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# Significance of Nano N Fertilizer on uptake, efficiency and Yield of Rice Crop

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**ABSTRACT: A field experiment was carried out during the *kharif* season of 2020 and 2021 at Research Farm of IGKV, Raipur, Chhattisgarh, India to study the impact of different combination of nano N on yield and uptake of rice and efficacy of the fertilizer in the crop. The experiment was laid out in a randomized block design (RBD) with twelve treatments, each replicated thrice. The different treatment combinations were $T_1$ – 0% N (control), $T_2$ - 50% RDN, $T_3$ – 75% RDN, $T_4$ – 100% NPK (RDF - 120:60:40 kg $ha^{-1}$), $T_5$ – 0% N + 2 sprays of nano N @ 4 ml $l^{-1}$, $T_6$ – 0% N + 2 sprays of nano N @ 8 ml $l^{-1}$, $T_7$ – 50% N + 2 sprays of nano N @ 4 ml $l^{-1}$, $T_8$ – 50% N + 2 sprays of nano N @ 8 ml $l^{-1}$, $T_9$ – 75% N + 2 sprays of nano N @ 4 ml $l^{-1}$, $T_{10}$ – 75% N + 2 sprays of nano N @ 8 ml $l^{-1}$, $T_{11}$ – 50% N + 2 sprays of 2% urea and $T_{12}$ – 50% N + 3 sprays of 2% urea. The results indicated that the treatments *i.e.* 100% RDF ($T_4$), 75% N + 2 sprays of nano N @ 8 and 4 ml $l^{-1}$ ($T_{10}$ and $T_9$), 50% N + 2 sprays of nano N @ 8 and 4 ml $l^{-1}$ ($T_8$ and $T_7$) and 50% N + 3 sprays of 2% urea ($T_{12}$) obtained significantly higher grain yield over the others while straw yield was found highest in 100% RDF ($T_4$) followed by 75% N + 2 sprays of nano N @ 8 and 4 ml $l^{-1}$ ($T_{10}$ and $T_9$) treatments in both the seasons. The highest total N uptake was found under $T_4$ - 100% RDF (98.12 kg $ha^{-1}$), $T_9$ -75% N + 2 sprays of nano N @ 4 ml $l^{-1}$ (94.25 kg $ha^{-1}$) and $T_{10}$ - 75% N + 2 sprays of nano N @ 8 ml $l^{-1}$ (94.09 kg $ha^{-1}$). Lastly, The Nitrogen Use Efficiency (NUE) was maximized 47.49% in 50%N + 2 sprays of nano N@4ml $l^{-1}$ ($T_7$) followed by 46.82 to 43.81% in different N levels combined with nano N and urea sprays.**

**Keywords:** Nano N, Nitrogen use efficiency, N-uptake, Foliar application, Rice.

## INTRODUCTION

Agriculture is one of the major sectors and backbone of the Indian economy. It has been around in our nation for thousands of years. The ability to feed the expanding global population and slow climate change are the two biggest issues faced by the existing agricultural economy. For more than half of the world's population, rice (*Oryza sativa* L.) is regarded as staple food crop (Dangwal *et al.*, 2010). The overall area under rice cultivation in India was 45.50 million hectares, with an average productivity of 4.10 t $ha^{-1}$ (USDA Report 2022). Chhattisgarh is known as the ‘rice bowl of India’ because it is a major paddy-growing state. The crop occupies an average of 3.6 million ha in the state, of which 20–30% of the rice is grown in the low-lying areas of *Vertisol* (Pandey *et al.*, 2010). Fertilizers are crucial for rice cultivars that are high-yielding and fertilizer responsive in terms of increasing food output and quality. Among the essential nutrients, nitrogen plays a significant role in the rice production. The requirement of nitrogen is higher in cereal crop for its growth, development and grain production as compared to other crops (Sahrawat, 2000). Currently, high yields of irrigated rice are attributed to substantial use of fertilizer N (Barker and Dawe 2001). Nitrogen (N) is very essential for the cultivation of rice, and is the most yield-limiting nutrient in irrigated rice production across the globe

