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Evaluation of Fifteen Rice (Oryza sativa, L) Genotypes for Adaptation in the Upper Highland Zone of Liberia

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Abstract: The Study was conduced to evaluate exotic and improved local rice genotypes for adaptation and high yield (YLD) for sustainable production and food security in Liberia. This study assessed the performance of various rice genotypes to identify superior options for increasing food production in the country. The evaluation involved four mutant rice genotypes, six salinity-tolerant rice genotypes, and five iron toxicity-tolerant rice genotypes. These genotypes were tested using a randomized complete block design in the Suakoko District, situated in the upper highlands of Liberia. Data were collected on days to booting, days to flowering, plant height, panicle length, number of tillers, number of grains per panicle, and 100-grain weight. Spikelet fertility was determined by counting the filled grains and the total number of grains per panicle. Organoleptic test was done to assess the food quality of the rice varieties. Each genotype was assessed for tolerance to iron toxicity using a standard evaluation score (SES) on a scale from 0 to 9, where 0 indicates no symptoms and 9 indicates complete leaf death. Sidenuk and Isora were identified as highly susceptible to iron toxicity, receiving scores of 5 and 7, respectively. The other materials demonstrated varying levels of tolerance. When comparing the genotypes against standard checks, G-2-early and Sidenuk had the highest 1000-grain weights, measuring 28 grams and 26 grams, respectively. Isora, BRRI-67-Dahn, and BRRI-61 recorded the highest number of fertile spikelets, with BRRI-67-Dahn outperforming local checks. Nine of the rice varieties assess for food quality were scored for strong to mild aroma. The rest of the six rice varieties were had little of no aroma. However, Suakoko-8, G-2_early, V-4, and Sidenuk recorded the highest scores for aroma. BBRI-61 was inadventedly excluded from the sensory test.

Keywords: *Genotypes, Iron-Toxicity, Salinity, SES, Phenotypic, Organoleptic, Sensory, Aroma, Texture, Appearance.*

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I. INTRODUCTION

Rice (Oryza sativa L.) is cultivated on every continent except Antarctica and is the world's most widely consumed cereal grain, playing a unique role in alleviating global famine (Chen *et al.*, 2020). It is the world's most widely consumed food, and it was initially planted some 10,000 years ago in China's middle Yangtze and upper Huai rivers (FAO, 2014). For 2,000 years, the crop spread along rivers at Non NokTha in Thailand's Korat province. Because of the increase in population, agriculturists and rice specialists worldwide have developed wide varieties, such as NERICA-L-19 (Matsunami 2015).

Rice is considered the most important staple food crop in Liberia, playing an essential role in the daily diet of its 5.7 million population. It comprises approximately 33% of the overall food consumption in the country, and almost 50% of the caloric intake for adults comes from rice (GFSR, 2009). This highlights not only the importance of rice in nutrition but also its significance in food security.

The agricultural sector is a cornerstone of Liberia's economy, employing over 70% of the workforce and providing livelihoods for a vast majority of the population. This sector encompasses various activities, including crop production, livestock rearing, and fishing, but rice remains the dominant crop. Most farming practices in Liberia rely on rain-fed irrigation, making them highly susceptible to variations in weather patterns.

The reliance on rain-fed agriculture poses significant challenges, particularly in light of climate change, with shifts in rainfall patterns and increasing frequency of extreme weather events, which threaten the stability and predictability of agricultural outputs in Liberia. These climatic changes not

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only jeopardize food production but also impact the livelihoods of farmers and communities that depend on rice cultivation. As a result, there is an urgent need for strategies to enhance climate resilience in agriculture, ensuring sustainable food production and improving the overall well-being of the population that relies on this staple.

The strong demand for rice in Liberia stems from demographic trends, dietary preferences, and cultural significance. Despite this high demand, Liberia is only able to produce about one-third of the rice needed to meet its consumption requirements, leading to a substantial reliance on rice imports. The nation imports approximately 300,000 metric tons of rice each year, costing around US$200 million (Ousman *et al*, 2023). This dependence is concerning, particularly given the potential impacts of climate change on supply chains and food prices.

