.61	9.89	9.53	1.04
No nutrients (Absolute control)	0	963	37.49	4.40	41.82	83.71	-	-	-	-

Recommended fertilizer dose (RFD) =150-75-75 kg NPK/ha, RFD nano = 25 kg/ha, *Azotobacter* = @ 5 kg/ha PFP = Partial factor productivity, AE = Agronomic efficiency, NUE = Nutrient use efficiency, ANR = Apparent nutrient recovery

Table 1: Effect of simple and nano NPK with and without organic sources on economics of baby corn

Treatments	Baby corn Yield (t/ha)	Green forage yield (t/ha)	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net profit (Rs/ha)	B:C ratio
100 % RFD through simple fertilizer (SF)	3.05	19.63	325046	143046	182000	2.27
100% RFD (Nano NPK)	1.21	10.05	131506	134600	-3094	0.98
50% RFD (Nano NPK) + 50% RFD (SF)	2.55	19.52	274727	138823	135904	1.98
75 %RFD (Nano NPK) + 25 % RFD (SF)	1.87	14.87	201374	136712	64661	1.47
125% RFD (SF)	3.93	20.00	412498	145970	266528	2.83
125% RFD (Nano NPK)	1.44	11.65	156025	135412	20613	1.15
75% RFD (Nano NPK) + 50 % RFD (SF)	2.93	18.40	311103	139636	171467	2.23
75% RFD (SF)+ 25% RDN (VC)	2.71	18.27	289730	166372	123358	1.74
75 % RFD (Nano NPK) + 25% RDN (VC)	1.50	11.71	162123	160038	2085	1.01
75% RFD (SF)+ 25% RDN (VC) + *Azotobacter*	2.55	18.46	273042	166547	106495	1.64
75 % RFD (Nano NPK) + 25% RDN (VC) + *Azotobacter*	1.78	11.81	189517	160213	29304	1.18
No nutrients (Absolute control)	0.96	9.32	105656	125350	-19694	0.84

Recommended fertilizer dose (RFD) =150-75-75 kg NPK/ha, RFD nano = 25 kg/ha, *Azotobacter* = @ 5 kg/ha,
Cost of produce = Rs. 100 /kg, Green forage = Rs. 1000/t

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