(Samonte *et al.*, 2006). The major source of nitrogen for rice in lowland is soil N, biological nitrogen fixation and fertilizer N. Organic fraction of soil nitrogen is frequently lost through plant removal, denitrification, leaching and ammonia volatilization. These losses from the field are a major problem through various processes and pose a serious threat to the environment. Therefore, it is a challenging task to achieve a higher nitrogen use efficiency. The use of conventional fertilizers leads to major environmental complications such as heavy metal accumulation in soil and their biomagnification in plant systems (Abdel *et al*., 2017). Therefore, current theories on nano fertilizers can bring a revolution in crop production with the aim to boost crop yield efficiency and reduce nutrient losses in the soil. In comparison to conventional fertilizers, their supplemental pattern of nutrients for plants' needs reduces leaching and increases fertilizer use efficiency (Subbarao *et al*., 2013).

Nano particles/materials are defined as materials with single unit between 1 to 100 nm in size in at least one dimension (Liu and Lal 2015). Nano fertilizers provide the major nutrients to the crop as per the requirement in a gradual manner as it contains nutrients and growth promoters encapsulated in nanoscale polymers. Many previous studies have proved the beneficial influence of nano fertilizers, however more studies need to be carried out on crops like rice to know the nutrient use efficiency by using nano fertilizers. Hence, the present study was conducted to outline the influence of nano N fertilizer on uptake, efficiency and yield of the rice crop.

## MATERIAL AND METHODS

The experiment was conducted at the research farm of Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, India (21˚ 16″ North and 81˚ 36″ East at an attitude of 298.56 m above the mean sea level) during *Kharif* season of the year 2020 and 2021 to investigate the response of nano N application on the rice production. The soil of the experimental area was clayey in nature falling under the category of *Vertisol*, which is a fine, hyperthermic, montmorillonitic chromustert soil. The soil is locally known as *Kanhar* and is classified as Arang II series. The chemical properties of soil of the experimental site are presented in Table 1. Rajeshwari, a variety released from IGKV was used as the test crop in the experiment. The experimental land was prepared thoroughly by ploughing twice with the help of cultivator and were later divided into plots of size 4 × 5 m. The plots were cleaned up by collecting and removing weeds and stubbles of previous crop. The plots were labelled uniformly and were laid down as per the design of the experiment. The experiment was laid out in randomized block design (RBD) with 12 treatments replicated thrice. Treatments were randomly distributed in all the plots. The treatments comprised of various combinations of different levels of nitrogen in conventional and nano form *viz.* $T_1$– 0% N (control), $T_2$– 50% RDN, $T_3$– 75% RDN, $T_4$– 100% NPK (RDF - 120:60:40 kg ha$^{-1}$), $T_5$– 0% N + 2 sprays of nano N @4ml l$^{-1}$, $T_6$– 0% N + 2 sprays of nano N @8ml l$^{-1}$, $T_7$– 50% N + 2 sprays of nano N @4 ml l$^{-1}$, $T_8$– 50% N + 2 sprays of nano N @8 ml l$^{-1}$, $T_9$– 75% N + 2 sprays of nano N @4ml l$^{-1}$, $T_{10}$–75% N + 2 sprays of nano N @8ml l$^{-1}$, $T_{11}$– 50% N + 2 sprays of 2% urea and $T_{12}$– 50% N + 3 sprays of 2% urea. All the treatments consisted a common dose of 100% recommended dose of P and K. The fertilizers used in this experiment were Urea, Single super phosphate, Muriate of potash and nano N. The urea, SSP and MOP were administered through soil application as basal dose whereas, nano N and urea were given 2 times (at tillering and panicle initiation stage, respectively) through foliar application, as per the treatments. The soil samples collected from the furrow slice before commencement of the experiment and after the harvest of each crop for two years were analyzed to ascertain the soil chemical properties. The after harvest plant samples were also analyzed for their nutrient contents (N, P and K) by following the standard procedures and the nutrient uptake and efficiencies were calculated. The yield data collected from field and those recorded in the laboratory were subjected to statistical analysis. The analysis of variance approach was used to examine the analytical data in this experiment as described by Gomez and Gomez (1984).

