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Effect of Inorganic fertilizers and organic manure on soil properties and yield attributes of Maize (*Zea mays* L.) var. Ganga

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Abstract
A field experiment was conducted at the research farm in the 'Central Research Farm, Sam Higginbottom Institute of Agriculture, Technology and Sciences' during the kharif season to study the effect of inorganic fertilizers and organic manure on the soil properties, yield and growth attributes of maize. The experiment was laid out in randomized block design (RBD) comprising of 9 treatments and 3 replications of varying levels of FYM (0, 10, 20 t ha^{-1}) and Zinc (0, 5, 10 kg ha^{-1}). The application showed a significantly higher values in the soil properties, growth and yield attributes of maize. Maximum values and increased percentage were recorded in respect to the plant height, weight per cob, cob length, cob girth, grain yield and stover yield of 100.90 cm, 303.89 g, 18.81 cm, 18.45 cm, 4,494 kg ha^{-1}, 5,111 kg ha^{-1} with T_9 followed by T_8, T_7 and T_6. The lowest values were recorded in the T_1 with absolute control followed by T_2 were only the NPK were applied. The soil samples were found to be slightly acidic in reaction, with medium organic carbon content, low available nitrogen, medium phosphorous level and zinc and high in available potassium. The studies proved the previous studies that the application of Zinc and FYM has a significant effect on the soil health enhancing its physical attributes and also supplying nutrients to the plants for their growth by increasing their availability in soil.

Keywords: Maize, FYM, zinc, inorganic, organic, soil, yield, etc

Introduction
Soil is a very essential agricultural resource that needs to be managed with all the care and accurate measure to obtain sustainable productions. The soil properties are inter-related with plant growth significantly due to their interactions. Maintenance of the soil quality would reduce the problems of land degradation, decreasing soil fertility and rapidly declining production levels that occur in the many parts of the world which not only lack the basic principles of good farming practices but weak technical knowhow as well (Khalid).

Maize according to various studies is the second most abundantly produced cereal in the world which requires a pulverized, fine smooth field for seed emergence and root growth. According to the worldwide production status for the year 2024, maize is highly produced by U.S.A followed by China, Brazil, European Union, Argentina and India (www.investopedia.com). Maize contains about 9.736% grain protein, 4.85% grain oil, 9.432% grain crude fiber, 71.966 % grain starch, 11.77% embryo. Maize is known widely as the 'Queen of Cereals' because of its wide adaptability and its genetic yield potential under various agroecological conditions. The maize crop with its high potential is also sometimes known as the 'Miracle crop'. Maize is also known as the best indicator of the zinc deficiency. The leading states in kharif 2023 included Madhya Pradesh, Karnataka, Rajasthan, Maharashtra, Uttar Pradesh. India also ranks the 14th largest exporter of maize in the world according to the APEDA.

In plant nutrition although both the primary nutrients and the secondary nutrients are present, importance is given to primarily to the primary than the secondary. Among these nutrients the secondary nutrients have recently gained importance and attention due to its growing deficiency in the soils all over the world as well as on the daily diet of human beings. But in maize zinc nutrition plays a major role in plant metabolism and yielding potential. There are several studies conducted to enhance the content of zinc in plants by using FYM enriched with Zn solublizers

and inorganic zinc fertilizers. However, less awareness about micronutrients application and indiscriminate use of major nutrients led to the imbalance in soil nutrient status and as a result micronutrient deficiency is noticed in many parts in general and among them zinc is particular. Negative correlation between irrigation and phosphorous was observed with Zn uptake which leads to the reduction of Zn content in kernels, a major cause of Zn malnutrition among maize consumers (P. Nandini *et al.,* 2021) [16]. In recent years, this deficiency has been expected to increase from 44% to 48%. It is also predicted that within the year of 2025 the deficiency would be risen unto 63% in India (Preetha and Stalin, 2014) [17].

Maize is one of the cereals most vulnerable to zinc deficiency. Because high-yielding maize varieties are planted, chemical fertilizers of high purity and cropping has got more intensive in recent decades. Zinc treatment has been reported to boost maize grain yield all over the world (Harris). Zinc has a major contribution to the plant metabolism as well as the growth as it is mainly involved in the protein synthesis, creation of auxin and the chlorophyll cytochrome pigment. It is also required for the nitrogen metabolism (Satyavir and Guru, 2021). Increasing zinc fertiliser rates may provide more accessible Zn to crops, but it may not be cost-effective (Harris).

