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Research Article

Impact of FOMI organo-mineral fertilizers on pH and organic carbon of the soils under tobacco (*Nicotiana tabacum* L) production in Tanzania

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Abstract

A study was conducted in selected tobacco-producing areas in Tanzania to evaluate the impact of Fertilisants Organo Minéraux (FOMI), organo-mineral fertilizers on soil pH and soil organic carbon (SOC) levels after harvesting the tobacco crop K326 from the three sites of Tumbi-Tabora, Mtanila-Chunya and Ushetu-Shinyanga in the 2023/24 cropping season. The experiment involved eight treatments: an unfertilized control; standard NPK fertilizers at 500 kg ha^{-1} and CAN at 133 kg ha^{-1}; FOMI SUPA applied at 1000, 800, and 600 kg ha^{-1} on day 7, combined with FOMI CANS at 133, 83, and 67 kg ha^{-1} on day 21; and FOMI GREEN at 650, 517, and 383 kg ha^{-1} on day 7, combined with FOMI NENEPESHA at 233, 183, and 133 kg ha^{-1} on day 21. The results showed that all FOMI fertilizers improved soil pH at all application rates without significant differences between them and also significantly (*p =0.05*) improved the SOC content. FOMI fertilizers for the first time, increased soil pH by 0.07 units and organic carbon content by 0.01%. Thus, the application of organo-mineral FOMI fertilizers significantly enhanced SOC levels, with more pronounced effects observed in acidic soils and at higher application rates, highlighting their potential to improve soil fertility and promote long-term soil health. Therefore, this study recommends promoting the use of organo-mineral FOMI fertilizers in acidic soils, owing to their capacity to ameliorate soil acidity and enhance SOC, thereby supporting long-term soil health and sustainable agricultural productivity.

1. Introduction

Soil is the key to agriculture and has a significant connection to the survival of human beings, hence it accounts for a useful resource for the development of any nation when soil is tillaged for crop production [1]. Inorganic fertilization is an important measure in agricultural production, as it improves soil nutrients for increased crop yield [2, 3]. However, prolonged application of inorganic fertilizers may lead to nutrient imbalance, reduce organic matter and have negative effects on the soil by increasing soil acidity (H^+) a by-product of nitrification. [4, 5]. Soil pH plays a critical role in influencing the biological, chemical, and physical properties of soil that determine plant growth and productivity [3]. The interactions between soil pH and biological, geological, and chemical processes, such as fertilizer application, can alter soil

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pH through these interconnected systems.

Tanzania's tobacco sector has been importing inorganic fertilizers for tobacco, over seven decades [6] with a value of over 56,147,770 US$. Researchers have found that long-term use of inorganic fertilizers alone degrades soil organic matter, makes the soil more acidic, and pollutes the environment by causing heavy metals to, accumulate which lowers the quality and health of the soil [7-10]. However, other researchers have found that a combination of inorganic and organic fertilizers can enhance soil health [11]. Recently, the use of organo-mineral fertilizers has become popular in the fertilizer industry to combine organic and inorganic fertilizers and rock resources to improve soil health and fertility. Researchers have also linked it to improved mineral nutrient use efficiency [12,13].

The concept of organic culture emerged from the promotion of organic fertilizers to counteract the negative effects of chemical fertilizers [14,15]. Organic fertilizers include compost, farmyard manure, bacterial biofertilizers, or plant growth-promoting rhizobacteria (PGPR). Returning organic amendments to the field can alleviate soil problems, improve soil components by increasing soil organic matter, and improve soil fertility to a certain extent [15]. This advantage could be due to the fact that organic materials in the organo-mineral fertilizers contain a significant amount of organic matter and functional microorganisms, which can effectively transform nutrients in the soil [14]. However, it's important to note that many of these microorganisms may not be cultivable.

Organomineral fertilizers improve soil physical properties, reduce soil acidity, improve soil bulk density, increase water infiltration rate, increase soil porosity and aeration, reduce nutrient leaching, and increase SOC. By boosting the amount of organic carbon, humus content of the soil increases altering the biological characteristics of the soil, and fostering the growth of beneficial macro- and microorganisms. This, in turn, improves soil fertility and boosts crop productivity, while utilizing eco-friendly and economical methods [13].

