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Growth performance and nutrient quality of three *Moringa oleifera* accessions grown as potplant under varied manure rates and watering intervals

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Growth performance and nutrient quality of three *Moringa oleifera* accessions grown as potherbs under varied manure rates and watering intervals were investigated at the Department of Crop Science, University of Nigeria, Nsukka. The treatments included three accessions of Moringa (Awo-Anaekpa, Idere and Kano), three pig manure rates (0, 10 and 20 t/ha) and three watering intervals (3, 4 and 5 days). These were laid out as 3 x 3 x 3 factorial in a completely randomized design, replicated three times. Results showed that seeds of Awo-anekpa accessions had the highest cumulative emergence percentage (97%) and number of emerged seedlings. Plant height and stem girth at 3 months, and number of leaves at 2 and 3 months, after treatment application were higher in Awo-anekpa and Idere accessions than in Kano accession. The leaf proximate composition showed that Idere accession accumulated the highest ash (7.6%) and crude fibre (11.9%). Awo-anekpa contained the highest carbohydrate (41.1%) and moisture (20.7%), while the highest crude protein (26.9%) and oil content (3.0%) were found in Kano accession. Generally, plant height, stem girth and number of leaves increased with increase in manure rate; however, the leaf proximate compositions were not significantly ($p > 0.05$) influenced by manure application. Only stem girth was significantly ($p < 0.05$) affected by watering interval. The thickest stem girth (12.2 mm) was associated with 3 day watering interval, whereas 5 day watering interval produced the tiniest stem girth (10.8 mm). Second order interaction of accession, manure rate and watering interval suggests that Idere accession grown with 20t/ha of pig manure and watered at 3 day interval was most adaptable to the container growing condition. Evidences from this study suggest that *Moringa* can successfully be grown as a potherb if appropriate horticultural practices are followed.

Key words: *Moringa oleifera*, potherb, pig manure, watering interval, leaf proximate qualities.

INTRODUCTION

Moringa oleifera is commonly known as drumstick tree, horseradish tree and ben oil tree. It is a multi-purpose plant widely known for its ethno-medicinal (Price, 2007; Mughal et al., 1999; Farooq et al., 2012) and culinary properties (Price, 2007; Farooq et al., 2012; Stevens et al., 2013). All parts of the Moringa tree are edible and have long been consumed by humans (Fahey, 2005). In developing countries, Moringa has the potential to improve nutrition, boost food security, foster rural development, and support sustainable land care (NRC, 2006). *M. oleifera* leaves have been reported a valuable source of macro and micro nutrients, being a significant source of beta-carotene, vitamin C, protein, calcium, iron and potassium (Fuglie, 1999; Olugbemi et al., 2010). Moringa plant is a soft wood tree with low timber quality but has been reported to provide nutritional, medicinal and industrial uses to man, livestock feed and crop nutritional benefits (Fuglie, 1999). It is increasingly becoming popular for use as food supplements especially by nursing mothers, as a weaning food for children due to its nutritional benefits. It is reported to contain more than 92 useful compounds; including 46 antioxidants, 36 anti-inflammatory constituents, 18 amino acids and 9 essential amino acids (Duke, 1983; Olsen et al., 1987; Nnam, 2009). There is a recent upsurge in utilization of Moringa (Stevens et al., 2013) and research interest has grown tremendously in Nigeria. Most research efforts in Nigeria are on basic science, nutritional and medicinal properties and utilization of the plant (Nnam, 2009; Eze et al., 2012). Study on germplasm collection and evaluation are probably not adequately documented except the report by Ndubuaku et al*.* (2014). Besides, there is no information in relevant literature on growing Moringa as a potherb (container grown vegetable).

Developing horticultural techniques for growing Moringa plant as a potherb will ensure that urban dwellers could plant the crop within the house and compound with ease. More so, growing Moringa as a potherb makes it readily available to the household for consumption since the planting can be done on the balcony or backyard where there is sufficient insolation. A poor availability of essential nutrients in substrate for growing container plants reduces crop growth and yield (Fried and Broeshart, 1967; Baiyeri and Mbah, 2006). A vast array of organic wastes, compost and animal manures, as well as, inorganic fertilizers serve as amendments to improve on the soil/substrate fertility status (Stoffella et al., 1997). Just like other animal manures, pig dung serve as low cost fertilizer when applied to agricultural soils (Babalola and Adigun, 2013). Organic fertilizers supply plant nutrients in readily available form, and modify the physicochemical attributes of soils for improved crop performance (Aba et al., 2011); and pig manure is readily available in Nsukka environs owing to the prevalence of commercial pig farms in the area (Ezeibe, 2010).