FYM is one of the most essential organic manures which supplies around 0.5% nitrogen, 0.20% phosphorous and 0.5% potassium. FYM also contributes around 61 ppm of zinc and also various other micronutrients important for plant growth. While the inorganic fertilizers just add up to the chemical properties of the soil directly, the FYM influences both the physical as well as the chemical and biological properties of the soil. When cow dung and cow urine are applied, the plants receive a well-balanced diet. FYM can become a key source for food crops and reduce the need for fertilizers in families where agricultural and livestock production are combined (Harris). Thus, FYM if applied along with other fertilizers like zinc and potassium is beneficial to obtain enhanced yield quality and quantity.

Keeping in view the above facts, the present investigation was undertaken to assess the effect of application of inorganic fertilizers and organic manure via FYM on the yield attributes of maize.

Materials and Methods

The experiment was conducted in the field of the department of Soil Science and Agricultural Chemistry research field, SHUATS, Prayagraj during the kharif season (September to November, 2024). The experimental soil was found to be slightly acidic in nature with a pH of 6.9 and texture sandy loam. The soil was low in organic matter content with 0.40 % while the available nitrogen was 241.36 kg ha^{-1}, available phosphorous was 21.61 kg ha^{-1}, available potassium was 165.64 kg ha^{-1}, and the available zinc was 0.69 mg kg^{-1} The experiment was carried out in RBD with 9 treatments and 3 replications. Three treatments of FYM (0 t ha^{-1}, 10 t ha^{-1}, 20 t ha^{-1}) and Zinc (0 kg ha^{-1}, 5 kg ha^{-1}, 10 kg ha^{-1}) were applied before sowing in the field trial alongside the RDF@ 100%. The RDF was kept constant in all the treatments except the absolute control where no fertilizers or manure were applied. The NPK was applied at the rate of 120:60:40 through urea, DAP and MOP. The sowing of the maize was done on 06th of September, 2024 before which the pre analysis of the pre-sowing soil was done. The net unit plot size used in the experiment was 196.24 m^2.

Pre sowing operation like ploughing, harrowing, levelling and FYM and Zinc application were done at the time of layout preparation. Soil samples were randomly collected to conduct the pre-sowing analysis using the soil auger, air dried, sieved with 2 mm screen and tested for various parameters and the values recorded as shown in Table 1.

Table 1: Results and methodology of the pre-sowing soil analysis

Particulars	Results	Method
Bulk density (Mg m^{-3})	1.30	(Muthuval *et al*.,1992) [14]
Particle density (Mg m^{-3})	2.45	(Muthuval *et al*.,1992) [14]
Pore space (%)	42.07	(Muthuval *et al*.,1992) [14]
Water holding capacity (%)	44.11	(Muthuval *et al*.,1992) [14]
Soil pH (1:2)	6.90	(Jackson, 1958)
Soil EC (dS m^{-1})	0.37	(Wilcox, 1950) [28]
Organic Carbon (%)	0.40	(Walkley and Black, 1947) [27]
Available Nitrogen (kg ha^{-1})	241.36	(Subbiah and Asija, 1956) [24]
Available Phosphorous (kg ha^{-1})	21.61	(Olsen *et al.*, 1954) [15]
Available Potassium (kg ha^{-1})	165.64	(Toth and Price, 1949) [26]
Available Zinc (mg ha^{-1})	0.69	(Linsen and Norvell, 1975)

FYM was applied 10 days before sowing at a rate of 10 and 20 t ha^{-1} in the treatments T_4, T_5, T_6, T_7, T_8, T_9 and zinc was applied along two days after the application of phosphorous on the treatments T_2, T_3, T_5, T_6, T_8, T_9.

