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Swallow Droppings for The Chemical Properties of Alluvial Soil As Growing Medium For Ebony (*Diospyros Celebica*)

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Abstract: This study aimed to determine the effects of swallow bird droppings bokashi on several soil chemical properties such as pH, C-Organic, N, P, K, CEC, and to determine the appropriate dosage of bokashi fertilizer for the growth of ebony seedlings. This research was conducted at Permanent Nursery located at Tadulako University. This study was conducted using a completely randomized design with 5 treatments and 4 replications, 20 experimental units as: P0 (control), P1 (7 tons/ha), P2 (14 tons/ha), P3 (21 tons/ha), and P4 (28 tons/ha). The results showed that the swallow droppings bokashi fertilizer was able to improve: soil pH 7.18 to 7.55 with a neutral status, P from 41.34 to 65.06 with very high status, K from 46.26 to 53.87 with high status, C-Organic from 5.30 to 10.25 with high to very high status, and N-Total from 0.12 to 0.34 although in low status in the soil. The application of swallow droppings bokashi into the soil was very much needed. C-Organic content in swallow droppings bokashi was 50.23%, N (4.26). The application of swallow droppings bokashi with a treatment of 21 tons/ha (61.25 g/pot) was the best dose for the growth (height) and the increase number of leaves of ebony seedlings.

Keywords: Ebony Seeds; Soil Chemistry; Swallow Dropping Bokashi Fertilizer.

Introduction

Eboni wood, also known as black wood, is one of the endemic flora species of Central Sulawesi (Darmawan et al., 2021). Eboni wood is known as a type of wood with high strength, solid color, luxurious aesthetics, and high economic value (Chen et al., 2018); (Sitanggang & Luthan, 2019). Generally, eboni wood is used as raw material for handicrafts that are widely favored by the public (Eder et al., 2021). Additionally, eboni wood is also utilized for making bridge pillars, fences, furniture, statues, carvings, and home decorations. However, the existence of this valuable resource is increasingly scarce due to excessive exploitation and environmental changes (Chen et al., 2018). As a species that cannot grow in isolation, eboni trees heavily depend on the surrounding environmental conditions, especially soil and climate, for optimal growth (Karlinasari et al., 2021). The interaction between eboni and its environment is crucial, as environmental factors significantly influence the development and sustainability of this species (Weil & Brady, 2017; Hüppi et al., 2015; Darmawan et al., 2021).

Soil conditions play a vital role in the growth of eboni seedlings. In the Palu city valley area, the dominant soil type is alluvial soil, which is categorized within the Entisols order (Hikmatullah & Al-Jabri, 2007 (Larekeng et al., 2024). This type of soil has several challenges, including low organic matter content, varying fertility levels, acidity, and limited availability of macro and micro nutrients. Additionally, alluvial soil, commonly found in lowlands and valleys, has high sand content, high porosity, and low water-holding capacity,

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making it less ideal for supporting the growth of high-value tree species like eboni (Weil & Brady, 2017.

To overcome the limitations of alluvial soil properties in the Palu City Valley, the use of organic fertilizers (OF) is an appropriate solution to improve the existing soil quality. Organic fertilizers not only enhance the physical and chemical properties of the soil, particularly in sandy soils, but they also improve structure, water retention, and nutrient availability (Jain & Kalamdhad, 2020; Niu et al., 2022). These fertilizers contain nutrients required by plants and reduce chemical residues in the soil, as well as essential factors needed for the growth of eboni seedlings. Therefore, the use of bokashi made from swiftlet droppings as a soil ameliorant is an innovative approach that has not been extensively studied. Swiftlet droppings are a byproduct of the rapidly growing bird's nest industry, and their potential as a high-value organic fertilizer has not been widely exploited (Karlinasari et al., 2021).

This research offers novelty in the innovative exploration of using bokashi from swiftlet droppings as an alternative organic fertilizer to enhance the growth of eboni seedlings in alluvial soil. This research is pioneering in highlighting the potential benefits of utilizing abundant but underutilized resources in Central Sulawesi. The use of bokashi from swiftlet droppings is expected to be a wise and sustainable solution to improve soil quality and support the cultivation of rare and economically valuable tree species.

