American Journal of Plant Sciences, 2019, 10, 1142-1153
http://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Mango Yield Performance in Lake Victoria Cresent Region of Uganda

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How to cite this paper: Ddamulira, G., Ramathani, I., Sebikejje, T., Naluyimba, R., Otim, A., Pariyo, A. and Maphosa, M. (2019) Mango Yield Performance in Lake Victoria Cresent Region of Uganda. *American Journal of Plant Sciences*, **10**, 1142-1153.
https://doi.org/10.4236/ajps.2019.107082

Received: May 4, 2018
Accepted: July 16, 2019
Published: July 19, 2019

Abstract

A study was conducted to evaluate yield performance of mango (*Mangifera indica L.)* genotypes in the Lake Victoria Crescent zone. The experiment was superimposed on a seven-year-old mango field with 36 genotypes laid out in a randomized complete block design, replicated thrice. Mango fruit set, fruit drop and yield were significantly ($P < 0.05$) differently among years and genotypes. The highest fruit set was recorded in 2015 and the lowest in 2014. Among genotypes, the maximum and minimum fruit set were observed in Koona and Pinero, respectively. The highest fruit drop was observed in Heidi followed by Keitt and MP1 genotypes. The highest yield of 59.6 kg/tree/year was recorded in Kate while Kensington pride genotype yielded least (3.5 kg/tree/year). In this study variation in mango yield was mainly due to varietal differences. The findings will aid in selecting mango genotype suitable for production in Lake Victoria Crescent agro-ecological zone.

Keywords

Genotypes, Fruit Set, *Mangifera indica*

1. Introduction

Mango (*Mangifera indica L.*) is among the most important fruit crop in the tropical and subtropical regions of the world. The fruit is considered important because it provides; income, nutrition security and health to smallholder farmers and consumers at large [1]. Mango is also rich in vitamins, minerals and phytochemicals [2] that provide stronger antioxidant activity capable of reducing incidences of chronic cardiovascular diseases [2] [3].

Because of its importance in Uganda mango has been widely grown for several decades by smallholder farmers in their fields and near homesteads [4]. This is because most mango growing areas in Uganda share tropical climatic conditions that favour mango production. Although the tropical conditions in Uganda favour mango production but its yields are still low compared to other global mango producing countries such as India. In India, the average yield stands at 11.7 ton·ha^{-1} [5] while in Uganda mango yields are still below 5.8 ton·ha^{-1} [4]. This is partly due to low yielding local mango cultivars which are traditionally grown by farmers with little or no improved management practices [6]. Additionally, most of the local mango cultivars are high in fibre content which makes them less attractive for processing and export market [7].

In order to address, the challenges of low yielding mango cultivars, a research initiative was started in 1990 to explore the wide variability of mango through local germplasm collection and introducing mango varieties from different mango growing countries [4]. This initiative led to the establishment of a core mango collection of 38 introductions at Kawanda Agricultural Research Station in 1999. This core collection was later transferred to National Crops Resources Research Institute (NaCRRI) at Namulonge in 2007. The collection consisted of introductions from Kenya, South Africa, Puerto Rico and local landraces collected from Uganda. The collection was established with a target of providing different mango germplasm for future crop improvement in Uganda. The mango genotypes which constituted the core collection were anticipated to vary in flowering, fruiting and yield attributes because they were developed under different agro-climatic conditions. Hence there is the need to identify mango accessions with potential to increase yield in mango growing areas [8].

Lake Victoria Crescent is one of the agro-ecological zones in Uganda government earmarked for production of high value and marketable fruits including mango. Because of this niche, acreage under fruit production and farmers engagement in fruit production has increased overtime [4]. Indeed in the last half a decade, area under mango production has increased from 6581 to 12,123 ha [9]. This agro-ecological zone covers mostly central and some eastern parts of Uganda (Luwero, Masaka, Iganga, Mayuge and Kamuli, districts) with high potential for mango production due to its nearness to urban markets in Kampala. Given this market potential if mango production is increased from the current status, farmers will easily sell their mango at premium prices as compared to other potential agro-ecological zones of Uganda.

However, to realise the mango production potential within the Lake Victoria Crescent agro-ecological zone, selection of mango genotypes varieties with the best yield potential is essential. Therefore, a study was conducted to assess the yield performance of various mango genotypes to identify genotypes with the best within the Lake Victoria Crescent agro-ecological zone.