Thus, this study was conducted to evaluate the growth performance and nutritional quality of three Nigerian accessions of Moringa grown as potherbs, using three rates of pig manure and three watering intervals. Water management in commercial nurseries, particularly with container grown plants could be tasking and expensive. Judicious management of irrigation water in terms of volume and/or frequency of application could help nursery-men cut cost, save labour, and maximize crop water use.

MATERIALS AND METHODS

Study area

This experiment was conducted at the Department of Crop Science Teaching and Research Farm, University of Nigeria, Nsukka. Nsukka lies between latitude 06° 52'N and longitude 07°24'E and at an altitude of 447 m above sea level. The average daily temperature ranges between 27 and 28°C, and two predominant seasons prevail – the rainy season lasting from April to October and the dry season from November to March (Ofomata, 1978). The vegetation of the area is derived savannah.

Experimental design and treatment

The experimental design was a 3×3×3 factorial in completely randomized design (CRD) making up 27 treatment combinations replicated three times in a pot experiment. The treatment combinations comprised three Nigerian accessions of Moringa (Awo-Anaekpa, Idere and Kano, respectively obtained from Kogi, Oyo and Kano states of Nigeria), three pig manure rates (0, 10 and 20 t/ha) and three watering intervals (3, 4 and 5 days). Both field and laboratory experiments were conducted.

Field experiment

The experiment was conducted using 18 L perforated nursery buckets filled with 17.6 kg topsoil (Figure 1). Substrates were moistened to container capacity and thereafter five seeds were sown per bucket. Watering was done twice daily, morning and evening due to low relative humidity accentuated by the dry harmattan season. Dry grass mulch was applied 3 days after planting to help conserve moisture and to enhance germination. Seedling emergence was noticed after 9 days. Seedlings were later thinned down to three per bucket. Weeds were handpicked when necessary. The application of manure and watering treatments commenced 8 weeks after seed planting. Manure was applied in three split doses at 2 week intervals. The first application was done at the 8th week after seeding; the second application was done at the 10th week, while the third application was at the 12th week. Watering was done at every 3, 4, or 5 days until the experiment was terminated (at the third month after treatment application). The irrigation treatment commenced with the application of water at 2.8 L per bucket, which was equivalent to the container capacity.

Field data collection

The following data were measured: percentage seedling emergence was calculated as the ratio of emerged seedlings to the total number of seeds sown multiplied by 100; mean daily emergence was calculated as the total number of emerged

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Figure 1. *Moringa oleifera* accessions growing in 18 L buckets.

Table 1. The effect of accession on *Moringa oleifera* seedling emergence parameters.

Accession	Cumulative emergence percentage	Emergence span	Mean daily emergence	Number of non-emerged seedlings	Number of emerged seedlings
Awo-anekpa	97.0	3.0	2.7	0.15	4.9
Idere	56.3	1.9	2.0	2.4	2.6
Kano	88.9	3.1	2.2	0.6	4.4
$LSD_{0.05}$	9.7	ns	ns	0.4	0.4

seedlings divided by the cumulative number of days to seedling emergence; emergence span was estimated as the number of days from first seedling emergence to the last seedling emergence. Plant growth parameters measured included: Plant height (cm) and number of leaflets per plant which were determined before manure and watering treatment application and were thereafter repeated on monthly basis for three consecutive months. The stem girth (mm) of each plant was measured at 20 weeks after planting (WAP). At the 21st week, destructive sampling of the plants was done and the leaves were dried at the Department of Crop Science glasshouse.

Laboratory analysis

The laboratory analysis was carried out at the Department of Animal Science Analytical Laboratory, University of Nigeria, Nsukka. Proximate qualities of the air-dried leaf samples were carried out to determine the crude protein, crude fibre, moisture, ash, fat and carbohydrate contents. These proximate qualities were determined using the standard procedures of Association of Official Analytical Chemistry (AOAC, 1990). The crude protein content of the samples was determined using the Khedahl technique (Pearson, 1976). The ash of an agricultural material is the inorganic or mineral residue remaining after the organic matter has been burnt away (Pearson, 1976), hence was determined by subtraction of all other component fractions from 100%.

Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) following the three-way procedure for factorial experiments using GenStat Release 10.3 DE (2011). Significant treatment means were separated using Fisher's Least Significant Difference at 5% probability level.

RESULTS

Data in Table 1 shows the results of the seedling emergence parameters as influenced by accession. It was observed that emergence span and mean daily emergence were non-significant (P > 0.05) but the number of emerged seedlings, non-emerged seedlings and cumulative emergence percentage significantly differed with accessions. The cumulative emergence percentage (97%) and number of emerged seedlings (4.9) were highest in Awo-anekpa accession. Invariably, the number of non-emerged seedlings was least with Awo-anekpa (0.15). Comparatively, the Idere accession had the least number of emerged seedlings (2.6),

Table 2. Main effects of accession, manure and watering interval on the plant height and stem girth of *Moringa oleifera,* months after treatment application.

Treatment	Plant height (cm)				
	Initial	1 month	2 months	3 months	*Stem girth (mm)
Accession					
Awo-anekpa	27.1	51.1	64.3	86.5	12.5
Idere	25.8	48.2	64.8	86.4	12.7
Kano	24.5	45.3	60.6	77.3	9.5
$LSD_{0.05}$	ns	ns	ns	8.2	1.0
Manure (t/ha)					
0	27.7	36.3	40.7	56.8	9.0
10	24.3	48.3	64.3	83.2	12.1
20	25.4	60.0	84.7	110.2	14.0
$LSD_{0.05}$	ns	6.0	6.5	8.2	1.0
Watering interval					
3	26.1	50.0	66.4	86.5	12.2
4	25.8	49.4	64.6	84.6	11.9
5	25.5	45.3	58.7	79.1	10.8
$LSD_{0.05}$	ns	ns	ns	ns	ns

ns = non-significant; *Stem girth (mm) was determined 3 months after treatment application.

cumulative emergence percentage of 56.3% and consequently the highest number of non-emerged seedlings (2.4).

Main effects of accession, manure and watering interval on the plant height and stem girth of *M. oleifera*

Table 2 shows the main effects of accession, manure and watering interval on the plant height and stem girth of *M. oleifera*. The baseline data on plant height (that is, the plant height recorded before manure/irrigation treatment application) and the subsequent heights after one and two months of treatment application were not significantly ($p > 0.05$) different among the accessions. But at three months after treatment application, Awo-anekpa and Idere accessions were statistically taller and had thicker stem girth than *Kano* accession. The manure effect indicated that the plant heights at one, two and three months were significantly ($p \leq 0.05$) influenced by the manure rate (Table 2). At each month interval, plant height increased with increasing manure rate. The tallest plants were obtained with the application of 20 t/ha pig manure (that is, 60, 84.7 and 110.2 cm, respectively for one, two and three months after treatment application). A similar trend exists for stem girth. The no manure application gave the least values for plant height and stem girth. Watering intervals did not significantly ($p > 0.05$) affect the plant height at all the month intervals (Table 2). However, 3 days watering interval produced the widest stem girth (12.2 mm) while the 5 days interval had the least stem girth (10.8 mm).

Effect of accession, manure rate and watering interval on the number of leaves per plant

The effects of accession, manure and watering on the number of leaves per plant at different periods of growth are shown in Table 3. The highest number of leaves at 1 month after treatment application was associated with Idere while Kano and Awo-anekpa accessions had numerically similar number of leaves. At 2 and 3 months, Awo-anekpa and Idere accessions had the highest number of leaves. At 1 month after treatment application, there was no significant difference in number of leaves per plant among the manure rates (Table 3); but at 2 and 3 months, the number of leaves increased with increase in manure rate. The application of 20 t/ha pig manure produced the highest number of leaves in the 2 and 3 months after treatment application. Watering interval did not influence the number of leaves throughout the growth stages (Table 3). The interaction effect of accession and manure rate indicated that the number of leaves and stem girth increased with increase in manure rate irrespective of the accession (Table 4). The number of leaves and stem girth were highest at 20 t/ha manure rate for the three accessions. The least number of leaves and thinnest stem were obtained with no manure

Table 3. Main effects of accession, manure and watering interval on number of leaves per plant of *Moringa oleifera*, months after treatment application.