**Table 1: Chemical analyses of the experimental soil.**

| Properties | Ratings/Value |
|---|---|
| pH | 7.2 |
| EC (dS m$^{-1}$) | 0.38 |
| Organic carbon (%) | 0.45 |
| Available Nitrogen (kg ha$^{-1}$) | 221.30 |
| Available phosphorus (kg ha$^{-1}$) | 15.5 |
| Available potassium (kg ha$^{-1}$) | 398.70 |
| DTPA extract. Zn (ppm) | 1.78 |
| DTPA extract. Mn (ppm) | 8.10 |
| DTPA extract. Cu (ppm) | 2.2 |
| DTPA extract. Fe (ppm) | 12.7 |
| **Mechanical Analysis** | |
| Sand (%) | 23 |
| Silt (%) | 29 |
| Clay (%) | 48 |
| Textural class | Clayey |

## RESULTS AND DISCUSSION

The results of grain and straw yield of the rice crop after two years of experimentation (2020 and 2021) are presented in Table 2. Application of different treatment combinations including foliar application of different amount of nano N in combination with different levels of nitrogen resulted in a significant increase in grain and straw yield compared to control treatment in both the seasons. Addition of 120 kg N ha$^{-1}$ (100% RDN) as soil application pronouncedly produced the highest grain yield followed by 90 kg N + 2 foliar sprays of nano N @ 8 ml l$^{-1}$ during the *kharif* 2020 and 2021.The treatments containing 50 and 75% N in combination with foliar sprays of urea and nano N were found at par with 100% RDF in both seasons. In addition to this, the plants treated with 75% RDN ($T_3$), 50% N + 2 sprays of nano N @4 and 8 ml l$^{-1}$ ($T_7$ and $T_8$), 75% N + 2 sprays of nano N @4 and 8 ml l$^{-1}$ ($T_9$ and $T_{10}$) and 50% N + 2 and 3 sprays of urea ($T_{11}$ and $T_{12}$) showed no significant differences to each other in the two seasons. The application of half the amount of recommended dose of N i.e., 60 kg N ha$^{-1}$ with 2 sprays of nano N @4 and 8 ml l$^{-1}$ ($T_7$ and $T_8$) and 2 and 3 sprays of urea in $T_{11}$ and $T_{12}$, respectively gave the better results, but still the yield was lower than the 100% RDF ($T_4$). The higher grain yield was obtained by the effective utilization of resources that increased the performance of the crop. The increased grain yield may also be attributed to the influence that N in nano form had on the crop, particularly in later phases (the reproductive stage), as well as their prolonged period of availability to the crop. Additionally, because of their large surface area, nanoparticles play an integrated role with other elements and serve as a catalyst to speed up the enzymatic reactions. Similar results were obtained by Alam *et al*. (2010); Manik *et al.* (2016); Elavarasan *et al*. (2021); Gharieb (2021).

The straw yield ranged from 35.41 to 66.62 q ha$^{-1}$ and 36.47 to 71.56 q ha$^{-1}$ in *kharif* seasons of 2020 and 2021, respectively. In *kharif* 2020, 75% N + 2 sprays of nano N @ 8 ml l$^{-1}$ (64.04 q ha$^{-1}$) and 75% N + 2 sprays of nano N @ 4 ml l$^{-1}$ (63.38 q ha$^{-1}$) and 50% N + 3 sprays of 2% urea (61.78 q ha$^{-1}$) were statistically identical to 100% RDF (66.62 q ha$^{-1}$). However, in the *kharif* 2021 experiment, the highest straw yield was obtained in 100% RDF ($T_4$ :71.56 q ha$^{-1}$) followed by the application of 75% N + 2 sprays of nano N @8 ml l$^{-1}$ in $T_{10}$ (65.57 q ha$^{-1}$) while the minimum straw yield was recorded in the control (36.47 q ha$^{-1}$). Foliar application of nano N might have caused nitrogen to become readily available and absorbed more quickly, causing crops to respond more quickly increasing the dry matter and straw yields. Moreover, the particles of nano form of fertilizers are so small that it gets absorbed in the leaf epidermis rapidly making it available to the crop quickly and for a longer time. These results are in good harmony with Manik *et al.* (2016); Elavarasan (2021); Gharieb (2021).