2. Materials and Methods

2.1. Plant Materials

Mango genotypes which constituted part of the core collection held at NaCRRI, Namulonge were evaluated for yield performance. The materials from the core collection evaluated mango genotypes from Uganda (15), Puerto Rico (19), Kenya (1) and South Africa (1) (Table 1). This core mango germplasm collection was established in 2007 with the aim of conserving mango germplasm for mango improvement through breeding in Uganda. Some of the Ugandan mango genotypes such as Kagogwa, Koona, Suu and Sejjembe are adapted to Ugandan climatic conditions and are locally grown by smallholder farmers.

2.2. Study Area

The trial was conducted at NaCRRI, Namulonge, Wakiso district, 19 km North of Kampala. Mean daily temperatures at the experiment site were 28.5˚C maximum, and 13.0˚C minimum. Namulonge lies at an altitude of 1150 metres above sea level (m.a.s.l) with a bimodal rainfall pattern, annual mean temperature of 28.4˚C, with red sandy clay loam soils of pH 4.9 - 5.0. However, the second rain season (August-November) at Namulonge is much longer than the first rain season (March-June). This site was chosen because it lies within the Lake Victoria crescent and depicts the weather conditions for the Lake Victoria Crescent agro-ecological zone in terms of rainfall pattern and temperature.

Table 1. Mango genotypes used in the yield performance experiment at NaCRRI, Namulonge.

Entry Number	Genotype	Origin	Entry Number	Genotype	Origin
1	Alphonso	Puerto Rico	20	Keitt	Puerto Rico
2	Apple mango	Uganda	21	Kensington pride	Puerto Rico
3	Asante	Uganda	22	Kent	Puerto Rico
4	Bire	Uganda	23	Koona	Uganda
5	Boribo	Uganda	24	MP1	Uganda
6	Doodo red	Uganda	25	Ngowe	Uganda
7	Duncan	Puerto Rico	26	Palmer	Puerto Rico
8	Early gold	Puerto Rico	27	Parvin	Puerto Rico
9	Edward	Puerto Rico	28	Pascal	Puerto Rico
10	Florigon	Puerto Rico	29	Pinero	Puerto Rico
11	Glenn	Puerto Rico	30	R2E2	Puerto Rico
12	Haden	Puerto Rico	31	Sejjembe	Uganda
13	Heidi	South Africa	32	Suu	Uganda
14	Irwin	Puerto Rico	33	Takataka	Uganda
15	Julie	Puerto Rico	34	Tommy Atkins	Puerto Rico
16	Kagoogwa	Uganda	35	Vandyke	Kenya
17	Kate	Uganda	36	Zillate	Puerto Rico
18	Kawanda Green	Uganda			
19	Kawanda wide	Uganda			

2.3. Experimental Design

Thirty six uniformly growing mango genotypes were evaluated for yield performance from 2014 to 2016. The experiment was superimposed on a seven year old mango field which was laid out in Randomized Complete Block Design during establishment, with three replications. Each block constituted 222 mango trees and each replicate had four mango trees of the same genotype. The mango trees selected received uniform agronomical practices such as; two pruning regimes per year and weed control by slashing once every month. Pest control through application of one fruit fly trap in every 30 m radius and disease control was not done purposely to mimic farmer's practices of producing mango in Uganda.

2.4. Fruit Set and Drop Determination

Every year starting from the flowering stage, 20 panicles were randomly tagged per tree for each genotype. The number of flowers on each tagged panicle was counted. Then three weeks after flowering the total number of fruits found on the tagged panicle was recorded. Fruit set was quantified as the percentage of fruit set on the panicles over number of flowers on tagged panicles. Fruit drop was also recorded bi-weekly from fruit set up to harvest time by counting the number of fruits found on the ground. At harvest the number of all dropped fruits per tree and all harvested fruits from the tree were recorded. Fruit drop was calculated as the percentage of fruits dropped from the tree before harvest compared to fruits attached to the tree at harvest.

2.5. Yield and Alternate Bearing Measurements

Four trees per replicate were tagged to earmark trees for yield data collection. At maturity; yield data was collected from only marked trees by counting the total number of fruits per tree in each replicate. All fruits on trees were counted and their fresh weights determined using an electronic balance and the weight was computed to yield/tree in kilograms.

