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Impact of Progressive Pruning on Leaf Miner (*Coelaenomenodera lameensis*) Incidence and the Yield of Oil Palm (*Elaeis guineensis*)

—A Case Study of Benso Oil Palm Plantation Plc, Adum Banso Estate, Ghana

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Abstract

The oil palm leaf miner, *Coelaenomenodera lameensis*, is currently the most destructive pest of oil palm in Ghana and other African oil palm growing countries, causing significant losses in fresh fruit bunch yield. Progressive pruning is an oil palm pruning method in which pruning is done at the same time as fresh fruit bunch harvesting. This study evaluated the impact of progressive pruning on leaf miner population in oil palm and how these two factors (leaf miner and progressive pruning) affect the yield of oil palm at the Benso Oil Palm Plantation Public listed company (BOPP. Plc). Five distinct blocks in the plantation were selected for observations on fronds at various ranks (33, 25, or 17) based on the degree of defoliation by counting the number of pests on leaflets at different phases of insect development. Fronds from selected plots were sampled in a Completely Randomized Design (CRD). The size of plots used for the study ranged between 19 to 45 hectares. A minimum of 78 fronds were evenly cut from each block for pest count depending on the block size. Secondary data on annual yields of fresh fruit bunches before and after the introduction of progressive pruning were also obtained from BOPP. Plc records from 2011-2020. The results from the analyzed data on leaf miner index before and after the introduction of progressive pruning showed that progressive pruning has, to a high extent (64% to 36%), reduced leaf miner populations in the plantation. Paired t-test on fresh fruit bunch yield has also revealed a significant ($p < 0.001$) increase in annual fresh fruit bunch yield due to progressive pruning. A regression analysis, however, revealed a lower rate of yield loss (3.05 to 2.70 tonnes) to leaf miner infestation after the in-

troduction of progressive pruning. The study recommends progressive pruning as a key cultural practice for improving crop yields in leaf miner prone plantations.

Keywords

Coelaenomenodera lameensis, *Elaeis spp*, Leaf Miner, Oil Palm, Progressive Pruning, Fresh Fruit Bunch, BOPP. Plc

1. Introduction

Oil palm, *Elaeis guineensis* Jacq., is native to the tropical rainforest belt of West and Central Africa between Guinea and northern Angola, but has since spread throughout the tropics [1] [2] [3]. With an annual production of 4.5 to 9 tonnes per ha, it is considered the most productive oleiferous plant. It yields 5 to 10 times more oil than groundnut and soybean [4]. It is currently grown in over 16 countries. Southeast Asia is the largest production region, with Malaysia and Indonesia accounting for roughly 90% of global palm oil production [5] [6]. Indonesia has the largest production area of 7.825 million ha, followed by Malaysia which has 4.853 million ha [7].

In Ghana, oil palm is cultivated in the forest belt, mostly in the Western, Central, and Eastern Regions, where annual precipitation exceeds 1200 mm and is bimodally distributed [8]. The major oil palm plantations (nucleus estates and outgrowers), as well as processing facilities situated in these areas, include Ghana Oil Palm Development Company (GOPDC) at Kwae near Kade in the Eastern Region, Benso Oil Palm Plantation Public listed company (BOPP. Plc) and Norwegian Oil Palm Ghana Limited (NORPALM) in the Western Region, and Twifo Oil Palm Plantation (TOPP) limited in the Central Region. Ghana currently has an estimated 330,000 ha of oil palm [8]. The productivity of oil palm in the country varies with the various sources. Large estates produce 10 - 13 tonnes per hectare; smallholder outgrowers produce 7 - 10 tonnes per hectare; and private small-scale farmers produce 3 tonnes per hectare [8].