Results and Discussion

Effect of application of zinc and FYM on the physico-chemical properties of soil

The application of zinc and FYM showed a significant improvement in the physical properties of the soil as well as the chemical properties. Application of FYM according to the previous studies has significant effect on the soil properties as it releases organic matter into the soil during its decomposition thus binding the soil particles together. The aggregation leads to the increase in the pore spaces in the soil and also reduced bulk density. The increase in the pore space thus provides for more water holding capacity. According to the studies conducted by Satyavir and Guru, there has been a significant improvement in the soil health and hence in the productivity of maize also. The decrease in the bulk density is also due to the addition of the humic substances to the soil (Gajanand, Sharma and Jat, 2012). The FYM and Zinc supplementation has enhanced the micro-pores in the soil which further led to the increased water holding capacity (WHC). The enhancement in the water holding capacity has hence positively affected the growth of the crop. The particle density has shown to be reducing with the application of Zinc and FYM.

Table 2: Effect of various levels of Inorganic fertilizers and organic manures on the bulk density, particle density, pore space and water holding capacity

Treatments	BD (Mg m^{-3})		PD (Mg m^{-3})		Pore space (%)		WHC (%)	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
Absolute control	1.30	1.31	2.46	2.45	42.73	42.74	44.59	44.65
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@0%]	1.30	1.30	2.46	2.45	42.75	42.77	44.74	44.77
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@0 %]	1.29	1.31	2.47	2.45	42.88	42.92	44.98	45.12
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@10 t ha^{-1}]	1.27	1.30	2.49	2.46	43.70	43.80	46.19	46.26
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@10 t ha^{-1}]	1.26	1.28	2.49	2.48	43.90	43.95	46.50	46.62
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@10 t ha^{-1}]	1.24	1.26	2.50	2.48	44.05	44.12	46.83	46.90
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@20 t ha^{-1}]	1.21	1.25	2.51	2.50	45.26	45.30	47.65	47.75
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}]	1.21	1.24	2.51	2.50	45.62	45.69	47.90	48.02
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]	1.20	1.23	2.52	2.51	45.95	46.02	48.08	48.19
F- test	S	S	S	S	S	S	S	S
S. Em (±):	0.01	0.01	0.01	0.01	0.54	0.53	0.10	0.10
C.D.:	0.03	0.03	0.03	0.03	1.62	1.58	0.31	0.30

A non-significant change has been observed and recorded in the pH and EC of the post-harvest soil. The maximum pH of 6.91 and 6.89 was recorded in 0-15cm depth and a depth of 15-30cm in the treatment of T_1 [Absolute control]. Then as the rate of application of FYM increases the soil pH reduces because of the release of organic acids during the decomposition of the organic matter. The maximum EC was recorded as 0.44 dS m^{-1} in the depth of 0-15 cm and the 15-30 cm soil depth EC was recorded as 0.42 dS m^{-1} in the treatment of T_9 [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]. The slight increase of soil EC is as salts are added and solubilization of native minerals due to slight acidity of soils similar to findings by Rangaswamy *et al.*, (2023).

According to the studies conducted by Satyavir and Guru, some significant changes has been observed in the levels of organic carbon (%) in the soil after application of FYM. The FYM potentially adds organic carbon to the soil during its decomposition thus stimulating the growth of maize hence its yield. Higher biomass production might have also improved the organic carbon content of the soil. The study conducted by Sarwar *et al.*, revealing that the substitution of 25 or 50% N with FYM + 4 kg Zn ha^{-1} performed better than 100% N fertilizer alone, with respect to, soil organic matter content and nutrient uptake was proved hence.

Table 3: Effect of various levels of inorganic fertilizers and organic manure on the pH, EC, organic carbon

Treatments	pH (1:2)		EC (dS m^{-1})		OC (%)	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
Absolute control	6.91	6.89	0.35	0.37	0.43	0.41
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@0%]	6.90	6.89	0.38	0.36	0.44	0.41
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@0 %]	6.90	6.89	0.40	0.37	0.46	0.44
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@10 t ha^{-1}]	6.86	6.84	0.43	0.38	0.50	0.48
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@10 t ha^{-1}]	6.82	6.80	0.41	0.38	0.51	0.48
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@10 t ha^{-1}]	6.80	6.79	0.43	0.38	0.52	0.49
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@20 t ha^{-1}]	6.76	6.75	0.43	0.41	0.55	0.52
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}]	6.74	6.72	0.46	0.40	0.56	0.54
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]	6.72	6.72	0.46	0.42	0.58	0.55
F-test	S	S	NS	NS	S	S
S. Em (±):	0.01	0.03	0.09	0.09	0.02	0.02
C.D.:	0.04	0.09	0.27	0.27	0.06	0.06