Alternate bearing was analyzed for the mango growing season from 2014 to 2016. It was considered a change in yield due to alternate bearing if more than 75% of the yield in two seasons was obtained in one season. If the yield was higher as in the previous year it was classified as yield increase, when it was lower, it was classified as decrease. If in both years more than 25% of the yield of the two seasons was obtained, it was considered as no alternation.

2.6. Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using Genstat version 14 (Payne, 2011). The mean values for fruit set, drop and yield were computed for 36 genotypes over a period of three years. The means were subjected to ANOVA, to test for significance difference ($P < 0.05$) [10]. Fisher's least significant difference was used to determine the significant difference between means and the interaction analysis by general linear model (GLM) procedure. In terms of seasons no significant differences were observed for fruit set, drop and yield, hence the two season data where there was no alternate bearing were combined to give total yield per year.

3. Results

3.1. Mean Fruit Set and Drop among Mango Genotypes

Fruit set is among the attributes in mango which greatly contribute to yield but influenced by several weather conditions. The findings from the study indicated a significant ($P < 0.05$) variation in percent fruit set for the different years. The maximum percent fruit set in mango was observed during 2015, while the minimum in 2014 (**Table 3**). Although significant variation in fruit set was observed between 2015 and 2014, the fruit set between 2016 and 2014 was not statistically different. In terms of genotypes a significant ($P < 0.05$) difference in fruit set was observed between mango genotypes. The highest percent fruit set was recorded in Koona genotype, while the lowest in Pinero genotypes, respectively (**Table 2**).

In this study, understanding the percent fruit drop and retention was important because fruit drop directly impacts on yield which was our target in the process of identifying suitable mango genotypes for the Lake Victoria Crescent zone. A significant ($P < 0.05$) variation in percent fruit drop was observed among years over the period the experiment was conducted. The highest percent fruit drop was observed in 2014 and the lowest on 2015 (**Table 3**). Though equally high fruit drop was recorded in 2016 but it was not significantly different from percent drop in 2014. On the other hand, a significant ($P < 0.05$) difference in fruit drop was observed among the genotypes that were tested. Genotype Heidi recorded the highest fruit drop followed by Keitt genotype, and lowest percent fruit drop was recorded in MP1 (**Table 3**). Though most mango genotypes experienced mean fruit drop below 45% but Heidi, Edward and Keitt had mean fruit drop above 45% which affected their total yield.

3.2. Yield of Different Mango Genotypes

Mango yield was affected by years and genotypes though years and genotypes did not significantly interact to affect yield. A significant variation ($P < 0.05$) in mango yield was observed for the three years the experiment was conducted with highest mango yield observed in 2015 and the lowest in 2014 (**Table 4**). The

Table 2. Mean annual rainfall and temperature at NaCRRI, Namulonge from 2014 to 2016.

Year	Rainfall (mm)	Temperature (˚C)	
		Minimum	Maximum
2014	1177.5	16.7	29.1
2015	1353.2	17.2	26.4
2016	1059.3	16.7	29.8

Table 3. Fruit set and fruit drop of 36 mango genotypes at Namulonge for three years of trial.