Rice yield in Liberia is at an all-time low, and there are several contributing factors to the low productivity of rice cultivation in Liberia; these factors include limited access to modern agricultural technology, prevalent inefficiencies in farming practices, and insufficient levels of both public and private investment in the agricultural sector. Furthermore, the value chain for rice is often fragmented, resulting in a lack of coordination and support for farmers throughout the production process.

To address these issues, the introduction and evaluation of high-yielding, climate-resilient rice varieties are necessary to significantly enhance agricultural output and improve food security in the Country. By identifying and promoting best-performing improved rice varieties, Liberia can work toward reducing its dependence on imported rice, thereby enhancing food sovereignty and boosting the incomes and livelihoods of local farmers.

Increasing domestic rice production is key for Liberia to reduce its reliance on imports while addressing the growing concerns of food availability and security in the face of climate-related challenges. This approach will not only benefit consumers but also foster a more resilient agricultural sector, ultimately contributing to the nation’s economic stability and development. Therefore, the primary objective of the study was to evaluate the rice genotypes in Liberia to enhance food security and reduce the country's dependence on imported rice.

II. MATERIALS AND METHODS

- *Location of Experiment*

The field experiment was initiated during the late rainy season of 2024 and concluded with final data collection in the early dry season of 2024/2025 at the Central Agricultural Research Institute (CARI) in Suakoko District, Bong County, Liberia. The trial site was positioned at 6.68° N latitude and 9.40° W longitude, situated within a central plateau in Liberia characterized by loamy soil. This region experienced approximately 2000 mm of rainfall in 2024, which facilitated the irrigated conditions necessary for the study.

- *Experimental Materials*

Fourteen (15) rice varieties, including four (4) mutant rice genotypes introduced from Indonesia, ttwo (3) salt-tolerant rice introduced from the UAE, five (5) iron toxicity tolerance rice from AfricaRice Center and Liberia, and three (3) newly developed salinity-tolerant rice from CARI.

The crop genotypes evaluated in this study are presented in Table 1.

Table 1 Detailed Information on Rice Varieties Used in the Trial

S/N	Variety	Source	Characteristic/description
1	ISORA	BRIN	Mutant variety
2	LAMPAI	BRIN	Mutant variety
3	SIDENUK	BRIN	Mutant variety
4	MUSTAJAB	BRIN	Mutant variety
5	BRRI-47	ICBA	Salinity-tolerant
6	BRRI-67 Dahn	ICBA	Salinity-tolerant
7	BRRI-61	ICBA	Salinity-tolerant
8	G-2	CARI	Salinity-tolerant (Newly developed)
9	G-2 (1)	CARI	Salinity-tolerant (newly developed)
10	G-2 (Early)	CARI	Salinity-tolerant (newly developed)
11	NERICA-L-19	AfricaRice	Iron toxicity tolerant
12	CY-2	AfricaRice	Iron toxicity tolerant
13	ORYLUX-6	AfricaRice	Iron toxicity tolerant
14	SUAKOKO-8	CARI	Iron toxicity tolerant
15	V-4	CARI	Iron toxicity tolerant

III. METHODOKOGY

The trial field was ploughed mechanically and laid out according to the design of the experiment. The seeds of fifteen rice varieties, both local and exotic, were nursed in a raised bed for fourteen days and subsequently transplanted in a 2m x 2m plot. One seedling of rice was transplanted per hill with a plant spacing and row spacing of 20 cm by 20 cm. Before transplanting, a basal fertilizer NPK (15-15-15) at a rate of 200 kg/ha was applied followed by two split applications of urea fertilizer at 25 days after planting and 45 days intervals after planting at a rate of 150 kg/ha. To minimize a high competion of weed with the trial meterials, weeding was carried out at intervals, 30 days and 50 days after transplanting, respectively. Agro-morphological data were collected at different growth stages of the rice varieties.

Sensory evaluation is crucial for assessing the sensory attributes of rice. It offers unbiased evaluations of flavor, aroma, texture, and visual appeal to guarantee product quality. This technique is vital since rice is a fundamental staple, and consumer approval largely depends on its sensory characteristics. To determine consumer's acceptance of the rice varieties, 20 persons including farmers and staff of the food processing department at the Central Agricultural research institute (CARI) were invited to assess the food qualities of the fourteen rice varieties based on the scales indicated in table 4. Each rice variety was milled using the mortar and pestle, winnowed and 250 grams weighed for cooking. The staff of the canteen cooked the rice until it arrived at the right texture and consistency. The boiled rice was placed in plastic bowls assined with only nmbers to avoid bias and each participant was invited to evaluate the rice for its appearance, texture and aroma.