Thus, this research will provide a solution in responding to the urgent need for sustainable cultivation methods for eboni wood by improving the physical, chemical, and biological properties of suboptimal alluvial soil through the application of bokashi from swiftlet droppings. Additionally, this research opens the way for more responsible and environmentally friendly management of bird's nest industry waste by converting it into a high-value agricultural resource.

This study aims to determine the effect of bokashi from swiftlet droppings on several soil chemical properties such as pH, C-Organic, N, P, K, CEC, and to determine the appropriate dose of bokashi for the growth of eboni seedlings."

Method

Study Design and Time Research

This research was conducted from February to July 2021 at the Center for Watershed and Protected Forest Management (BPDASHL) Palu-Poso Permanent Nursery, Tadulako University, Palu city, Indonesia. The soil used as the seedling medium was Alluvial soils from Vatutela, Tondo Village, Palu City, Indonesia. The analysis of soil samples was carried out at the Laboratory of Soil Science, Faculty of Agriculture, Tadulako University. The area used for the experimental location was cleaned of rubbish and then the pots for planting the ebony seedlings were prepared.

This research used ebony seedlings aged 3 months (5 treatments and 4 replications), so 20 experimental units were experimental total with various doses of swallow droppings bokashi mixed with 7 kg of soil, as follows: P0 = without bokashi, P1 = 7 tons/ha (20.42 g/pot bokashi), P2 = 14 tons/ha (40.84 g/pot bokashi), P3 = 21 tons/ha (61.66 g/pot bokashi), and P4 = 28 tons/ha (81.67 g/pot bokashi).

Preparation of Bokashi, Planting Media

The materials for making swallow droppings bokashi were prepared, i.e., 10 kg of swallow droppings, 1.5 kg of rice husk, 1 kg of fine bran, 0.5 cups of granulated sugar solution, 2 bottle caps of EM_4 solution and 2 L of water. Furthermore, the swallow droppings that have been cleaned were poured onto a tarpaulin measuring 1 x 1 m to facilitate the materials mixing process. 2 L of water was poured into a baking dish, then was mixed with 2 bottle caps of EM_4 solution and 0.5 cups of granulated sugar, and then was stirred to mix well. After that, the mixed water and the solution was poured into a bucket containing rice husks, so that when mixing with swallow droppings, it can be mixed evenly.

The mixed husks and the solution were then mixed into the swallow droppings that had previously been prepared, stirred until well blended and then bran was added, it was stirred again until all the materials were thoroughly mixed. Sufficient water content is one of the triggering factors for whether the bokashi produced is good or not. A good moisture content around 30% was achieved by taking a little mixed bokashi and holding it firmly until the water drips. Finally, bokashi fertilizer was ready to be left and stored. The storage process must also be considered, such as the bokashi fertilizer was covered with a tarpaulin of the same size, stored in a place that was free from sunlight and not exposed to rain. The longer the storage, the better the bokashi fertilizer produced, normally around 2-3 weeks. In this study, the storage time was 2 weeks.

Alluvial soil samples were taken from Vatutela, Tondo Village (depth of 0-20 cm). The soil was first cleaned of vegetation, roots, and the remains of plant organs. Furthermore, the soil was air-dried until moist, then it was mashed and sieved with a 2 mm sieve, and was used to produce the same (uniform) soil grains. Then the sieved samples were put into pots, each equivalent to seven kg according to the treatments.

The soil in each pot was mixed with swallow droppings bokashi at a rate according to the treatment dose. Then it was stirred until smooth (homogeneous). After that, the soil mixture was put in the pot and then water was added to field capacity and incubated for 1 week which aimed to provide interaction between the OF and the soil. Planting is carried out in small polybags that have been treated pots. A hole was made in the pot with the diameter size of the small poly bag, and then the small polybag was sliced carefully using a knife, so that it can be easily removed. Then, the 2-month-old plant and the soil was added into the pothole. Then, the soil was pressed around the hole to make it more solid. Maintenance was carried out every day, watering regularly, especially at the beginning of plant growth and dry weather. Watering was applied 1-2 times a day, i.e., in the afternoon to keep the soil from getting too dry and not too wet. Watering was done homogeneously/uniformly to each plant sample. If the soil was still wet, then watering was not necessary. If there are weeds growing in the pot that is planted with ebony seeds, pull out every weed around the plant.