The data on nutrient uptake after the harvest as influenced by the addition of different treatments are presented in Table 3. The application of nano N had a significant effect on the grain, straw and total N uptake of the rice crop. The maximum total N uptake (97.94 and 98.31 kg ha$^{-1}$) was recorded in 100% RDF ($T_4$) whereas, the lowest total N uptake (51.49 and 52.62 kg ha$^{-1}$) was found in control ($T_1$), respectively in *kharif* 2020 and 2021. The total N uptake with application of 75% N with 2 sprays of nano N @ 4 and 8 ml l$^{-1}$ ($T_9$ and $T_{10}$) were at par with each other and also at par with the 100% RDF ($T_4$). In case of grain N uptake, highest value was recorded in 100% RDF (69.46 and 70.01 kg ha$^{-1}$) followed by 75% N + 2 sprays of nano N @ 8 ml l$^{-1}$ (69.71 and 66.47 kg ha$^{-1}$) and 75% N + 2 sprays of nano N @ 4 ml l$^{-1}$ (68.86 and 67.40 kg ha$^{-1}$) in *kharif* 2020 and 2021, respectively which were also at par with each other. On the other hand, N uptake in straw was found highest in 100% RDF (28.48 and 28.30 kg ha$^{-1}$), respectively in 2020 and 2021.The higher uptake of N as a result of nano based fertilizer formulations verified the nutrient availability for a longer period. Additionally, due to their huge surface area and extremely small particle size, nano fertilizers may better absorb nitrogen by reaching plant tissues from the application surface. Present results are concomitant with the findings of Alam *et al*. (2010); Manik *et al*. (2016); Elavarasan *et al*. (2021).

The nitrogen use efficiency (NUE)as influenced by different treatment combinations is shown in Table 4 and Fig. 1. In general, there was an increase in the nitrogen use efficiency with the application of the foliar spray of either nano N or urea in combination with 50 and 75% RDN over the 100% RDF. The highest value of NUE (47.49%) was found with the application of 50% N +2 sprays of nano N @ 4 ml l$^{-1}$ followed by 75% N + 2 sprays of nano N @ 4 ml l$^{-1}$ while the lowest NUE was obtained in the treatment with 50% RDN. Application of 50, 75, and 100% RDN ($T_2$, $T_3$ and $T_4$ respectively) to the soil seems to result in lower NUE than foliar applications of nano-N and urea combined with 50 and 75% RDN in $T_7$, $T_8$, $T_9$, $T_{10}$, $T_{11}$ and $T_{12}$ treatment. This demonstrates that foliar nitrogen applications to rice, in addition to soil applications, can increase NUE more than soil applications alone. This might be as a result of different losses of applied N occurring in the soil as a result of denitrification, volatilization, fixation, leaching runoff, and other processes. These results were also in line with the findings of Janmohammadi *et al.* (2016); Dapkekar *et al*. (2018); Sankar *et al*. (2020).