The supplementation of FYM and zinc has not only made the macronutrients available for plants but also the micro-nutrients. FYM also supplies a certain amount of Nitrogen, phosphorous and potassium thus increasing the levels of NPK in the soils alongside the recommended dose of NPK. Both the inorganic and organic sources together add to the NPK levels to the soil thus improving the soil fertility status. The maximum Nitrogen level of 254.70 kg ha^{-1} and 254.60 kg ha^{-1} was recorded in the 0-15 cm soil depth and in the depth of 15-30 cm in the treatment of [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]. The maximum phosphorous level of 26.2 kg $ha^{-1}$and 26.1 kg ha^{-1} was recorded in the soil of depth 0-15 cm and in the 15-30 cm soil depth with the treatment of T_9 [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]. Application of FYM and zinc altogether showed more available phosphorous status when compared with pre-sown soil. It might be due to organic acids which were released during microbial decomposition of organic matter which helped in the solubility of native phosphates, thus increasing the available phosphorus in soil. Besides these appreciable quantities of carbon dioxide released during the organic matter decomposition might have formed carbonic acid, which enhance the solubility of phosphates resulting in higher availability of phosphate in plots treated with organic matter. Similar results were earlier reported by Satish *et al*. The maximum potassium level was recorded 208.1 kg ha^{-1} in the soil of depth 0-15 cm and 208.0 kg ha^{-1} in the 15-30 cm soil depth with the treatment of [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@ 20 t ha^{-1}].

Zinc absorption capacity is reduced by high phosphorus utilization and Zinc in plant and soil has an antagonism state with phosphorus (negative interaction). The zinc levels were also tested and showed some significant changes with difference in the levels of supplying. The maximum zinc levels were recorded to be 0.78 mg ha^{-1} in the soil depth of 0-15 cm and 0.69 mg ha^{-1} in soil depth of 15-30 cm.

Table 4: Effect of various level of inorganic fertilizers and organic manures nutrients uptake by pos- harvest soil

Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		Zn (mg ha^{-1})	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15 cm	15-30cm
Absolute control	248.43	248.39	21.6	21.2	195.55	195.21	0.69	0.69
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@0%]	249.10	248.97	21.7	21.4	195.94	195.90	0.70	0.69
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@0 %]	249.60	249.59	21.9	21.7	196.57	196.43	0.74	0.71
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@10 t ha^{-1}]	251.22	251.15	22.5	22.4	200.77	200.60	0.72	0.70
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@10 t ha^{-1}]	251.75	251.60	22.8	22.5	202.99	202.84	0.75	0.73
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@10 t ha^{-1}]	251.92	251.87	23.2	22.7	203.81	203.69	0.76	0.73
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@20 t ha^{-1}]	253.75	253.68	25.6	25.1	206.32	206.18	0.75	0.72
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}]	253.97	253.89	25.9	25.8	206.74	206.68	0.78	0.77
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]	254.70	254.64	26.2	25.5	208.10	207.86	0.81	0.78
F-test	S	S	S	S	S	S	S	S
S. Em (±):	0.22	0.11	0.26	0.25	0.22	0.22	0.01	0.01
C.D.:	0.66	0.32	0.77	0.74	0.65	0.60	0.04	0.03

Other than the zinc supplied through zinc fertilizers, zinc was also applied in a considerable rate by the FYM also. The increasing trend of the zinc levels is due to increase in the supplementation of zinc and FYM. The FYM during decomposition releases certain acids and also chelating agents that prevents the precipitation and oxidation of the micronutrients. The lowest levels of NPK and zinc of 248.43 kg ha^{-1}, 21.6 kg ha^{-1}, 195.5 kg ha^{-1}, 0.69 mg ha^{-1} were recorded in the treatment T1 [Absolute control] as there were no fertilizers or manures added. Similar findings were stated earlier by Rangaswamy *et al.*

Effect of application of zinc and FYM on the yield attributes of Maize

Similar to the effect of Zinc and FYM application on the soil properties there were significant effect on the yield attributes of maize too. The attributes taken in the study were plant height, weight per cob, cob length and cob girth. Application of FYM leading to the alteration of the physical and the chemical properties of the soil lead to the increment in the height of the maize crop. The maximum plant height of 100.90 cm was observed with the treatment of T_9 [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}] while the lowest height of 93.57 cm was observed with treatment of T_1 [Absolute control] where no fertilizers were applied 90 DAS. This proves the previous studies conducted by Satyavir and guru stating that the zinc application improved the growth of the crop due to the involvement of zinc in the hormone and protein synthesis. These findings are similar to the findings Satyavir and Guru.