➢ *Data Collection and Analysis*

The data collected were subjected to statistical analysis using the Genstat software 2013 version. Analysis of variance (ANOVA) was performed to test the significance of the differences among the varieties. The means were compared using the Tukey Honestly Significant Difference (HSD) test at a 5% level of significance. Correlation test was performed to determine the relationship between key agronomic traits and grain yield according to Gomez & Gomez, 1984 and Kumar & Chopra, 2012.

➢ *Data Collection Procedures*

The rice genotypes were evaluated based on eight quantitative variables representing the reproductive and ripening growth stages. The standard evaluation score (SES) followed the method by Gregorio *et al.* (1977), and trait selection and measurement techniques were based on the IRRI standard evaluation system of rice (IRRI 2002).

Days to flowering (DTF) was recorded as the number of days from transplanting to 50% flowering for each variety (IRRI, 2013).

Panicle length was measured in centimeters from the base of the plant to the tip of the panicle, while plant height was recorded in centimeters from the base of the shoot to the tip of the tallest leaf blade. Spikelet sterility readings were obtained by counting well-developed spikelets in proportion to the total number of spikelets of five panicles.

The 100-grain weight was determined from a random sample of 100 well-developed, whole grains within a population, dried to 13% moisture content, and weighed on a precision balance. Reproductive tillers were considered those tillers that produced spikelets with or without filled grains and were counted for all genotypes.

The number of tillers was considered as the number of shoots that grew after the initial parent shoot. Days to 50% flowering was determined as the number of days from sowing to when 50% of the rice population had flowered, and grain yield was considered as the average weight of filled grains on five panicles per plant.

All recorded data for the traits were analyzed using the Genstat statistical package version 14, and means of the traits were separated using the Tukey Honestly Significant Test (HSD).

IV. RESULTS AND DISCUSSION

➢ *Means Separation*

The Tukey Honestly Significant Difference test was conducted/used to identify which means among the experimental units exhibited significant differences. Nine parameters were measured throughout the study, revealing that each variety demonstrated varying performance levels for iron toxicity.

In terms of plant height, Suakoko-8 emerged as the tallest rice variety, reaching a height of 113 cm, while NERICA-L-19 measured 104 cm. In terms of 1000-grain weight, G-2-Early recorded the highest grain weight (28grams), followed by Sidenuk with a grain weight of 26 grams. Notably, Suakoko-8, which served as the local check variety, recorded the lowest value for 1000-grain weight, perhaps due to its small grain size. It is essential to highlight that 1000-grain weight is regarded as the most heritable yield trait in rice (Huang *et al*., 2013).

In the assessment of tiller number per plant, the variety BRRI-61 recorded the highest average, achieving 15.67 tillers, whereas Orylux-6 recorded an average of 15.13 tillers. Conversely, the lowest tiller counts were observed in NERICA-L-19 and G-2-1, with averages of 8.98 and 8.67, respectively.

Regarding grain production per panicle, the variety V-4 exhibited the highest grain count, with 136 grains, followed by G-2-1 at 125 grains. In contrast, both BRRO-67-Dahn and Orylux-6 recorded the lowest grain counts, each having approximately 69 grains per panicle.

Although V-4 and G-2-1 displayed higher grain counts, BRRI-67-Dahn experienced superior spikelet fertility, reaching 90%, which is comparable to that of the local check, Suaoko-8 (91%). In comparison, V-4 demonstrated a significantly lower spikelet fertility percentage of 53.29%, while Lampai was also noted for its reduced fertility levels as seen in Table 1.