Prolonged reliance on inorganic NPK fertilizers in tobacco-growing areas of Tanzania has intensified soil acidification and nutrient depletion, posing a significant challenge to soil fertility sustainability given the high nutrient demands of tobacco [16]. Thus, organo-mineral fertilizers offer a promising alternative for improving soil fertility and soil health [14]. The Fertilisants Organo Minéraux (FOMI), an organomineral fertilizer is produced by the International Trading Company (ITRACOM) Fertilizers Ltd in Tanzania. These organo-mineral fertilizers included basal fertilizers FOMI GREEN ($N_{10}P_{14}K_{11}$) and FOMI SUPA ($N_5P_9K_{12}$) and top-dressing fertilizers FOMI NENEPESHA ($N_{11}P_0K_{22}$) and FOMI CANS ($N_{18}P_0K_1$) respectively. Therefore, the objective of this study was to evaluate the influence of FOMI organo-mineral fertilizers on soil pH and soil organic matter and its potential in enhancing soil health for the sustainability of tobacco production in the cropping season 2023/24.

2. Materials and methods

2.1. Description of the experimental sites

The selected soil characteristics (nutrients) of the experimental sites are presented in Table 1. During the 2024–25 cropping season, field experiments were carried out at the Tumbi site, in the Tabora region, Ushetu in Shinyanga and Mtanila, in Chunya-Mbeya. The Tumbi site located at 5°3'41.96772" S, 32°40'13.07892" E; 1168 m a.s.l in Tabora District had a mean atmospheric temperature and rainfall of 29 °C and 1050 mm, respectively; Ushetu, located at 4°7'15.76488" S, 32°16'7.61664" E, 1,153 m a.s.l in Shinyanga region had mean atmospheric temperature and rainfall of 25 °C and 890 mm, respectively. Mtanila located at 7°54'26.02044" S, 33°19'21.8226" E, 1,368 m a.s.l. in Chunya Mbeya region had a mean atmospheric temperature and rainfall of 24 °C and 750 mm, respectively. Table 1 lists the specific soil characteristics of the experimental location. The Tobacco Research Institute of Tanzania's (TORITA) K326 tobacco seed variety was used.

2.2. Soil samples analysis prior to the experiment

A zigzag method for soil sampling to a depth of 0-30 cm a using soil auger was adopted across the sites to make a composite sample at each site before the trial and at each plot to make a composite sample after the trial. The soil composite samples were used to

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Table 1. Some soil physical-chemical characteristics before the experiment.

S/No	Parameter	Unit	Ushetu-Shinyanga	Tumbi-Tabora	Mtanila- Chunya
1	OC	%	0.18	0.18	0.21
2	pH (water)	-	5.17	5.11	5.09
3	Total N	%	0.02	0.02	0.02
4	Avail P	mg kg^{-1}	7.99	6.57	5.00
5	Exch K	$cmol^{+}kg^{-1}$	0.40	0.45	0.42
6	Exch Ca	$cmol^{+}kg^{-1}$	0.40	0.42	0.59
7	Texture class	-	Loamy sand	Loamy sand	Sandy loam

Table 2. Experimental treatments across the sites.

No.	Basal and Topdressing Fertilizers	Basal rate at 7 DAT	Topdressing rate at 21 DAT
1.	UNFERTILIZED	0 kg ha^{-1}	0 kg ha^{-1}
2.	STANDARD (ST) + CAN (CN)	500 kg ha^{-1} $N_{10}P_{18}K_{24}$	133 kg ha^{-1} CAN27%N
3.	FOMI SUPA (FS) + FOMI CANS (FC)	1000 kg ha^{-1} $N_5P_9K_{12}$	133 kg ha^{-1} $N_{18}P_0K_1$
4.	FOMI SUPA (FS) + FOMI CANS (FC)	800 kg ha^{-1} $N_5P_9K_{12}$	83 kg ha^{-1} $N_{18}P_0K_1$
5.	FOMI SUPA (FS) + FOMI CANS (FC)	600 kg ha^{-1} $N_5P_9K_{12}$	67 kg ha^{-1} $N_{18}P_0K_1$
6.	FOMI GREEN (FG) + FOMI NENEPESHA (FN)	650 kg ha^{-1} $N_{10}P_{14}K_{11}$	233 kg ha^{-1} $N_{11}P_0K_{22}$
7.	FOMI GREEN (FG) + FOMI NENEPESHA (FN)	517 kg ha^{-1} $N_{10}P_{14}K_{11}$	183 kg ha^{-1} $N_{11}P_0K_{22}$
8.	FOMI GREEN (FG) + FOMI NENEPESHA (FN)	383 kg ha^{-1} $N_{10}P_{14}K_{11}$	133 kg ha^{-1} $N_{11}P_0K_{22}$