Pests and diseases impair normal, healthy growth and significantly reduce crop yields, whether grown on vast plantations or small farms. To guarantee healthy oil palm development at all phases and to optimize crop productivity by obtaining high oil yield per hectare, it is important to manage pests and diseases effectively [7]. Various plant health problems that affect oil palm production cause it to deviate from its native ecology. Insects, especially those from the orders Coleoptera and Lepidoptera, are capable of causing havoc on oil palm [4]. The oil palm leaf miner, *Coelaenomenodera lameensis* (Coleoptera Chrysomelidae: Hispinae), has become common with oil palm cultivation over the last 30 years [9] and is currently being considered as the most threatening pest of oil palm in West Africa [10]. Both adults and larvae cause damage to the foliage of

the crop. The larvae cause the most widespread and catastrophic damage due to the large number of mines they produce [9]. The larvae live and develop within the leaflet, and as a result of the larvae's feeding habits, the fronds are defoliated and deprived of enough palm surfaces for maximum photosynthesis to occur. Adults swarm and feed on the undersides of leaflets, carving out grooves parallel to the veins and partially drying out the fronds. In a severe infestation, only the spears may be unharmed, while the other fronds appear dried, resulting in a decrease in the photosynthetic activity of the leaves [11]. Over a two-year period, heavily attacked trees may lose up to 90% of their fronds, resulting in a 50% reduction in fresh fruit bunch (FFB) yields [12]. At various times, the beetle has attacked all of Ghana's major oil palm plantations and estates, resulting in a significant drop in FFB output [13].

Over the years, various methods used to control the incidence of *C. lameensis* include phytosanitary monitoring, biological control, planting of resistant varieties and the use of synthetic insecticides through hot fogging, trunk injection and fluid air spraying. The only preferred synthetic insecticide for the control of adult *C. lameensis* in Ghana at the moment is Evisect S® [14]. However, it has become very important to find other alternative control measures due to the risk of insects developing resistance to synthetic pesticides as a result of continued usage, the negative effects of these chemicals on the environment, and residues in the fruits produced [15]. Biological control seems to be both environmentally friendly and safe for reducing the incidence of insect pests [16]. In the hunt for other innovative control strategies, pruning has also been found to be an environmentally-friendly pest control method. Pruning improves structural integrity and influences flowering and fruiting. Oil palm fronds are pruned once a year, though this varies depending on the age of the palm tree. In the immature stage, sanitation pruning is performed at least six months before the mature stage. This method is carried out to enable the palms bear fruit. Most palms only require pruning on a regular basis to remove dead and unwanted fronds. Marcelino and Diaz [17] reported that frond pruning significantly affected the quantity and weight of harvested bunches in oil palm. However, excessive frond pruning causes poor palm development and lowers production [17].

Progressive pruning is the type of pruning where the oil palm is pruned at every harvest. This is done to obtain certain added benefits that the former annual or biannual method of pruning could not offer. Progressive pruning rids the palm constantly of less functional fronds and diseased/infected fronds thereby helping the palm channel more nutrients into growth and fruit production. Moreover, progressive pruning aids easy identification of ripped bunches as it prevents overcrowding of dead fronds on the palm. This prevents the rotting of fruits on the palm and helps improve aeration in the field. Furthermore, progressive pruning is more cost effective to practice than semiannual or biannual method of pruning as it does not require the employment of a pruning gang (as in the case of biannual pruning). Progressive pruning is an interesting topic in oil palm production, but it has been based on personal experience and casual

observation rather than experimental data. BOPP. Plc formerly practiced the annual pruning of excessive fronds depending on the age of the palm trees until 2016, where the company introduced progressive pruning to control the incidence of oil palm leaf miner and to improve on the yield of FFB. No proper assessment has been made since the practice was implemented. This study was therefore conducted based on this analogy, to evaluate the impact of progressive pruning on the incidence of leaf miner and consequently, the impact of these two factors (leaf miner infestation and progressive pruning) on the yield performance of oil palm at the BOPP. Plc, Adum Banso Estate.

2. Materials and Methods

2.1. Study Period and Location

The study was designed to cover data made available from January, 2011 to December, 2020 at BOPP. Plc, Adum Banso Estate. Adum Banso Estate is located in the Mpohor District of Ghana's Western region. The district has a tropical climate, with an average annual rainfall of 1500 mm that ranges from 1300 to 2000 mm. The average temperature is 30˚C. The rainy season lasts from March to July, while the dry season lasts from November to January. The Mpohor District is mostly dendritic. Subri, Butre, and Hwini are some of the rivers and streams in the district [18].