Table 5: Effect of various levels of inorganic fertilizers and organic manure on the plant height, weight per cob, cob length and cob girth

Treatments	Plant height (cm)	Weight per cob (g)	Cob length (cm)	Cob girth (cm)
Absolute control	93.57	291.07	18.41	18.26
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@0%]	94.31	299.71	18.45	18.28
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@0 %]	95.87	318.12	18.48	18.32
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@10 t ha^{-1}]	96.67	324.72	18.56	18.35
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@10 t ha^{-1}]	98.05	325.51	18.69	18.39
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@10 t ha^{-1}]	98.09	332.48	18.70	18.40
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@20 t ha^{-1}]	99.81	354.74	18.72	18.42
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}]	99.98	359.21	18.78	18.46
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]	100.90	373.89	18.81	18.49
F-test	S	S	S	S
S. Em (±):	1.48	12.28	0.10	0.27
C.D.:	4.44	36.82	0.29	0.81

Economics

The following table illustrates the economics of the various treatments and the benefit cost ratio as it decides the efficiency of each treatment. The present study revealed that the cropping of maize with the application of FYM and Zinc has brought maximum C:B ratio of 1:1.59 in treatment T_9 [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}] which was closely followed by T_8 [I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}] with C:B ratio of 1:1.59. Data indicated that the highest gross return of 1,59,408 has been recorded in the T_9 [I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}] and maximum net return of 84,078 has been recorded un the T_9 followed by the T_8[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}].

Table 6: Effect of various levels of inorganic fertilizers and organic manure on the economics of different treatment combination of maize

Treatments	Stover yield ₹	Grain yield ₹	Net return ₹	Gross return ₹	Cost of cultivation ₹	C:B ratio
Absolute control	1,422	2,125	27,154	40,503	27,710	1:1.46
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@0%]	1,788	2,454	16,144	50,274	34,130	1:1.47
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@0 %]	1,987	2,587	18,319	55,449	37,130	1:1.49
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@10 t ha^{-1}]	2,214	2,733	26,585	77,715	51,130	1:1.51
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@10 t ha^{-1}]	2,785	3,824	28,982	83,112	54,130	1:1.53
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@10 t ha^{-1}]	3,458	4,285	31,517	88,647	57,130	1:1.55
[I_{NPK}@100% + Zn@0 kg ha^{-1} + FYM@20 t ha^{-1}]	4,044	4,996	39,474	1,12,004	71,130	1:1.57
[I_{NPK}@100% + Zn@5 kg ha^{-1} + FYM@20 t ha^{-1}]	4,244	5,212	42,762	1,17,492	74,130	1:1.58
[I_{NPK}@100% + Zn@10 kg ha^{-1} + FYM@20 t ha^{-1}]	4,494	5,111	46,059	1,23,189	77,130	1:1.59

Conclusion

It is concluded from the trial that different levels of Inorganic NPK, Zinc and Organic (FYM) fertilizers significantly influences on the *physico-chemical* soil properties as well as the yield attributes of maize. The integrated application of inorganic fertilizers and FYM has produced higher yield accompanied by the increase in the growth attributes like plant height and yield attributes like weight of cobs, number of cobs, cob length and cob girth enhancing considerably. The application of NPK and FYM has influenced the bulk density, pore space and water holding capacity of the soil. The treatment T_9 - [I_{NPK} @ 100 % + Zn @10 kg ha^{-1} + FYM @ 20 t ha^{-1}] gave maximum cost benefit ratio of 1:1.59. Hence, the present study has indicated that the combined application of NPK along with Zinc and FYM at considerate levels gives improved yield and net returns. The application of inorganic fertilizers and organic manure shows an improvement in the soil health as well as the maize yield.

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Competing Interest

Authors have declared that no competing interest exist.

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