Collection data of soil chemical properties, plant growth

CEC was conducted by washing. This was very important because it is closely related to soil fertility. The determination of N was conducted using the Kjeldahl method. The P determination was performed using the Bray 1 method. The K determined using the Flame Photometer. N-Total content in soils was carried out by taking a soil sample and then analyzing it in the laboratory. C-Organic analysis was performed using the Walkley and Black method.

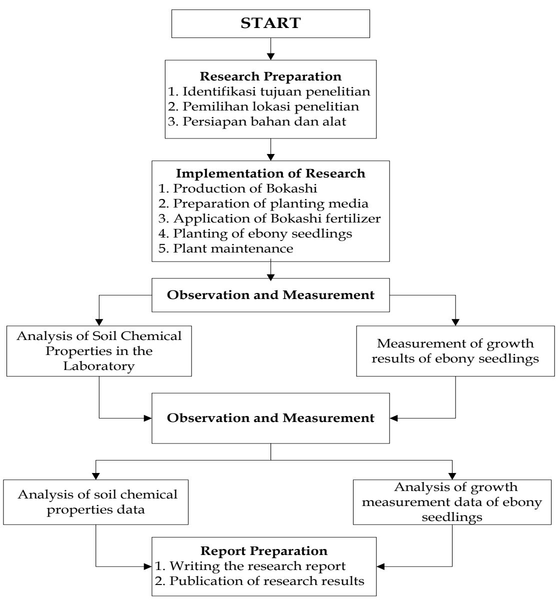

Figure 1. Research Flow Diagram

The plant growth parameters measured in this study were as follows Plant height was measured from the ground surface/base of the plant stem to the top of the plant using a ruler/meter. This measurement was routinely performed two weeks after planting, and then was measured 12 times a week. Parameters was conducted once a week until the 12th week. The leaves counted were leaves that had opened. The research flow will be presented in the form of a flowchart in Figure 1.

Data Analysis

Analysis of variance (ANOVA) and the Tukey's Honestly Significant Difference (HSD) test were used to determine the growth of ebony seedlings

Result

Swallow Droppings Bokashi Application on The C-Organics

Figure 1 shows the correcaltion C-Organic and some treatments of swallow droppings bokashi. The results of soil analysis showed that the soil given swallow droppings bokashi with various doses indicated an increased value of C-Organic soil from the value of soil analysis without the treatments (control) (P0<P1<P2<P3<P4). The highest C-Organic was obtained in the 28 tons/ha treatment (the bokashi treatment of 84.48 g/pot) with a value of 10.25 %, whereas the lowest C-Organic was obtained in the control (without swallow droppings bokashi) with of a value of 5.30%.

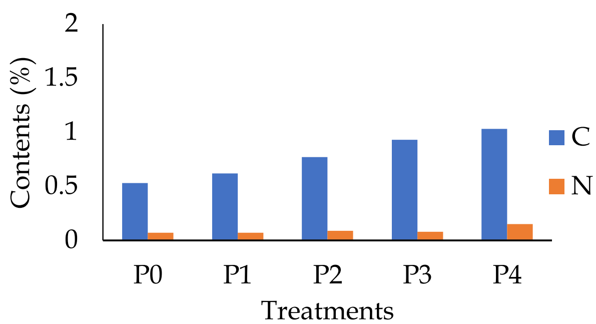

Figure 2. C-Organic (%) in the soil with different doses of swallow droppings bokashi.

The results of the N-Total after the treatments were that in the soil treated with different doses of swallow droppings bokashi, the value of increasing Nitrogen (N) varied at each treatment dose. Figure 2 shows that the highest N-Total value was obtained in the 28 tons/ha treatment (the bokashi treatment of 84.48 g/pot) with a value of 0.34, while the lowest N-Total was obtained in the control (without swallow droppings bokashi) with a value of 0.12. These results are consistent with previous studies showing that the use of bokashi as a soil amendment can significantly increase nitrogen availability, depending on the dosage and type of organic materials used in bokashi production (Quiroz & Céspedes, 2019). Additionally, other studies have shown that increasing the dose of bokashi can increase the total nitrogen content in the soil, contributing to improved soil fertility and plant growth (Ramlan, 2022). The use of bokashi in combination with other materials, such as zeolite, has also been shown to be effective in enhancing nitrogen availability in various soil types (Narulita et al., 2023).