2.2. Experimental Design and Field Survey

Field surveys were conducted in the plantations to collect data at different developmental stages of the oil palm leaf miner pest including egg, larva, pupa and adult stages. The Completely Randomized Design (CRD) was employed in five replicated blocks. Five blocks labeled Block 023, 025, 026, 027 and 029 measuring 19, 30, 36, 41 and 45 hectares respectively were selected. Sampled plants were planted between 2001 and 2006 and were generally matured palms. Observations on the level of damage at the pest's developmental stages were made during the survey.

Fronds were cut from the lowest ranks of the sampled plants to monitor the populations of the pest. The fronds were cut in rows of ten to ensure even distribution. This implies that the next batch of fronds was cut from the tenth row away from the first batch/row. There were 3 to 4 rows and 136 to 160 palm trees per hectare. The number of rows in a block is therefore determined by multiplying the block size (in hectare) by the number of rows per hectare. Six fronds were cut within one row, and each block had a maximum of 78 fronds cut evenly. For the purpose of uniformity, the first three rows at the edge of each block were not included in the data collection process.

C. lameensis infested leaflets on cut fronds were detached using a counting and selective monitoring method depending on the level of defoliation of the leaves. The mines were opened and the number of larvae, pupae, internal adult, and external adult found in each mine was recorded. A calculation was also per-

formed to determine the leaf miner index for each surveyed block. Blocks surveyed in a given month were not surveyed again in that month. However, some of those Blocks were surveyed in subsequent months. On average, 1 Block was polled per session. The survey was conducted five times a week, from 6:00a.m. to 10:00a.m. each morning.

2.3. Leaf Miner Monitoring

Due to the effective damage of the leaf miner, the monitoring of the leaf miner started from East to West in order capture the external adults that are able to fly at sunrise. Since the leaf miner feeds from the lowest ranks (fronds) to the upper ranks (fronds), the 17th to 25th rank of the fronds was cut down for examination. As soon as the frond was cut, it was turned over to examine underside on which the external adults are found. The frond was turned over again to examine the small larvae, large larvae, pupae, internal adults and external adults and after each stage was counted and recorded.

Counting method: This method was employed when the incidence of leaf miner was high on the leaflet. The leaflets were picked from both sides of the fronds of an interval of 10. The number of leaf miner found in the leaflets were multiplied by 10 and recorded.

Selective method: This method was employed when the incidence of leaf miner was very low on the leaflet. The damaged leaves were selected randomly and the leaf miners found were counted and recorded.

2.4. Progressive Pruning

This type of pruning was done at every harvest using Malayan knife to remove dead fronds and some other fronds blow the 33rd rank of the palm tree to prevent overcrowding of the fronds. The pruning was undertaking at the same time as fresh fruit bunches were being harvested. Blocks of the field selected for the study had gone through a minimum of 5 consecutive prunings since the introduction of progressive pruning.

2.5. Data Collection

2.5.1. Indices of Leaf Miner at the Various Developmental Stages

The leaf miner index at the various stages was calculated as:

$$\text{Live index} = \text{Live total}/\text{number of palms Sampled} \quad (1)$$

$$\text{External adult live index} = \text{number of external adult}/\text{number of palms sampled} \quad (2)$$

$$\text{Live total} = \text{number of small larvae} + \text{number of large larvae} + \text{number of pupae} + \text{number of internal adults} + \text{number of external adults.} \quad (3)$$

2.5.2. Secondary Data

Data on annual yield (tonnes/ha) gathered before the introduction of progressive pruning from 2011 to 2015 and after the implementation of progressive pruning from 2016-2020, as well as on leaf miner indices from 2011 to 2020 were ob-

tained from the records of the Adum Banso Estate of BOPP. Plc.

2.6. Statistical Analysis and Presentation of Results

Data collected during the field survey and secondary data were subjected to descriptive analysis in the form of percentages and trend analysis, as well as two-sample paired t-test and regression analysis. The percentages were used to determine the proportion of leaf miner before and after the implementation of progressive pruning. This was done by finding the aggregate of the leaf miner for the overall period; 2011 to 2020 and the various percentages computed. The trend analysis was used to compare the average FFB yields before and after the introduction of progressive pruning. The paired t-test at 5% significance level was used to compare the mean FFB yield before and after the introduction of the progressive pruning, to ascertain whether progressive pruning has had a significant impact on the yield of the crop. The simple linear regression model was used to determine the rate at which the prevalence of the leaf miner affect crop yield. This was done for both before and after the progressive pruning. With this, the researchers were able to determine whether a unit increase in leaf miner will increase or decrease crop yield. The statistical analysis was done with Excel, SPSS, Version 20 and STATA. Excel was used in grouping the data, drawing the pie chart and the trend plot. SPSS was used in conducting the paired t-test whereas STATA was used for the regression analysis.