Treatment	Number of leaves			
	Initial	1 month	2 months	3 months
Accession				
Awo-anekpa	10.5	8.5	8.9	11.8
Idere	10.9	9.8	8.7	10.8
Kano	9.2	8.7	6.8	8.5
$LSD_{0.05}$	0.9	0.8	0.6	1.1
Manure (t/ha)				
0	9.7	8.5	6.9	9.4
10	10.3	9.4	8.4	10.4
20	10.5	9.0	9.1	11.4
$LSD_{0.05}$	ns	ns	0.6	1.1
Watering interval				
3	10.4	9.3	8.6	10.6
4	10.0	9.2	7.9	10.1
5	10.2	8.5	8.0	10.4
$LSD_{0.05}$	ns	ns	ns	ns

ns = non-significant

Table 4. The interaction effects of accession and manure rate on the number of *Moringa oleifera* leaves and stem girth, three months after treatment application.

Accession	Manure rate (t/ha)	Number of leaves	Stem girth (mm)
	0	8.3	10.1
Awo-anekpa	10	9.0	12.9
	20	9.4	14.7
	0	6.8	9.4
Idere	10	8.9	12.3
	20	10.6	16.6
	0	5.7	7.3
Kano	10	7.4	10.9
	20	7.6	10.5
$LSD_{0.05}$		1.2	1.8

application in Kano accession. The values for the number of leaves and stem girth in Kano accession were significantly ($p < 0.05$) smallest at all manure rates.

Effect of accession, manure rate and watering interval on the leaf proximate composition of *M. oleifera*

The leaf proximate composition was significantly influenced by accession (Table 5). Idere accession had the highest ash content (7.6%) and crude fibre (11.9%) while Kano accession had the least value (5.5%) for ash content. Awo-anekpa accession had the highest carbohydrate (41%) and moisture contents (20.7%), although the value for the moisture content was statistically similar with that of Idere (19.9%). The least carbohydrate and moisture contents were associated with Idere and Kano accessions, respectively, although the crude protein was highest in these accessions. However,

Table 5. The main effect of accession, manure and watering interval on the leaf proximate composition of *Moringa oleifera*.

Accessions	Ash (%)	Carbohydrate (%)	Crude protein (%)	Oil (%)	Crude fiber (%)	Moisture (%)
Awo-anekpa	6.1	41.1	20.3	1.8	9.4	20.7
Idere	7.6	32.5	25.6	2.3	11.9	19.9
Kano	5.5	35.9	26.9	3.0	9.8	19.1
$LSD_{(0.05)}$	0.7	3.1	2.6	0.5	1.9	1.1
Manure (t/ha)						
0	6.4	36.9	25.1	2.7	10.6	19.2
10	6.1	36.7	23.1	2.5	10.1	20.3
20	6.7	35.9	24.6	2.0	10.4	20.2
$LSD_{(0.05)}$	ns	ns	ns	0.5	ns	ns
Watering intervals (days)						
3	6.8	35.2	24.8	2.5	11.2	19.3
4	6.2	37.3	23.1	2.5	9.8	20.0
5	6.1	37.0	24.9	2.2	10.1	20.4
F-$LSD_{(0.05)}$	ns	ns	ns	ns	ns	ns

ns = non-significant

Table 6. The interaction effect of manure rate and watering interval on the leaf proximate composition of *Moringa oleifera*.