**Table 2: Effect of nano N on grain and straw yield of rice in 2020 and 2021.**

| Treatment details | Grain yield (q ha$^{-1}$) | | Straw yield (q ha$^{-1}$) | |
|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 |
| $T_1$ – 0% N (Control) | $30.50^{d}$ | $31.23^{g}$ | $35.41^{e}$ | $36.47^{g}$ |
| $T_2$ - 50% RDN | $45.50^{c}$ | $45.82^{d}$ | $51.17^{c}$ | $51.17^{de}$ |
| $T_3$ – 75% RDN | $53.18^{b}$ | $54.13^{c}$ | $59.51^{b}$ | $62.27^{bc}$ |
| $T_4$ – 100% NPK (RDF - 120:60:40) | $58.24^{a}$ | $59.67^{a}$ | $66.62^{a}$ | $71.56^{a}$ |
| $T_5$ – 0% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | $34.88^{d}$ | $36.70^{ef}$ | $39.99^{de}$ | $42.51^{f}$ |
| $T_6$ – 0% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | $37.64^{d}$ | $39.37^{e}$ | $43.67^{cd}$ | $46.45^{ef}$ |
| $T_7$ – 50% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | $54.57^{ab}$ | $55.13^{abc}$ | $61.58^{b}$ | $63.59^{bc}$ |
| $T_8$ – 50% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | $55.23^{ab}$ | $55.47^{abc}$ | $61.23^{b}$ | $60.25^{bc}$ |
| $T_9$ – 75% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | $57.38^{ab}$ | $57.55^{abc}$ | $63.38^{ab}$ | $64.28^{bc}$ |
| $T_{10}$ – 75% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | $58.04^{ab}$ | $58.08^{ab}$ | $64.04^{a}$ | $65.57^{b}$ |
| $T_{11}$ – 50% N + 2 sprays of 2% urea | $54.11^{ab}$ | $54.88^{abc}$ | $60.78^{b}$ | $58.92^{c}$ |
| $T_{12}$ – 50% N + 3 sprays of 2% urea | $55.45^{ab}$ | $55.07^{abc}$ | $61.78^{ab}$ | $60.30^{bc}$ |
| SEM± | 1.70 | 1.83 | 1.71 | 1.89 |
| CD (p = 0.05) | 4.97 | 5.37 | 5.00 | 5.55 |

**Table 3: Effect of nano N on nitrogen uptake of rice during 2020 and 2021.**

| Treatment details | Grain | | Straw | | Total | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| $T_1$ – 0% N (Control) | $35.54^{de}$ | $36.35^{e}$ | $15.95^{de}$ | $16.27^{ef}$ | $51.49^{de}$ | $52.62^{e}$ |
| $T_2$ - 50% RDN | $50.13^{c}$ | $51.06^{c}$ | $21.40^{c}$ | $21.01^{cd}$ | $71.53^{c}$ | $72.08^{c}$ |
| $T_3$ – 75% RDN | $59.78^{b}$ | $59.30^{b}$ | $24.67^{b}$ | $25.64^{ab}$ | $84.45^{b}$ | $84.94^{b}$ |
| $T_4$ – 100% NPK (RDF - 120:60:40) | $69.46^{a}$ | $70.01^{a}$ | $28.48^{a}$ | $28.30^{a}$ | $97.94^{a}$ | $98.31^{a}$ |
| $T_5$ – 0% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | $37.79^{de}$ | $40.46^{de}$ | $16.00^{d}$ | $17.19^{ef}$ | $53.80^{de}$ | $57.65^{de}$ |
| $T_6$ – 0% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | $38.71^{d}$ | $42.65^{d}$ | $15.80^{de}$ | $18.37^{de}$ | $54.51^{d}$ | $61.02^{d}$ |
| $T_7$ – 50% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | $57.86^{b}$ | $58.36^{b}$ | $22.52^{bc}$ | $22.45^{c}$ | $80.39^{b}$ | $80.81^{b}$ |
| $T_8$ – 50% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | $58.77^{b}$ | $58.66^{b}$ | $21.58^{c}$ | $20.96^{cd}$ | $80.35^{b}$ | $79.62^{bc}$ |
| $T_9$ – 75% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | $68.86^{a}$ | $67.40^{a}$ | $25.03^{b}$ | $27.20^{a}$ | $93.89^{a}$ | $94.60^{a}$ |
| $T_{10}$ – 75% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | $69.71^{a}$ | $66.47^{a}$ | $24.79^{b}$ | $27.21^{a}$ | $94.50^{a}$ | $93.68^{a}$ |
| $T_{11}$ – 50% N + 2 sprays of 2% urea | $58.62^{b}$ | $58.89^{b}$ | $23.89^{bc}$ | $23.74^{bc}$ | $82.51^{b}$ | $82.63^{b}$ |
| $T_{12}$ – 50% N + 3 sprays of 2% urea | $58.23^{b}$ | $59.82^{b}$ | $23.61^{bc}$ | $22.66^{c}$ | $81.84^{b}$ | $82.47^{b}$ |
| SEM± | 2.10 | 2.13 | 1.00 | 1.01 | 2.58 | 2.66 |
| CD (p = 0.05) | 6.17 | 6.23 | 2.94 | 2.97 | 7.57 | 7.79 |