Sample t-Test

In determining whether there has been a significant impact on the yield of the oil palm following the adoption of the progressive pruning, we used paired sample t-test.

Here, we tested the following hypothesis:

$H0_a$: Mean yield before and after the introduction of progressive pruning are not different.

$H1_b$: Mean yield is before and after the introduction of progressive pruning are different.

In determining whether there has been a significant impact on the incidence of leaf miner following the adoption of the progressive pruning, we used paired sample t-test.

Here, we tested the following hypothesis:

$H0_a$: Total live index of leaf miner before and after the introduction of progressive pruning are not different.

$H1_b$: Total live index of leaf miner before and after the introduction of progressive pruning not different.

3. Results

3.1. Yield of Oil Palm before and after Introduction of Progressive Pruning

Figure 1 shows yield of FFB of oil palm before and after the implementation of

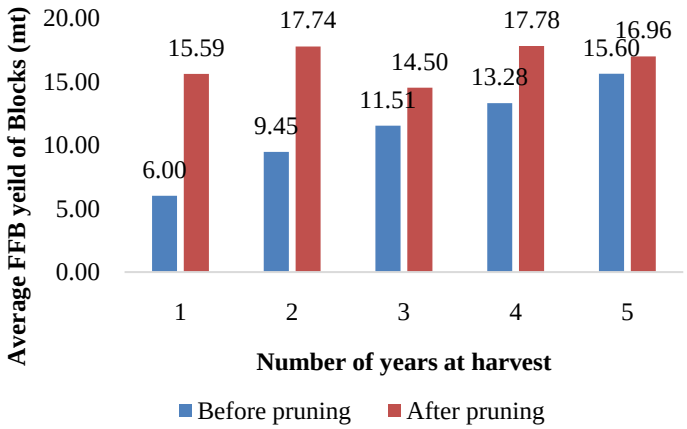

Figure 1. Average FFB yield of selected blocks before and after progressive pruning over a 5-year production period.

progressive pruning over a 5-year production period. Average FFB yields before the introduction of progressive pruning from 2011 to 2015 (6.00, 9.45, 11.51, 13.28, and 15.60 mt respectively) were lower than the correspondent yields of 15.59, 17.74, 14.50, 17.78 and 16.96 mt recorded from 2016 to 2020 respectively, after the implementation of progressive pruning. There was an annual increasing trend of FFB yield before the introduction of progressive pruning. However, there was an alternating rise and fall in average yields recorded after the introduction of progressive pruning over the 5-year period.

Paired Sample t-Test on FFB Yield per Ha for Selected Blocks

Results on the paired sample t-test conducted on Yield per hectare (YPH) are presented in Table 1. There was a highly significant ($p < 0.001$) difference between the FFB yield before and after the introduction of progressive pruning, hence we fail to accept $H0_a$.

3.2. Leaf Miner Index before and after Introduction of Progressive Pruning

The regression analysis (Figure 2) indicated that, the proportion of leaf miner on the palm trees were more (64%) before the introduction of the progressive pruning and less (36%) after the introduction of the progressive pruning.

3.3. Effect of Leaf Miner on the Yield of Oil Palm

3.3.1. Effect of Leaf Miner on the Yield of Oil Palm before Progressive Pruning

From the result (Table 2), the regression equation is given as:

$$Y = 26.94 - 3.05X \quad (4)$$

where Y = yield before progressive pruning;

X = leaf miner effect before progressive pruning.

The result indicated that, as the population of leaf miner increases, the yield of the oil palm decreases by 3.05.

Table 1. Paired sample t-test on the yield of oil palm.

	Summary					t	df	p-value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
YPH_Before-YPH_After	−5.344	3.648	0.7297	−6.850	−3.838	−7.32	24	<0.001

Table 2. Impact of Leaf Miner on yield before progressive pruning.