Manure (t/ha)	Watering intervals (days)	Ash (%)	Carbohydrate (%)	Crude protein (%)	Oil (%)	Crude fiber (%)	Moisture (%)
	3	6.4	34.9	26.0	2.8	13.0	18.5
0	4	7.1	36.0	24.1	3.0	8.8	19.0
	5	5.6	39.8	25.2	2.4	9.9	20.1
	3	6.4	35.2	24.6	2.3	10.2	19.8
10	4	5.8	38.4	21.4	2.7	9.9	20.4
	5	6.0	36.6	23.4	2.3	10.3	20.8
	3	7.7	35.4	23.9	2.4	10.4	19.6
20	4	5.7	37.6	24.0	1.7	10.6	20.6
	5	6.7	34.5	26.0	1.8	10.2	20.5
$LSD_{0.05}$		1.3	ns	ns	ns	ns	ns

ns = non-significant

oil content was highest with Kano accession. Manure rate only influenced the oil content of the leaf (Table 5). The oil content decreased with the application of pig manure. While, the highest leaf oil content (2.7%) was obtained with no manure application, the lowest (2.0%) was recorded when 20 t/ha manure was applied. The ash, carbohydrate, crude protein, crude fibre, oil and moisture contents of the leaf did not differ with watering interval (Table 5). The interaction of manure rate and watering interval only influenced the leaf ash content (Table 6). The application of 20 t/ha manure and 3 days watering interval resulted in the accumulation of 7.7% leaf ash content, compared to values of 5.6 to 7.1% obtained in other combinations. The least ash content of 5.6% was recorded in the control plants (which received 0 t/ha of manure) with 5 days watering interval. The interaction effect of accession, manure and watering interval on the leaf proximate composition of *M. oleifera* showed significant ($p < 0.05$) variations with respect to carbohydrate, crude protein and oil content (Table 7). However, there was no consistent trend in the variation. The range of the carbohydrate, crude protein and oil content were 25.4 to 46.1, 14.5 to 32.8, and 1.3 to 5.1%, respectively. For carbohydrate, the highest value of

Table 7. The interaction effect of accession, manure rate and watering interval on the leaf proximate composition of *Moringa oleifera*.

Accession	Manure (t/ha)	Watering intervals(days)	Ash (%)	Carbohydrate (%)	Crude protein (%)	Oil (%)	Crude fiber (%)	Moisture (%)
	0	3	5.9	40.3	20.1	1.3	12.4	18.3
		4	7.5	38.9	22.7	1.6	9.2	19.8
		5	5.4	41.4	20.3	2.0	10.3	20.5
	10	3	5.5	45.1	14.5	2.1	9.8	22.8
Awo-anekpa		4	5.6	37.7	22.5	2.2	9.6	22.5
		5	5.8	38.2	21.8	2.2	8.9	22.0
	20	3	7.6	39.6	20.8	1.9	8.5	20.5
		4	5.5	43.0	20.9	2.1	9.0	19.4
		5	6.3	45.3	19.7	1.3	7.0	20.4
	0	3	8.3	33.2	25.2	4.0	16.0	18.9
		4	8.4	33.1	28.0	2.3	9.8	18.2
		5	6.4	31.7	28.2	1.7	11.2	20.5
	10	3	8.0	25.4	30.0	2.0	11.6	18.9
Idere		4	6.9	40.4	19.2	2.8	10.1	19.5
		5	6.8	34.3	22.3	2.3	13.2	20.8
	20	3	10.0	27.0	28.5	2.6	12.9	18.7
		4	5.9	35.5	21.7	1.5	13.2	22.1
		5	7.5	32.1	27.5	1.5	9.5	21.7
	0	3	5.0	31.1	32.8	3.0	10.5	18.3
		4	5.6	35.9	21.6	5.1	7.5	18.9
		5	5.1	46.1	27.3	3.6	8.3	19.3
	10	3	5.7	35.2	29.2	3.0	9.4	17.6
Kano		4	5.1	37.2	22.5	3.3	9.9	19.3
		5	5.5	37.2	26.3	2.4	8.8	19.6
	20	3	5.7	39.6	22.4	2.6	9.9	19.6
		4	5.9	34.5	29.4	1.5	9.8	20.2
		5	6.5	26.3	30.9	2.7	14.2	19.3
$LSD_{0.05}$			ns	9.5	8.0	1.5	ns	ns

ns = Non-significant.

46.1% was obtained in the Kano accession with 0 t/ha of manure and 5 days watering interval. Similarly, carbohydrate was seemingly high in Awo-anekpa accession particularly with the application of 20 t/ha of manure. The Kano accession recorded the highest values for protein and oil contents irrespective of the manure and watering treatments.