Varieties	Mean fruit set (%)	Fruit set (%) for three years			Mean fruit drop (%)	Fruit drop (%) for three years		
		2016	2015	2014		2016	2015	2014
Alphonso	33.4	0.0	76.5	23.8	11.0	0.00	23.5	9.52
Apple mango	48.5	16.7	66.1	62.8	18.2	16.7	0.6	37.2
Asante	76.4	62.4	96.7	70.0	23.6	37.6	3.3	30.0
Bire	75.8	52.7	94.9	79.9	24.2	47.3	5.1	20.1
Boribo	58.8	55.6	61.6	59.3	30.1	44.4	5.1	40.7
Dodo red	61.4	33.5	93.9	56.7	38.7	66.5	6.1	43.3
Duncan	71.5	57.0	70.5	87.1	28.5	43.0	29.5	12.9
Early gold	69.4	75.9	92.3	40.1	14.9	24.1	7.7	12.9
Edward	58.8	59.1	61.9	55.4	46.8	57.6	38.2	44.6
Florigon	84.0	83.5	85.3	83.1	16.1	16.5	14.7	16.9
Glenn	78.0	64.4	84.2	85.4	22.0	35.6	15.8	14.6
Haden	56.4	42.4	79.0	47.8	43.6	57.6	20.9	52.2
Heidi	43.8	35.7	65.9	29.7	56.2	64.3	34.1	70.3
Irwin	41.5	55.6	63.5	5.5	25.2	11.1	3.2	61.2
Julie	73.1	92.7	90.9	35.8	15.7	7.3	9.1	30.8
Kagoogwa	89.7	85.2	96.7	87.3	10.3	14.8	3.3	12.7
Kate	84.5	95.8	97.7	59.9	3.53	4.20	2.3	4.1
Kawanda Green	61.2	56.9	91.5	35.1	38.8	43.1	8.5	64.9
Kawanda wide	62.7	74.3	92.3	21.5	37.3	25.7	7.7	78.5
Keitt	52.0	56.0	31.1	68.8	48.0	44.0	68.9	31.2
Kensington pride	54.2	49.2	55.2	58.2	34.7	50.8	11.4	41.8
Kent	77.5	84.5	95.5	52.4	22.5	15.5	4.5	47.6
Koona	93.0	89.0	98.3	91.6	7.1	11.0	1.7	8.4
MP1	28.0	0.0	84.1	0.0	5.3	0.0	15.9	0.0
Ngowe	53.7	78.3	82.9	0.0	13.0	21.7	17.1	0.0
Palmer	42.9	54.3	74.3	0.0	12.7	12.4	25.7	0.0
Parvin	85.8	86.8	87.8	82.8	14.2	13.2	12.2	17.2
Pascal	65.6	82.4	66.9	47.6	34.4	17.6	33.1	52.4
Pinero	27.0	0.0	45.8	35.1	28.6	0.00	54.2	31.6
R2E2	68.9	87.1	94.8	24.7	31.1	13.0	5.2	75.3
Sejjembe	57.2	74.7	96.8	0.0	9.5	25.3	3.2	0.0
Suu	86.3	86.3	87.0	85.6	13.7	13.7	13.1	14.4
Takataka	84.7	86.1	96.3	71.7	15.3	13.9	3.7	28.3
Tommy Atkins	87.4	87.8	98.1	76.2	12.6	12.2	1.8	23.8

Continued

Vandyke	88.7	85.8	98.3	81.9	11.3	14.2	1.7	18.1
Zillate	82.9	86.4	93.2	69.2	17.0	13.6	6.7	30.8
Mean	**64.2**	**61.4**	**79.7**	**50.6**		**24.6**	**14.0**	**30.1**
STDEV		**27.1**	**16.8**	**28.8**		**19.1**	**15.1**	**22.3**
$LSD_{0.05}$		**34.6**	**17.7**	**35.7**		**28.3**	**21.5**	**17.5**
CV (%)		**14.2**	**13.9**	**15.7**		**10.8**	**14.3**	**15.8**

Note: [1]The fruit set with zero values are from alternate bearing mango types whose fruiting did not occur in certain years during the experimentation; [2]In mango types where fruiting did not percent drop was not observed hence the occurring of zero values in the drop % column.

Table 4. Yield of 36 mango genotypes at NaCRRI, Namulonge from 2014 to 2016.

Varieties	**Mean mango yield/tree (Kg)**	**Mango yield/tree (Kg) for three years**		
		2016	**2015**	**2014**
Alphonso	7.2	0.0	21.7	0.0
Apple mango	34.4	0.2	28.9	74.1
Asante	12.4	19.3	15.1	2.9
Bire	44.2	0.0	94.9	37.7
Boribo	9.6	3.8	8.8	16.1
Dodo red	39.5	4.3	109.0	5.1
Duncan	46.5	30.9	81.1	27.5
Early gold	10.7	4.7	25.6	1.8
Edward	14.0	16.5	16.8	8.8
Florigon	34.1	12.5	47.0	43.8
Glenn	49.6	49.6	14.9	84.3
Haden	4.2	6.6	1.8	4.1
Heidi	35.7	13.2	87.1	6.7
Irwin	12.5	2.9	26.6	7.9
Julie	23.9	15.8	54.0	2.0
Kagoogwa	27.7	6.9	21.5	54.7
Kate	59.6	70.5	90.4	17.9
Kawanda Green	32.8	6.5	88.1	3.8
Kawanda wide	36.1	16.7	86.1	5.4
Keitt	11.1	19.7	7.4	6.1
Kensington pride	3.5	3.4	2.5	4.7
Kent	36.5	39.8	67.8	1.9
Koona	31.6	55.1	20.7	19.2
MP1	7.5	0.0	22.4	0.0
Ngowe	4.0	4.2	7.7	0.0