DAT = Days after transplanting tobacco seedlings.

determine the soil pH using a soil water ratio of 1:2.5, SOC by the Walkley Black method, total N was determined by the Kjedahl method, available P by the Bray-1 method, and exchangeable Ca, and K estimated by atomic adsorption spectrophotometer [17].

The sown tobacco seeds (K326) were sourced from TORITA in a 1.5 m wide and 20 m deep seedbed. The seedlings were raised in a seedbed of 1.5 x 20 m and fertilized with 5 kg NPK for basal application as per the treatments given below. Eight weeks after sowing, the seedlings were transplanted to the experimental plots at a spacing of 1.2 m between ridges and 0.50 m between plants, making a total of 24 plants per plot of size 4.8 m x 3 m, equivalent to a population of 16,666 plants/ha. The tests were set up in a randomized complete block design with eight treatments, with 4 replications, at the 3 sites. The standard basal fertilizer was composed of NPK (10:18:24) + 0.5MgO + 3CaO + 7S+0.012B and its topdressing fertilizer which composed of CAN 27%N + 1.7MgO + 3CaO + 3S. The FOMI SUPA basal fertilizer composed of NPK (5:9:12) + 3CaO + 1MgO + 4S + 0.01B and its topdressing FOMI CANS fertilizer composed of NPK 19:0:1) + 3CaO + 2MgO + 4S. The FOMI GREEN basal fertilizer was composed of NPK (10:14:11) +7CaO+1MgO and its topdressing FOMI NENEPESHA composed of NPK (11:0:22) + 4CaO + 2MgO. Table 2 shows the rates and times of application of both basal and topdressing fertilizers in each treatment.

Throughout the experiments, the experimental plots were kept weed-free and pesticides were applied only after counting the number of pests present. Confidor was used at the rate of 10g L^{-1} of water as a pesticide used across the sites. Tobacco plants were topped, followed by the application of Yamaotea Super 305 EC at the rate of 8 mls 10 L^{-1} of water as a sucker.

2.3. Analyses of statistics

The data collected across sites were analysed using a two factors analysis of variance (ANOVA). The analysis covered the different rates of two basal FOMI organo-mineral fertilizers, as well as their top-dressed counterparts. The STATISTICA 8th Edition, (StatSoft, Inc., Tulsa, OK, USA), was used. Significant means were compared using Fisher's least significant difference at p = 0.05.

3. Results and discussion

3.1. Effect of organo-mineral FOMI fertilizer on soil pH

The application of organo-mineral FOMI fertilizer

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Table 3. Effect of application of FOMI fertilizers on soil pH, and SOC.

Sites	Soil pH	Soil OC (%)
Mtanila-Chunya	5.16 ± 0.01 b	0.21 ± 0.00 a
Tumbi-Tabora	5.14 ± 0.01 c	0.19 ± 0.00 b
Ushetu-Shinyanga	5.18 ± 0.00 a	0.18 ± 0.00 c
Treatments		
T1 - Unfertilized	5.12 ± 0.01 b	0.18 ± 0.00 e
T2 - 500 kg ha^{-1} ST+133 kg ha^{-1} CN	5.12 ± 0.01 b	0.18 ± 0.00 e
T3 - 1000 kg ha^{-1} FS+133 kg ha^{-1} FC	5.18 ± 0.01 a	0.21 ± 0.00 a
T4 – 800 kg ha^{-1} FS+83 kg ha^{-1} FC	5.18 ± 0.01 a	0.20 ± 0.00 b
T5 – 600 kg ha^{-1} FS+67 kg ha^{-1} FC	5.17 ± 0.01 a	0.19 ± 0.00 c
T6 – 650 kg ha^{-1} FG+233 kg ha^{-1} FN	5.18 ± 0.01 a	0.20 ± 0.00 b
T7 - 517 kg ha^{-1} FG+183 kg ha^{-1} FN	5.18 ± 0.01 a	0.19 ± 0.00 c
T8 - 383 kg ha^{-1} FG+133 kg ha^{-1} FN	5.17 ± 0.01 a	0.19 ± 0.00 c
2-WAY ANOVA F-statistics		
Site (S)	19***	109.43***
Treatment (T)	16***	27.88***
S x T	3***	1.22ns