Source of variation	SS	d.f	MS	Number of obs. = 10		
Model	11.4808397	1	11.4808397	F(1, 8) = 2.74		
Residual	33.5414003	8	4.19267504	Prob > F = 0.1366		
				R-squared = 0.2550		
Total	45.02224	9	5.00247111	Adj R-squared = 0.1619		
				Root MSE = 2.0476		
Yield before	Coef.	Std. Err.	t	P > |t|	[95% conf.	interval]
Leafminer	−3.047935	1.841893	−1.65	0.137	−7.295349	1.199479
_cons	26.93849	7.884151	3.42	0.009	8.757605	45.11938

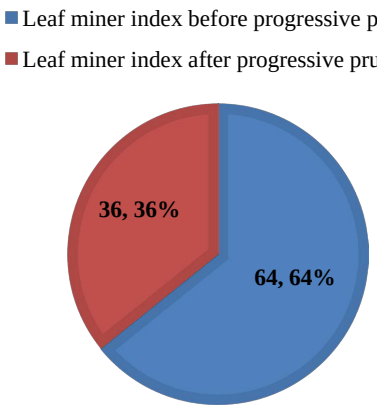

Figure 2. Leaf miner indices before and after pruning.

3.3.2. Effect of Leaf Miner on the Yield of Oil Palm after Progressive Pruning

From the result (Table 3), the regression equation is given as:

$$Y = 22.35 - 2.70X \tag{5}$$

where Y = yield after progressive pruning;

X = leaf miner effect after progressive pruning.

The result indicated that, as the population of leaf miner increases, the yield of the oil palm decreases by 2.70.

3.4. Paired t-Test on Leaf Miner Population before and after Progressive Pruning

The confidence interval [1.525, 2.247], where 1.525 is the lower limit and 2.247 is the upper limit (Table 4), does not contain zero so we reject $H0_b$ and conclude

Table 3. Impact of leaf miner on yield after progressive pruning.

Source of variation	SS	d.f	MS	Number of obs = 10	
Model	14.0954608	1	14.0954608	F(1, 8) = 7.46	
Residual	15.1132992	8	1.8891624	Prob > F = 0.0258	
				R-squared = 0.4826	
Total	29.20876	9	3.24541778	Adj R-squared = 0.4179	
				Root MSE = 1.3745	
Yield after	Coef.	Std. Err.	t	P > |t|	[95% conf. interval]
Leafminer	−2.701211	0.9889027	−2.73	0.026	−4.981625 −0.4207976
_cons	22.34688	2.393386	9.34	0.000	16.82773 27.86604

Table 4. Paired t-test on leaf miner population before and after introduction of progressive pruning.

PAIR	Mean	Standard deviation	95% confidence interval
Mean of leaf miner before −mean leaf miner after progressive pruning	1.886	0.55	1.525 - 2.247

that, the introduction of the progressive pruning resulted in a significant reduction of the leaf miner populace.

4. Discussion

4.1. Impact of Progressive Pruning on the Yield of Oil Palm

The paired sample test conducted on the yield of oil palm showed highly significant differences between the yield before and the yield after progressive pruning (**Table 1**). Although the yield of oil palm after the progressive pruning was not constantly progressing, corresponding yields before progressive pruning were lower. Previous studies have also proven that pruning has an effect on the yield of oil palm and progressive pruning may give a better result in terms of increasing yield. Penton Media Marcelino and Diaz [17] reported that frond pruning in oil palm trees significantly affect fruit bunch production, specifically on the number and weight of harvested bunches. Pruning and retention of fronds in oil palms basically point out that pruning some parts of the plant improves the structural integrity and influences flowering and fruiting. Similar research conducted by Marcelino and Diaz [17] revealed that the retention of 32 - 40 fronds per tree will produce more and heavier bunches than those trees with 24 fronds and trees without frond pruning. This indicates that over pruning (reducing fonds to a lower number) has a negative effect on the yield of oil palm as much as not pruning oil palm trees for longer period of time does. These are likely to be observed under the semi-annual pruning that was previously adopted by the company. However, the newly adopted progressive pruning ensures that the excess and dried palm fonds are removed from time to time, basically during

each harvest. This ensures that more nutrients are directed to the formation of fruits than to leaves that are near senescence and therefore are of less use to the plant.