**Table 4: Effect of nano N on the nitrogen use efficiency of rice during 2020 and 2021.**

| Treatment details | Nitrogen use efficiency (%) | |
|---|---|---|
| | 2020 | 2021 |
| $T_1$ – 0% N (Control) | - | - |
| $T_2$ - 50% RDN | 33.41 | 32.43 |
| $T_3$ – 75% RDN | 36.63 | 35.91 |
| $T_4$ – 100% NPK (RDF - 120:60:40) | 38.71 | 38.07 |
| $T_5$ – 0% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | - | - |
| $T_6$ – 0% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | - | - |
| $T_7$ – 50% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | 48.08 | 46.91 |
| $T_8$ – 50% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | 47.93 | 44.86 |
| $T_9$ – 75% N + 2 sprays of nano N @ 4 ml l$^{-1}$ | 47.06 | 46.60 |
| $T_{10}$ – 75% N + 2 sprays of nano N @ 8 ml l$^{-1}$ | 47.68 | 45.52 |
| $T_{11}$ – 50% N + 2 sprays of 2% urea | 47.14 | 45.61 |
| $T_{12}$ – 50% N + 3 sprays of 2% urea | 44.18 | 43.45 |

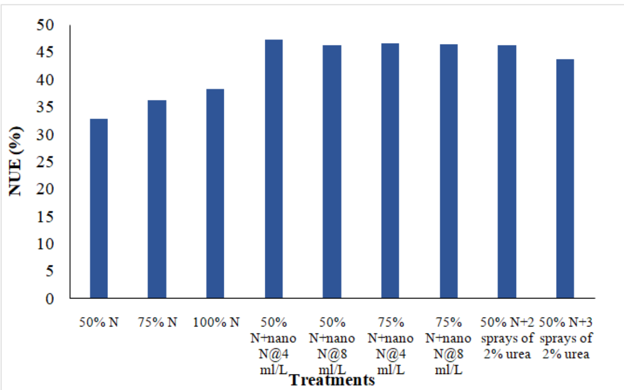


**Fig. 1.** Nitrogen Use Efficiency (NUE) as affected by nano N during 2020 and 2021.

## CONCLUSIONS

Nanotechnology application in agriculture is still in its early stages of development. A horrifying deficit of nutrients in agricultural soil has resulted in a sharp decrease in viability of yield and a severe economic crisis. From the results, we can conclude that the foliar application of nano N (@ 4 and 8 ml $l^{-1}$) in combination with either 50 and 75 % N ($T_7$, $T_8$, $T_9$ and $T_{10}$) and foliar application of 2% urea in 2 and 3 sprays with 50% N ($T_{11}$ and $T_{12}$) were comparable to the application of 100% RDF ($T_4$) thereby, indicating the importance of foliar application. Thus, the use of nano-N can reduce the recommended dosage of nitrogenous fertilizer by up to 50%. The N uptake was found optimum with the application of 75% N with 2 sprays of nano N @ 4 and 8 ml $l^{-1}$ ($T_9$ and $T_{10}$) along with 100% RDF ($T_4$). Overall higher NUE was obtained by the application of a mix of conventional and nano N than as obtained by 100% RDF. Therefore, it can be concluded that nano N helps in obtaining higher nitrogen use efficiency over the 100% RDF application using conventional NPK fertilizer. Finally, it can be concluded that nano N can be used with conventional nitrogenous fertilizer for higher yield, uptake and efficiency of nitrogen. But in order to validate the results of the current investigation, deeper research in this background is required to be done.

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**Conflict of Interest**: None.

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