Table 2. Mean Separation Using Tukey's Honestly Significant Test

Variety	PLH (cm)	No of tillers	P. L (cm)	Grains/panicle	FG	U G	SF (%)	100 GW (gm)	FE score
MUSTAJAB	79.30 ab	11.07 abc	21.34 a	100.50 abc	72.33 ab	28.20 abc	71.57abc	18 ab	2.33 a
G-2 -Early	98.80 d	10.40 abc	24.42 a	97.20 abc	71.73 ab	25.47 abc	73.66 abc	28.00 b	0.00 a
CY-2	88.50 c	10.33 abc	23.33 a	125.10 bc	82.00 ab	42.97 cd	65.42 abc	22.67 ab	0.00 a
ORYLUX-6	77.10 ab	15.13 bc	19.83 a	69.80 a	55.33 a	14.73 abc	78.30 abc	20.00 ab	0.67 a
G-2-1	102.00 d	8.67 a	26.05 a	125.30 bc	88.40 ab	37.47abcd	70.47 abc	24.00 ab	0.00 a
LAMPAI	79.00 ab	12.47 abc	20.35 a	98.00 abc	58.20 a	39.80 bcd	56.72 ab	20 ab	0.00 a
ISORA	73.30 a	12.07 abc	21.07 a	73.50 a	62.53 a	10.93 ab	85.28 bc	24 ab	7.00 b
BRRI-47	83.10 bc	12.47 abc	22.36 a	97.90 abc	55.47 a	41.80 cd	56.91 ab	24 ab	1.67 a
BRRI-67 Dahn	78.50 ab	12.20 abc	21.14 a	69.00 a	62.40 a	7.2 a	90.41 c	20.33 ab	1.67 a
G-2	101.00 d	9.13 ab	25.21 a	128.10 bc	92.38 ab	36.57 abcd	71.84 abc	24 ab	0.00 a
BRRI-61	76.10 a	15.67 c	21.03 a	84.30 ab	71.27 ab	12.67 abc	85.22 bc	22 ab	0.67 a
SIDENUK	75.20 a	12.50 abc	19.63 a	86.20 ab	52.47 a	33.80 abc	60.42 abc	26 ab	5.00 b
NERICAL-19	104.00 d	8.93 ab	24.52 a	119.70 bc	92.00 ab	27.67 abc	76.66 abc	24 ab	0.00 a
SUAKOKO-8	113.00 e	10.5 abc	21.56 a	124.80 bc	112.86 b	11.31 ab	90.32 c	16 a	0.00 a
V-4	87.70 c	9.47 abc	22.17 a	136.90 c	72.47 ab	64.33 d	53.29 a	20 ab	0.00 a
Means	87.84	11.4	22.26	100.8	70.6	30.3	71%	22.2	1.67

Note: The numbers followed by the same letter in the same column show no significant difference

(Refer to Tukey's Honestly Significant test at the α level of 5%)

➢ *Effects of Iron Toxicity on Trial Materials*

Iron toxicity in the rainfed lowlands of Liberia substantially reduces rice productivity, causing detrimental effects on plant growth, yield, and overall crop health. These lowlands are especially vulnerable to iron toxicity due to unique soil characteristics and extended periods of flooding. The fifteen rice varieties evaluated demonstrated diverse responses in yield, tillering, spikelet fertility, grain number, and interaction with iron, as illustrated in Figure 1. Based on the standard evaluation score for iron toxicity tolerance, Sidenuk and Isora were identified as the most susceptible varieties, while Mustajab exhibited moderate tolerance. Iron toxicity decreased grain weight in most varieties; however, G-2 (early) and Sidenuk achieved the highest yields, whereas Suakoko-8, the local check, recorded the lowest grain weight. The capacity of a variety to maintain grain weight and grain filling under Fe-toxic conditions indicated physiological tolerance mechanisms, including efficient internal Fe partitioning and reactive oxygen species (ROS) detoxification (Pawar *et al*, 2021).