The results of changes in available phosphorus (P) after the application of swallow droppings bokashi fertilizer are presented in Table 1. Soil given different doses of swallow droppings bokashi indicated an increase in the value of soil phosphorus (P) when compared to the untreated soil. The results indicated that the highest soil P was obtained in the 28 tons/ha treatment (the bokashi treatment of 84.48 g/pot) with a value of 65.06, while the lowest P was obtained in the control (without swallow droppings bokashi) with a value of 41.34.

Table 1. Average P and K (%) in the soil with different doses of swallow droppings bokashi.

Treatments	P (%)	K (%)
P0	41.34±0.52	46.26±9.32
P1	50.85±6.15	51.66±2.13
P2	53.87±8.46	51.84±2.25
P3	61.07±3.18	52.53±1.76
P4	65.06±3.27	53.87±1.99

Note : P0 (Control), P1 (7 ton.Ha^{-1}), P2 (14 ton.Ha^{-1}), P3 (21ton.Ha^{-1}), P4 (28 ton.Ha^{-1})

The results of soil analysis after the application of swallow droppings bokashi with different doses showed an increase in the value of soil Potassium (K) when compared to the untreated soil. This showed that the higher dose of swallow droppings bokashi resulted in the higher available K content in the soil. Table 1 shows that the highest available K was obtained in the 28 tons/ha (the bokashi treatment of 84.48 g/pot) with a value of 53.87, whereas the lowest K value was obtained in the control (without swallow droppings bokashi).

The increase in Potassium (K) content in the soil after the application of swiftlet manure bokashi can be caused by the ability of bokashi to provide important nutrients through the decomposition process of organic matter. According to Quiroz and Céspedes (2019), bokashi as an organic amendment can improve soil fertility and increase nutrient supply. In addition, research conducted by Pohan et al. (2019) revealed that bokashi compost significantly increases plant growth by increasing nutrients such as Potassium in the soil. Further research by Maass et al. (2020) also supports that bokashi contributes to increasing soil fertility, especially in the availability of phosphate and other nutrients needed for plant growth.

The results of changes in cation exchange capacity (CEC) because of the swallow droppings bokashi application are presented in Figure 6. The results of soil analysis showed that the soil given different doses of swallow droppings bokashi indicated an increased value of CEC when compared to the untreated soil. Figure 5 shows that the highest CEC value was obtained in the 28 tons/ha treatment (the bokashi treatment of 84.48 g/pot) with a value of 40.84, while the lowest CEC value in the soil was obtained in the control (without swallow droppings bokashi).

Cation exchange capacity (CEC) is a chemical property that is closely related to soil fertility. Soils with a high organic matter content or clay content have a higher CEC than soils with a low organic matter content or sandy soils.

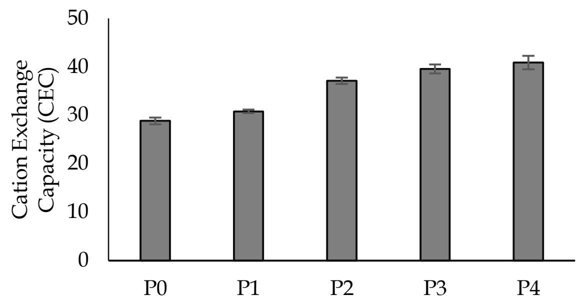

Figure 3. Cation Exchange Capacity (CEC) in the soil with different doses of swallow droppings bokashi

The height of ebony seedlings

The results on the average height of ebony plants at 4, 8, and 12 weeks after planting (WAP) are presented in Table 2. Based on the ANOVA results, the application of swallow droppings bokashi fertilizer had a very significant effect on the growth of ebony seedling height at 4, 8 and 12 WAP (Table 2).