DISCUSSION

Most of the parameters for seedling emergence, early growth and leaf proximate composition of *M. oleifera* distinctively differed with the accessions. Awo-anekpa accession had the highest emergence rate and number of emerged seedlings, indicating that it germinated faster than Idere and Kano accessions. However, the proximate qualities showed that no accession had a preponderance of the different proximate qualities rather each accession had some distinct proximate qualities it accumulated the most. For instance, Idere accession accumulated the highest ash and crude fibre, which implied that Idere contained more mineral elements than the other two accessions. Awo-anekpa had the highest carbohydrate and moisture contents while the highest crude protein and oil content were recorded in Kano accession. These observations could probably be due to variations in the genetic potentials of the accessions and/or the inherent variability across the collection environments. The accessions were collected from three locations belonging to different ecological zones. Ugwuoke et al. (2001) earlier reported that different agro-ecologies may differ in climatic and edaphic factors. The authors averred" that varying weather and soil conditions might result to varying nutrient concentrations in the different plant parts including the seeds.". Therefore, the variability observed in the accessions may not be unconnected with the ecological zones from where they were collected. Variability observed in the performances of the accessions also suggests that source of seed or seed collection centre could influence the quality of the seedlings thereof. The chemical compositions of the different accessions also showed that the crude fat contents were low, ranging from 1 to 4%, and this may be advantageous for obese sufferers (Lintas, 1992). Low fat foods are known to reduce cholesterol level (Wardlaw and Hampl, 2006). The present study also revealed that the *M. oleifera* accessions had moderate crude fibre content (the indigestible carbohydrate component that aids digestion and reduces diabetes and high levels of blood cholesterol). The range of 9.4 to11.9% obtained in this study is in agreement with the crude fibre value reported by Olugbemi et al. (2010). *M. oleifera* leaves, in the study, also contained high amount of crude protein ranging from 20.3 to 26.9%, which also falls within the crude protein value of 24.44% reported by Olugbemi et al. (2010). However, Mutayaba et al. (2011) reported much higher value of 30.65%. Crude protein is known to play a vital role in body building; and the protein content of *Moringa* leaves is adequate in controlling malnutrition in children and enough to support breast feeding mothers during their lactating months (Duke, 1983).

The application of manure increased plant height, number of leaves and stem girth of the plants. This observation agrees with earlier reports of Baiyeri and Tenkouano (2007), Ndukwe et al. (2011) and Aba et al. (2011) that animal manure is a valuable source of crop nutrients and organic matter, which can improve the soil biophysical conditions making the soil more productive and sustainable for plant growth. Chukwuka and Omotayo (2009) specifically noted that application of organic fertilizers significantly improves the soil chemical properties and nutrient uptake in plants, thereby enhancing plant growth. In the present study, the growth parameters were significantly highest with 20 t/ha of pig manure. Increased application of the organic fertilizer was found to favour vegetative growth in the plants, and this corroborates with the findings of Ewulo et al. (2008). For the leaf proximate composition, manure application particularly influenced the oil content. The oil content of the Moringa leaves obtained with 20 t/ha manure (2.0%) was significantly smaller than the values obtained with 10 t/ha (2.5%) and 0 t/ha (2.7%) manure rates. Irrigation water application at different intervals showed no significant effect on the plant height and number of leaves but only influenced the stem girth. The non-significant effect of watering on most growth traits could probably be due to the short water stress intervals applied in this study, vis-à-vis a blanket application of dry grass mulch, which must have conserved sufficient moisture for the test plants. Takano (2004) had earlier reported that *M. oleifera* could withstand severe drought once it had fully established. Evidence from the present study indicate that watering at 3 to 5 days interval could sustain adequate growth and quality of *M. oleifera* as potted plants.

Interactions between accessions, manure and watering (second order interaction) significantly influenced carbohydrate, crude protein, and oil contents. Heywood (2002) reported that variations in essential chemical compositions can occur as a result of differing soil conditions, seasonal fluctuations and other environmental factors. The slight inconsistency observed in the second order interaction may probably be due to the short watering intervals applied in the study. As such, wider watering intervals re-evaluated with these accessions under varied manure rates may probably elicit a clearer response. We conclude from the available data that *M. oleifera* plants could be grown as potherbs with organic soil amendment (20 t/ha of pig manure) and irrigation intervals of 3 to 5 days.

Conflict of interests

The authors did not declare any conflict of interest.

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