Means in the same category of evaluated interface sharing similar letter(s) do not differ significantly based on their respective Standard error (SE) at a 5% error rate. Values presented are means ± $SE_{\bar{x}}$ (Standard error of means); *** means significant at $P < 0.001$

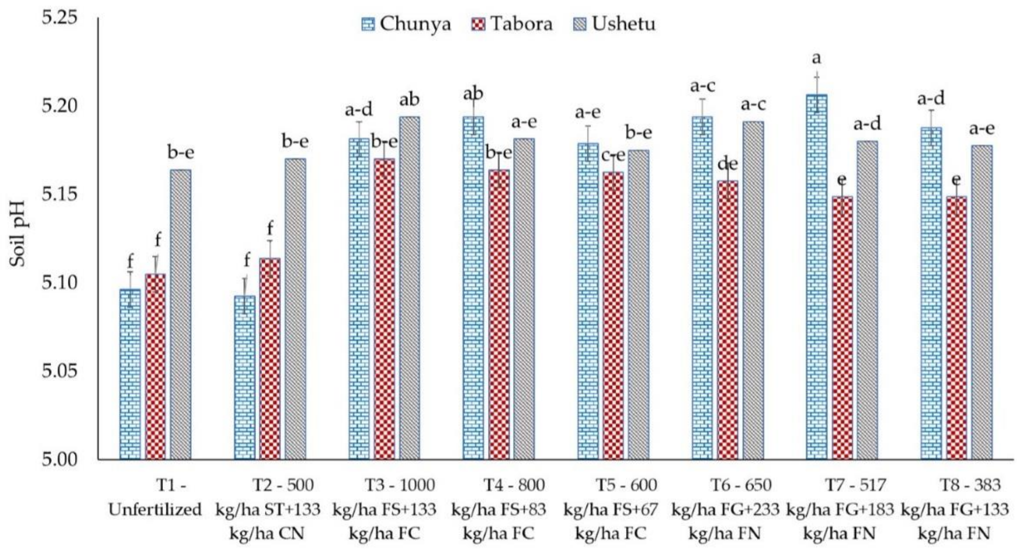

Figure 1. Effect of organic FOMI fertilizers on soil pH across the sites.

reduced soil acidity. Before applying FOMI fertilizers, the soil pH for the Ushetu-Shinyanga site was 5.17 (Table 1), after the trial, it was 5.18 ± 0.00, indicating a reduction in soil acidity by 0.01 unit for two application seasons. The soil pH for Tumbi-Tabora following the application of organic FOMI fertilizers reduced pH by 0.03 units, while the soil pH for the Mtanila-Chunya site reduced by 0.07 units. This indicates that the use of organo-mineral FOMI fertilizers results in a favourable response by reducing the soil pH, as shown in Table 3 and Fig. 1, due to additional organic content in the soil. Similar results were observed in other studies [14] and [15].

The more acidic the soil, the greater the change in pH due to the use of organo-mineral FOMI fertilizers (Fig. 2).