Table 2. Height (cm) dan Leaves of Ebony Seedlings at Different Doses of Swallow Droppings Bokashi Fertilizer

Treatment	Plant Height (cm)					Leaves (cm)
	4 WAP	8 WAP	12 WAP	4 WAP	8 WAP	12 WAP
P0 (Control)	8.91 ^{a}	10.59 ^{a}	11.28 ±^{a}	13.63 ^{a}	15.00 ^{a}	16.44 ^{a}
P1 (7 ton ha^{-1})	9.72 ^{ab}	11.73^{b}	14.06 ±^{b}	13.69 ^{a}	16.31 ^{b}	18.19^{b}
P2 (14 ton ha^{-1})	10.63^{bc}	13.96 ^{c}	15.97 ±^{c}	14.88 ^{b}	17.50 ^{c}	18.69^{bc}
P3 (21ton ha^{-1})	11.97 ^{c}	14.91 ^{c}	17.46±^{d}	15.13^{b}	16.88 ^{c}	18.88^{bc}
P4 (28 ton ha^{-1})	11.80^{c}	14.93 ^{c}	17.89 ±^{d}	15.75 ^{b}	18.50^{c}	20.88^{d}
HSD 5%	1.05	1.00	0.66	0.88	1.10	0.93

The results of number of ebony leaves at 4, 8, and 12 (WAP) are presented in Table 2. The ANOVA results revealed that treatment had a very significant on the number of ebony leaves at ages 4, 8 and 12 WAP. At the age of 4 WAP, the highest number of leaves was obtained in the 28 tons/ha treatment with a value of 15.75 leaves and the lowest number of leaves was obtained in the control of 13.63 leaves. At the age of 8 WAP, the highest number of leaves was obtained in the treatment of 28 tons/ha with a value of 18.50 leaves and the lowest number of leaves was in the control of 16.31 leaves. Meanwhile, at the age of 12 WAP, the highest number of leaves was obtained in the treatment of 28 tons/ha with a value of 20.88 leaves and the lowest number of leaves was obtained in the control of 16.44 leaves.

The treatment without swallow droppings bokashi fertilizer at all times of observation on the height of ebony seedlings was significantly different. The results of the height of ebony seedlings without treatments were 8.91 cm (at 4 WAP), 10.59 cm (at 8 WAP) and 11.28 cm (at 12 WAP). The statistical results showed that the ideal swallow droppings bokashi treatment was at a dose of 21 tons/ha. According to Table 1, it appears that the height of ebony seedlings with the 21 tons/ha bokashi fertilizer treatment was not significantly different from the 28 tons/ha treatment at all observation times.

Discussion

The higher dose of swallow droppings bokashi increased the value of C-Organic. This was presumably because carbon (C) is the main constituent of organic matter. An increase in C-Organic along with the addition of organic matter (Lai et al., 2013). In addition, carbon (C) content in organic matter reaches 48-58% of the total weight of the organic matter itself (Wild et al., 2014); (Gerke, 2022).

The administration of organic matter influences N in the soil properties. N enters has a form as ammonia and nitrate in soil with rainwater, in the form of free nitrogen fixation, or in the form of added synthetic fertilizers (Wang et al., 2023). The nutrient N in swallow's nest bokashi can increase the N content in the soil, but it remains low. The low N content after the application of swallow's nest bokashi fertilizer is due to the slow release of this bokashi fertilizer, as organic fertilizers generally have a slow release characteristic.

The slow release of nitrogen from bokashi fertilizers results in low nitrogen content in the soil, as found in several studies showing that bokashi and other slow-release fertilizers tend to release nitrogen gradually, which reduces its availability in the soil in the short term (Fan & Li, 2010; Claassen & Carey, 2007; Quiroz & Flores, 2018). In addition, factors that can affect the low N content are leaching, evaporation, and absorption by the plants. N elements were transported by harvest, some returned as plant residues, lost to the atmosphere and returned again, and also lost through leaching (Sainju, 2017). This has also been proven by Shareef et al. (2019), who found that nitrogen leaching decreased the efficiency of nitrogen recovery in sandy soils, while volatile ammonia also significantly reduced nitrogen from the soil-plant system (Mandal et al., 2019). In addition, Rushimisha et al. (2022) showed that the combination of irrigation and nitrogen fertilization affected the distribution of nitrate and total nitrogen uptake by rice plants. Therefore, it is very important to manage these factors through the selection of appropriate fertilization methods, the use of urease inhibitors, and efficient irrigation strategies to maintain optimal nitrogen levels in the soil.