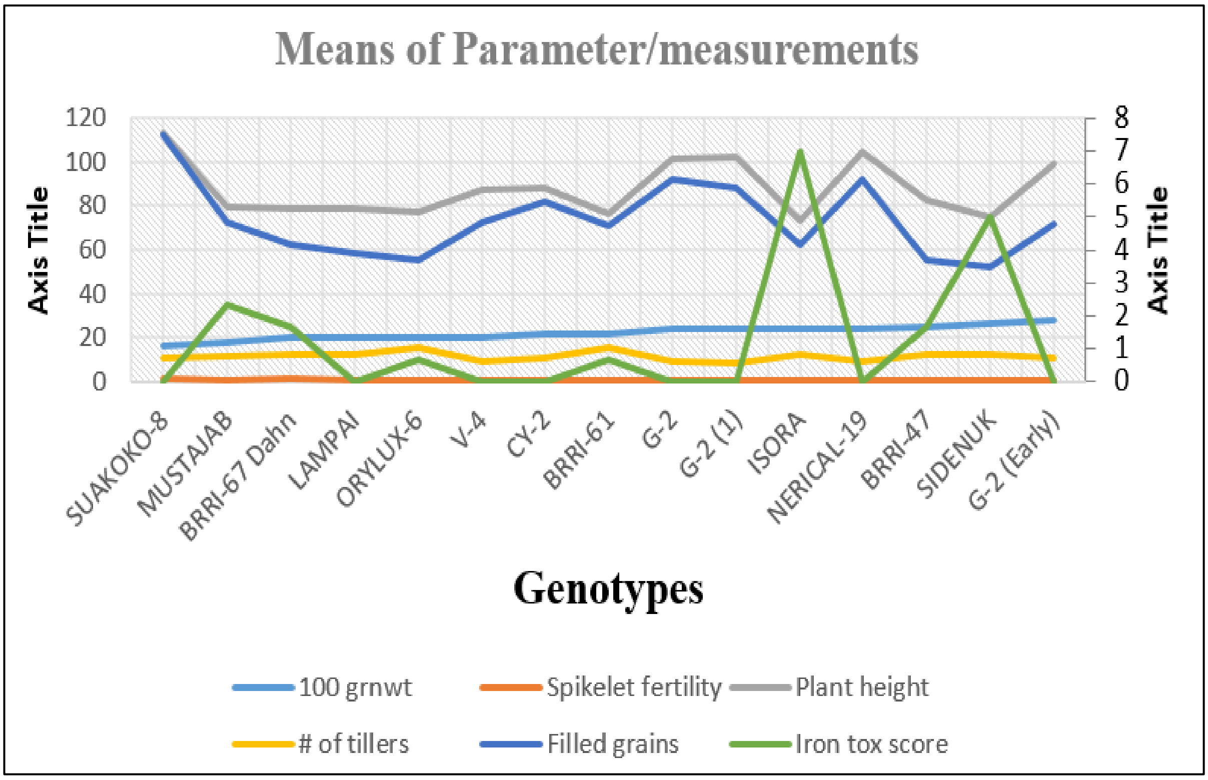

Fig 1 The Effect of Iron Toxicity on the Rice Genotypes Performance

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Similarly, other parameters, such as plant height, filled grains, number of tillers, and spikelet fertility, were also influenced by iron toxicity. As illustrated in Figure 1, the effects of iron toxicity was high on all target parameters measured during the experiment. This result agrees with the reports of previous studies on iron effects on rice growth. According to Wairich, Aung, *et al.* 2024, well-aerated soils maintain iron in its ferric form (Fe^{3+}), promoting iron homeostasis under optimal conditions. However, at low pH, iron shifts to its more soluble ferrous form (Fe2+), which can become toxic and cause irreversible damage to the growth of non-adapted plants (Rout and Sahoo, 2015), a condition that primarily persists in the lowland fields in Liberia.

Table 3 Correlation Table

	1000_grain_weight	**DTB**	**DTF**	**Iron_Tox_score**	**No_of_filled_grains**	**No_of_grain_panicle**	**No_of_tillers**	**No_of_unfilled_grains**	**Plant_Height**	**Spikelet_Fertility**
DTB	-0.31									
DTF	-0.41	0.93								
Iron_Tox_score	0.13	0.02	0.07							
No_of_filled_grains	-0.15	0.29	0.25	-0.36						
No_of_grain_panicle	-0.05	0.19	0.10	-0.46	0.75					
No_of_tillers	-0.06	0.00	0.03	0.16	-0.34	-0.50				
No_of_unfilled_grains	0.11	-0.10	-0.17	-0.24	-0.12	0.56	-0.32			
Plant_Height	0.01	0.32	0.26	-0.57	0.72	0.67	-0.55	0.10		
Spikelet_Fertility	-0.17	0.07	0.12	0.08	0.47	-0.20	0.16	-0.89	0.14	
panicle_length	0.05	-0.24	-0.23	-0.27	0.26	0.34	-0.32	0.20	0.43	-0.08