The treatment results indicated that the standard fertilizer $N_{10}P_{18}K_{24}$ (T2) did not improve the soil pH and did not differ from the absolute treatment (T1), which did not receive any fertilizer. However, all the

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organic fertilizers FOMI SUPA ($N_5P_9K_{12}$), FOMI CANS ($N_{18}P_0K_1$), FOMI GREEN ($N_{10}P_{14}K_{11}$), and FOMI NENEPESHA ($N_{11}P_0K_{22}$) (T3-T8) increased soil pH significantly ($p =0.05$) compared to the standard fertilizer (T2). The improvement of soil pH could be attributed to the calcium (Ca) and magnesium (Mg) oxides content combined in FOMI fertilizers. Therefore, the long-term application of organo-mineral FOMI fertilizers could alleviate soil acidity in tobacco-growing areas in the future. Other studies have also observed a similar trend for long-term application of organic fertilizers with Ca and Mg oxides for improving soil acidity [18-21].

3.2. Effect of organo-mineral FOMI fertilizer on SOC

The application of FOMI fertilizer at the Mtanila-Chunya site resulted in a significantly high content of SOC of 0.21 ± 0.00% (Table 3). The Tumbi-Tabora site showed a slight increase in SOC by 0.01% to 0.19 ± 0.00%. The SOC for the Ushetu-Shinyanga site, was the lowest in comparison to Mtanila-Chunya and Tumbi-Tabora (Fig. 2).

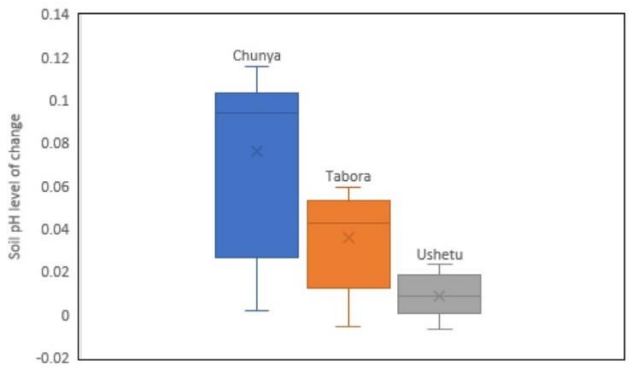

Figure 2. Impact of organo-mineral FOMI fertilizers on soil acidity and its pH change.

The inherent levels of SOC could have been attributed to the improvement in SOC. The standard treatment (T2) applied with standard NPK (10:18:24) at the rate of 500 kg ha^{-1} and top-dressed with CAN 27%N (133 kg ha^{-1}), did not improve the SOC, similar to the unfertilized treatment (T1). The application of basal fertilizer at a higher rate of 1000 kg ha^{-1} FOMI SUPA and top-dressed with 133 kg ha^{-1} FOMI CANS resulted in a significant increase in SOC, probably due to the nature of the soil that was not too ($p =0.05$) improve the SOC (0.21 ± 0.00%). The SOC level dropped to 0.20 ± 0.00% with a basal application rate of 800 kg ha^{-1} and top-dressing rate of 83 kg ha^{-1}. This did not differ significantly from the treatment that used 650 kg ha^{-1} of FOMI GREEN for the base and 233 kg ha^{-1} of FOMI NENEPESHA for top-dressing. These results show that organo-mineral FOMI fertilizers enhanced SOC more than the standard fertilizer.

Organo-mineral fertilizers are known to be beneficial for the recycling and preservation of SOC in soils. FOMI fertilizers are composed of organic functional groups enriched with oxidized and aliphatic carbon [22]. These different C species of mineral surfaces enhance the chemical composition of SOC bound in surfaces and become stable in organo-mineral. Through this mechanism, FOMI organo-mineral fertilizers are beneficial for the recycling and preservation of organic carbon in soils. Thus, the use of higher rates of FOMI organo-mineral fertilizer (1000 kg ha^{-1}) indicated an increase in the accumulation of organic carbon in the soil. This is a very crucial soil property, especially in these areas where SOC is naturally low [16]. Similar to the sites that naturally had low SOC content (Table 1). The application of FOMI organo-mineral fertilizers has also been indicated to keep or maintain its SOC (Fig. 3; Table 3).