Continued

Palmer	7.4	5.2	17.0	0.0
Parvin	34.9	24.6	23.4	56.9
Pascal	11.9	16.6	8.4	10.8
Pinero	5.5	0.0	16.6	0.0
R2E2	31.0	20.6	35.0	37.3
Sejjembe	18.3	27.1	27.9	0.0
Suu	51.2	64.7	84.0	4.8
Takataka	35.0	59.2	25.6	20.2
Tommy Atkins	48.7	32.4	80.0	33.6
Vandyke	48.5	54.5	74.3	16.6
Zillate	32.4	44.0	21.7	31.5
Mean	**25.8**	**29.3**	**59.5**	**18.9**
STDEV		**20.79**	**32.52**	**21.96**
LSD0.05		**28.46**	**4.69**	**53.99**
CV		**19.6**	**10.3**	**15.7**

Note: [1]The years with zero yield value means that particular mango types did not fruit during those years.

mango yield obtained in 2015 was significantly higher than that obtained either in 2016 or 2014. In terms of genotypes a significant($P < 0.05$) variation in yield was recorded with highest yield to a tune of 59.6 Kg/tree/year recorded in Kate genotype while the least yield was observed in Kensington pride genotype (Table 3). On the other hand, mango genotypes such as Palmer, Ngowe, Alphoso, Peach and Pinero which experienced alternate bearing had low average yield (Table 4).

4. Discussion

In this study mango fruit set varied among years possibly due to variation in the amount of rainfall received in the different years. Although little rainfall (mild drought) received at the initiation of reproductive stage is known to trigger flowering in mango due to changes in total phenolic content in terminal buds and alteration in phloem to xylem ratio of the stem [11]. Such changes restrict vegetative growth and enhance flowering through channeling nutrient supplies meant for the new growth to floral parts eventually leading to flowering and then fruit set. However, conditions of little rain can also limit the process of fruit setting if condition of water stress continues from flowering up to fruit set stage [12]. This was evidenced in this study by the positive correlation ($R^2 = 0.984$) between rainfall received and the percent fruit set. Percent fruit set was higher in 2015 when high rainfall was received compared to low fruit set in 2014 when low rainfall was received. Furthermore, the high rainfall received in 2015 could have availed soil moisture, a resource which is essential for fruit setting in mango

[13]. This was earlier reported by wolfram [12] who found out that high fruit set is positively influenced by soil moisture availability and high fruit set contributes to increased mango yield. Hence, farmers in the Lake Victoria Crescent are bound to experience more mango fruit set for years when high amount of rainfall is received.

Besides, the variation in fruit set by years, the difference in fruit set among mango genotypes was possibly due to varietal differences. Fruit set is a varietal character which depends on several factors such as time of flowering and fruiting, sex ratio, efficient cross pollination and alternate bearing [14] [15]. This was exemplified by, Koona genotype with the highest percent fruit set. This is a local genotype which overtime has been acclimatized to the local conditions by flowering at the end of the dry spell in February and July and sets fruits at the beginning of the rain season in March and August this flowering and fruiting synchrony ensures that fruit set in Koona genotype occurs when soil moisture which is a key resource in fruit set is sufficient.

Furthermore, the non-existence of alternate bearing trait in Koona genotype possibly also explained its high percent fruit set compared to other genotypes such Pinero genotype which is an alternate bearer and had the lowest percent of fruit set. Although there were other alternate bearer like Alphoso, MP1, Ngowe, Palmer and Sejjembe, their fruit set during the bearing years were high which compensated for non-bearing years. This also clearly indicated that within the alternating bearing mango genotypes variation in fruit set also existed. Such variations need to be selected for by breeders aiming at improving alternate bearing mango genotypes. Generally, the results indicated that mango genotypes differed from each other in traits that influence fruit set, which led to variation in percent fruit set observed.