Increased available phosphorus in the soil was due to reactions in the soil. The increase in soil P after the administration of organic matter was also due to the process of organic matter decomposition to produce organic acids which can help release P bound by the amorphous fraction (allophane), so that the concentration of soil P increases. The decomposition of organic matter produces humic and fulvic acids, so that bound P can be released and become available in the soil (Goulding et al., 2020). Soil conditions are important part of the increased activity of soil microorganisms. Research by Volpiano et al. (2022) shows that the interaction between soil, plants, and soil microbiota is crucial in enhancing plant growth. Decomposition of organic matter had key factor on the K availability in the soil (Goulding et al., 2020).

The results of the height of ebony seedlings at the age of 4, 8 and 12 WAP after the treatments of SDB showed that the average height tended to increase with increasing doses of the bokashi fertilizer. The application of plant organic matter affected the growth of ebony seedlings. Organic fertilizers can provide nutrients to the soil which will increase plant growth optimally (Ye et al., 2022). The increase in plant height is an indicator of plant growth and development that determines the plant productivity. A plant will thrive if all the nutrients needed are sufficiently available and in a suitable form for plant absorption (White & Brown, 2010). Increasing organic matter had affect a soil content quality, moreover it can be utilized by plants. This treatment indicated that plant height as vegetative growth. This is in accordance with the findings of Su et al. (2022) which showed that the use of compost increases soil organic matter, improves soil physical, chemical, and biological properties, and enriches the soil microbiome, all of which contribute to increased plant growth and yield.

The higher bokashi fertilizer given, the more N content in bokashi fertilizer will also be received by the soil, so that the N functions as a constituent of amino acids, proteins and amino acids which can assist in the process of photosynthesis which causes plant growth and development such as leaves can perform normally (Zheng, 2009). Table 2 described that the SDP fertilizer treatment had an incredibly significant effect in number of leaves. This shows that the bokashi fertilizer from swiftlet droppings contains enough nitrogen and potassium nutrients to stimulate the leaves. Nitrogen and potassium elements function to stimulate leaf growth and play a role in strengthening the leaves so they do not fall (Tränkner et al., 2018).

This study concluded that swallow droppings bokashi fertilizer can improve chemical properties of soils, i.e., Phosphorus (P) from 41.34 to 65.06 with very high status, Potassium (K) 46.26-53.87 with high status, C-Organic 5.3-10.3 with high-very high status, and N-Total 0.12-0.34 with low-moderate status, and the provision of bokashi swiftlet manure with a dose of 21 tons/ha or 61.25 g/pot with 7 kg of soil is the best dose for plant growth (height) and the increase in the number of leaves of ebony seedlings. Research on the effect of bokashi swiftlet manure fertilizer on the chemical properties of Vatutela alluvial soil as a planting medium for ebony seedlings suggests the provision of a dose of bokashi fertilizer with a dose of twenty-one tons/ha or 61.25 g/pot with 7 kg of soil to further increase the nutrient content in the soil.

Conclusion

This study concluded that 1) swallow droppings bokashi fertilizer can improve chemical properties of soils, i.e., Phosphorus (P) from 41.34 to 65.06 with very high status, Potassium (K) from 46.26 to 53.87 with high status, C-Organic from 5.30 to 10.25 with high to very high status, and N-Total from 0.12 to 0.34 with low to medium status, and 2) application of swallow droppings bokashi at a dose of 21 tons/ha or 61.25 g/pot with 7 kg of soil was the best dose for the plant growth (height) and the increase in the number of leaves of ebony seedlings. This research on the effect of swallow droppings bokashi fertilizer on the chemical properties of Vatutela alluvial soil as a growing medium for ebony seedlings. The research findings recommend a bokashi fertilizer dosage of 21 tons/ha or 61.25 g/pot with 7 kg of soil to optimally enhance the nutrient content in the soil.

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Author Contributions

Conceptualization: A.R., A.M and M.A.K; methodology: A.R., A.M and A.D.; software, T.O.; validation, A.R., D.W. and M.A.K; formal analysis, A.M.; investigation, A.D. and T.O; resources, A.R. D.W. and M.A.K; data curation, A.M. and A.D.; writing—original draft preparation, A.R., A.M. and D.W; writing—review and editing, M.A.K., A.D. and T.O.; visualization, A.D. and T.O.; supervision, A.R. and D.W.; project administration, M.A.K. and T.O.

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Conflicts of Interest

The authors declare no conflict of interest.

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