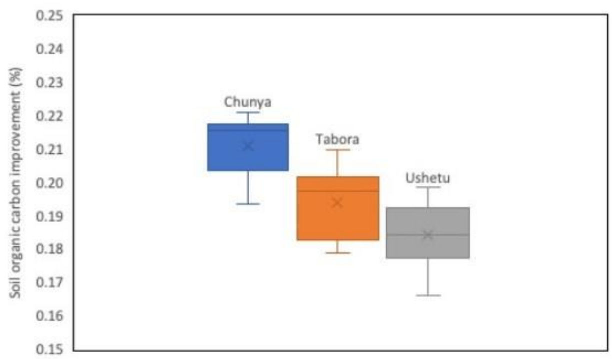

Figure 3. Impact of organic FOMI fertilizers in preserving/improving SOC.

However, there was a slight improve in the SOC at the Tumbi-Tabora site (Fig. 3, Table 3), indicating that prolonged use of FOMI organo-mineral fertilizer not only preserved but also improved the SOC. The organic carbon derived from organic matter (OM) in FOMI has the potential to provide agronomic value, contributing to fertilizer use efficiency and soil environmental conservation [23]. Thus, FOMI organo-mineral fertilizers have been observed to produce

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higher crop yields in comparison to the conventional fertilizers [24, 25].

These results indicate that the application of organic FOMI fertilizers enhanced and improved the soil pH, and preserved SOC. Similar studies have shown a slight improvement in soil pH and enhanced SOC due to the use of organo-mineral fertilizers [26, 27]. The enhancement of SOC is important for increasing crop yields and quality, as organic carbon is key for conserving the equilibrium of agricultural ecosystems [28] as it improves soil health, nutrient storage and availability to plants and soil pH [20, 29] which is a very important parameter for soil nutrient availability.

Therefore, this study established that the use of FOMI organo-mineral fertilizer in tobacco improves soil pH and SOC, which is in agreement with another study [30] that indicated that organic fertilizer improves organic carbon in soils. Additionally, recent research on the use of organic fertilizers in tobacco crops [31-35] has demonstrated that increasing SOC contributes to better soil health. Other studies have shown that organo-mineral fertilizers can improve the physical, chemical, and biological properties of soil, which helps plants grow by releasing nutrients at the right time [36]. Our study recommends long-term research to further study the impact of organo-mineral fertilizers not only to soil pH and organic carbon, but also for soil-plant nutrient interactions and soil microbial diversities.

4. Conclusions

The results demonstrated that the application of organo-mineral FOMI fertilizers had a positive effect on soil chemical properties by slightly reducing soil acidity and enhancing SOC content. Compared with standard mineral fertilizers, the use of FOMI fertilizer for the first time, increased soil pH by 0.07 units and the organic carbon content by 0.01%. FOMI fertilizers were more effective in improving SOC, with stronger responses observed in more acidic soils and at higher application rates, indicating their potential for improving soil fertility and long-term soil health.

Based on the study findings, the following recommendations are proposed. First, organo-mineral FOMI fertilizers should be promoted as an alternative to conventional mineral fertilizers, particularly in acidic soils, due to their ability to reduce soil acidity and improve SOC. Second, the appropriate application rates of FOMI fertilizers should be optimized and adopted by farmers to maximize improvements in SOC and sustain long-term soil fertility and productivity. Finally, for more comprehensive results, further research is needed to evaluate the effects of organo-mineral fertilizers on soil pH, SOC, and nutrient interactions between soil and plants, as well as the composition and diversity of microbial communities.

Disclaimer (artificial intelligence)

Author(s) hereby state that no generative AI tools such as Large Language Models (ChatGPT, Copilot, etc.) and text-to-image generators were utilized in the preparation or editing of this manuscript.

Authors' contributions

Conceptualization, research design and formal analysis, organization of trials in three sites, data curation, funding acquisition, manuscript write-up, review, editing, reading, and approval of the final manuscript, J.L; research design, investigation, supervision, manuscript review, manuscript write-up, review, editing, reading, and approval of the final manuscript, E.M,; methodology development, supervision of casual laborers, data collection, data entry and analysis, review of manuscript, reading and approval of the final manuscript, G.G.; R.K., E.M.; formulation of organomineral fertilizers, monitoring trials, agronomic activities, review, editing, reading, and approving the final manuscript, J.M., K.M., E.N., M.N., C.S.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare to have no conflict of interest regarding this paper publication. No potential conflict of interest was reported by the authors.

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