➢ *Correlation Co-Efficient*

The correlation coefficients of in Table 3 was used to measure the strength and direction of the linear relationships among pairs of variables in the trial. According to Table 3, there was a strong positive correlation (0.93) between date to flowering and date to booting indicating that earlier booting was related to early flowering. Similarly, nuber of filled grains and number of grains per panicle had a strong positive correlation, indicating the number of filled grains was related to the number of grains which influenced grain weight. Number of filled grains and plant height had a strong positive correlation, which indicated that taller plants tend to produce healthy panicles and grains. Conversely, the number of unfilled grains and Spieklet fertility had strong negative correlating indicating the lower the spikelet fertility the more the unfilled, vise visa.

➢ *Organoleptic Test*

The organoleptic test for texture, aroma and appearance was conducted to evaluate the quality of fouteen rice varieties as shown in Table 4. The evaluation serves as an active method for assessing the sensory qualities of rice, including its appearance, aroma, flavor, and texture, which are important for consumer approval and commercial success (*Farah Et al.*, 2025). The results of the test shows that each of the variety was accepted differently by the pannel. CY-2 has good appearance, non-sticky and mild aroma; Mustapha has good appearance, soft with mild to no aroma. Lampai has fair appearance, good texture and has a mild to no aroma characteristic. Isora has an excellent appearance, cohesive in texture and moderately aromatic. Suakoko, an indigenous rice varety has fair appearance, good texture and aromatic. BRRI_Dahn-67 has a good appearance, good texture with mild aroma. G-2_early, a rice variety developed by a CARI scientist has a fair appearance, sticky and aromatic.

Table 4 Sensory Test for Food Quality

	appearance/frequency				**Texture**				**Aroma**		
Variuety	**Excellent**	**good**	**Fair**	**poor**	**Hrad**	**Sticky**	**Cohesive**	**Fluffy**	**Strong**	**Mild**	**None**
CY-2	20	80	0	0	40	20	40	0	20	60	20
Mustajab	0	20	80	0	20	40	40	0	0	40	60
Lampai	0	40	60	0	60	40	0	0	0	60	40
Isora	60	40	0	0	0	20	80	0	40	20	40

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Suakoko	0	40	40	20	20	40	0	40	60	40	0
BRRI_Dahn-67	40	40	0	20	20	20	60	0	0	80	20
G-2 _Earluy	20	0	40	40	0	80	20	0	60	40	0
G_2_1	20	80	0	0	20	40	20	20	0	80	20
V-4	20	60	20	0	20	60	0	20	60	40	0
BRRI_47	0	20	60	20	80	0	20	0	40	20	40
Orylux_6	20	40	20	20	20	40	20	20	20	60	20
G_2	20	80	0	0	20	20	60	0	20	80	0
Sidenuk	40	0	40	20	0	60	40	0	40	40	20
NERICA_L_19	20	40	40	0	20	40	20	0	20	40	40

The V-4 rice developed by CARI sicientists, has a good appearance and good texture, and aromatic. BRRI_47, is fair in appearance, soft in texture and aromatic. Orylux developed by the africaRice Center, has a fair appearance, good texture and aromatic. G-2 rice developed by a CARI scientist, is fair in appearance, soft in textiure and aromatic. Sidenuk a mutant rice from Indonesia, is poor in appearance, soft in texture and aromatic. G-2-1, a rice variety developed by a CARI scientist has good apearance, good texture and less aromatic. Lastly, NERICA_L19 is fair in appearance, soft in tecture with a mild aroma.

V. CONCLUSION

The findings of this research suggest that the varied response to iron toxicity among the materials examined. G-2 and Sidenuk exhibited strong performance, recording the highest grain weight. Suakoko-8 the local check recorded low grain weight compared to the introudced varieties. The organoleptic test clearly differentiated the examined materials in terms of food quality, and the correlation coefficient showed the various relationships between the measured parameters of the genotypes in the trial field.

➢ *Conflict of Interest*

The authors declare no conflict of interest

The research was self-sponsored by the principle investigator

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