Fruit set and retention are often influenced by weather conditions (rainfall and temperature). The high rainfall and low temperature experienced in 2015 favored fruit retention while, the low rainfall and high temperature in 2013 favored fruit drop. This was due to direct correlations that are known to exist between drought and fruit set [16]. Drought is known to increase abscisic acid (ABA) which causes fruit abscission leading to fruit drop in fruit trees like mango [17]. In mango, there is often a heavy drop of young fruits. In this study it was not an exception because a considerable variation in percent mango fruit drop was observed among mango genotypes tested. Heidi genotype recorded the maximum fruit drop followed by Keitt genotype, and MP1 had the lowest percent fruit drop among the genotypes studied (**Table 3**). These findings emphasized the existence of fruit drop in mango genotypes that were evaluated. The fruit drop was mostly observed during the first three weeks after fruit set and steadily dropped towards maturity period. Although fruit drop in mango can be caused by a number of factors which may be varietal [15], moisture stress and fungal infection [18], in this study, the probable cause of fruit drop was varietal as some genotypes were more prone to fruit drop than others. Although earlier work by [15] reported the highest fruit drop of 88.4% in variety Rajiv in India but the highest fruit drop of 56.2% in Uganda was recorded in Heidi variety which was much lower. This indicated that mango genotypes under Ugandan conditions experience less fruit drop than those in India.

Yield per tree is indirectly contributed by fruit set and retention, in 2015 more average fruit set and less average fruit drop was observed as compared to 2013 due to variation in rainfall received as earlier explained in fruit set and drop section. It is the variation in fruit set and drop which explained the high yield obtained in 2015 when compared to 2014. These findings were supported by [18] who reported a direct relationship between fruit set and yield/tree which contribute to increase in mango yield under ideal environmental conditions. Furthermore, the variation in yield per tree may be attributed to fruit size and weight of different genotypes studied. Although Kate genotype produces small sized fruits but it is a heavy bearer with high number of fruits per tree. This is attributed to its high fruit set (84%), low fruit drop (4%) and yet it is not an alternate bearer. Presumably it is these three factors which were responsible for the high yield obtained from Kate genotype compared to other mango genotypes that were studied.

On the other hand, the low yield in certain genotypes like Kensington pride was attributed to alternate bearing which made fruit trees to bear fruits once or twice within a period of three years of study. For instance, in relation to alternate bearing mango genotypes such as Palmer, Ngowe, Alphoso, Peach and Pinero experienced alternate bearing period of two years which affected their mean yield performance during the experimentation period On the other hand, local genotypes; Kagogwa, Bire, Sejjembe, Kawanda wide, Boribo as well as new introductions such as; apple mango, Zillate, Kensington pride, RE2E2 were observed to have alternate bearing period of one year which also slightly affected their mean yield performance, though not as much as genotypes which experienced alternate bearing for two years. In this study, alternate bearing was observed to affect mean yield performance of certain mango genotypes; this can be alleviated through artificial flower induction. According to [18] alternate bearing can be alleviated through conservation of nitrogen reserves provided through spraying potassium nitrate. Therefore to reduce the effects of alternate bearing among mango genotypes grown in Uganda, use of potassium nitrate sprays to induce flowering needs to be validated.

5. Conclusion

Out of the 36 mango genotypes evaluated, differences in mango fruit set, drop and yield where exhibited due to varietal difference and variation in amount of rainfall received in the different years. Kate genotype exhibited the highest yield with highest yield, fruit set and minimum fruit drop. Based on attributes, Kate genotype was identified to have the potential of enhancing mango yield within the Lake Victoria Crescent agro-ecological zone in Uganda. Nonetheless, genotypes such Suu, Tommy Atkins, Glenn, Vandyke, Duncan and Bire were also identified to be suitable for this agro-ecological zone because they equally yielded high.

Acknowledgements

The research was supported by a grant from World Bank and Government of Uganda through the Agricultural Technology, Agribusiness services (ATAAS Project. The authors are grateful to National Crops Resources Research Institute under National Agricultural Research Organisation for hosting this research

Conflicts of Interest

We the authors of this paper hereby declare that there are no competing interests in this publication.

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