Also, progressive pruning improves the visibility of ripe fresh fruit bunches during harvesting. The only pruning that most palms need is the occasional removal of dead and unnecessary fronds. This can be achieved through progressive pruning. Excessive pruning of fronds results in poor palm growth and reduces yield [17], as workers may be more likely to over prune when the fonds are over grown due to long periods without pruning in attempt of trying to achieve the aesthetic structure of the plant. Experimental evidence indicated that the degree of frond removal of fonds influenced yield of oil palm. In the experiment by Marcelino and Diaz [17], it was indicated that pruning of fronds in plants with 32 fronds obtained a weight of 335.33 kg while 40 fronds had 286.50 kg two months after pruning. Lighter harvested bunches of 224.33 and 215 kg were observed in plants without pruning and those with 24 fronds respectively. In the Marcelino and Diaz experiment the fonds were maintained or pruned quarterly; this indicates the constant maintenance of fonds have more positive effects on the yield of oil palm, therefore progressive pruning is more likely to achieve these positive effects with time.

4.2. Impact of Progressive Pruning on Leaf Miner Infestation

The study revealed that the proportion of leaf miner infestation was higher before the introduction of progressive in the five sampled blocks (**Figure 2**). This indicates that progressive pruning has reduced the level of leaf miner incidence in BOPP. Plc plantations. The reduction in leaf miner infestation by 28% indicates that progressive pruning greatly has positive impact on leaf miner infestation. According to Obeng-Ofori [15], *C. lameensis* infestations can result in 90% defoliation, resulting in a 50% drop in fresh fruit bunches. Progressive pruning improves on the sanitation of the field while reducing the population of the leaf miner as many of the infected fonds are pruned to the ground more often as against the former practice of pruning the palms semi-annually. The semi-annual pruning helped build the population of the leaf miner as infested fronds remained undisturbed for a longer period of time, unlike the progressive pruning where such fronds are pruned constantly.

4.3. Effect of Leaf Miner Incidence on the Yield of Oil Palm

In Ghana, leaf miner outbreaks have been observed in all of the large oil palm plantations. This study has shown that as the population of leaf miner increases without pruning, the yield of the oil palm decreases by 3.05 tonnes. However, the reduction effect of leaf miner on oil palm yield reduced to 2.70 tonnes after the implementation of progressive pruning. This is an indication that with time, progressive pruning is likely to reduce to a minimum (if not eliminate), the negative impact of leaf miner infestation on oil palm yield. In 1985, Jukwa farms of

SOPP had an outbreak of *C. lameensis* and low yields resulted in the felling of the palm trees [19]. Between 1986 and 1987, a total of 2000 hectares out of 4200 hectares in the fields of GOPDC at Kwae also suffered serious outbreak of *C. lameensis* which led to a revenue loss of about $13506.49 [20]. TOPP limited and BOPP. Plc have also suffered recurring outbreak of the leaf miner pest leading to severe defoliation of the oil palm trees [13]. This indicates that leaf miner infestation can, to a high extent, reduce the yield of oil palm if not controlled effectively.

5. Conclusions

The research was conducted at BOPP. Plc has revealed that the introduction of progressive pruning has contributed significantly to the reduction of oil palm leaf miners in the plantation. The FFB yield analysis revealed that there has been a significant increase in oil palm yield in the estate after the introduction of progressive pruning. The entire BOPP. Plc estate has been enrolled on progressive pruning. The regression analysis has also revealed a lower rate of reduction in the yield of oil palm due to leaf miner infestation after the introduction of progressive pruning. The study, therefore, suggests that progressive pruning should be a key cultural practice for improving crop yields, especially in plantations that are prone to leaf miner infestation.

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Availability of Data and Material

The data used to support the findings of this study are available from the corresponding author upon request.

Authors' Contributions

Isaac Addo conceived the original idea, contributed to the experimental design and together with Samuel Awonnea Avaala, Kwasi Baah Ofori and Victor Tetteh Zutah carried out the experiment, collected the data and wrote the first draft of this manuscript. Geoffrey Smith Oduro supported the data collection. Emmanuel Ackah performed the analytical computations. Esther Fobi Donkor and Kwadwo Gyasi Santo read the first draft for all necessary corrections. All authors read and approved the final manuscript for submission.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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