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Phenological events and their interactions with climatic factors on *Vitellaria paradoxa* Gaertn

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ABSTRACT

Phenological studies provide information on functional rhythms of plants and plants communities. Timing of various phenological events may reflect biotic and/or abiotic environmental conditions. They are also useful for conservation and management of tree genetic resources because they determine reproductive success of species. This research aimed at studying phenological events in *V. paradoxa* and their interactions with some environmental factors. Thirty (30) *V. paradoxa* trees were randomly selected from two distinct locations (densely populated and sparsely populated sites and used in this research. From each selected trees, 8 branches were chosen and from each branch, reproductive phenological events and leaf phenological events were observed and recorded. The data collected were analyzed using Microsoft Excel® and their relationship with climatic conditions was determining using PAST software. Results revealed that *V. paradoxa* flower from October to March and fruits form March to August. The result also showed variation between the two locations with respect to flowering start dates in which trees in the sparse areas flowered earlier than those in the dense areas; and the flowering synchrony was estimated to 69.2%. Observations showed that *V. paradoxa* trees shed their leaves from November to March. Furthermore, leaf fall have a positive linear relationship with temperature and wind speed and a negative relationship with relative humidity. The information from this studies will be useful in breeding programmes and management of this important species.

INTRODUCTION

Vitellaria paradoxa Gaertn, commonly known as the shea butter tree, is indigenous to, and part of the major component of woody flora of the Sudan and Guinea Savannah vegetation zones (IPGRI;, 2006; Lovett & Haq, 2000; Nasare et al., 2019). It spreads from Senegal to Western Ethiopia and Uganda, in a belt that is 500-700 km wide, and separated from the Gulf of Guinea by forest. In Nigeria and Ghana, it occurs within 50km from the coast (Nikiema & Umali, 2007).

In Nigeria, shea trees grow naturally in the wild, mostly in the northern parts from guinea to Sudano-sahelian savannah. It normally starts fruiting at about 10-25 years of age and reach full maturity around 20-45 years (Nikiema & Umali, 2007; Seghieri, 2019).

Shea tree is one of the most important economic crop valued by the people of its indigenous location (Seghieri, 2019; Tom-Dery et al., 2018) as well as the world over. In addition to its local uses (Seghieri, 2019), it is highly demanded in the international market for its butter which is used in the production of chocolate as a substitute for cocoa butter (Chidiogo et al., 2013). The seed oil is widely utilized, locally for cooking purposes and as illuminant and industrially as skin moisturizer in lotions and lipsticks (Lovett & Haq, 2000; Tom-Dery et al., 2018) due to its excellent quality (Okullo et al., 2010). *V. paradoxa* is also used in various traditional medicine preparations for various ailments which include jaundice, stomachache, diarrhea and headache (Popoola & Tee, 2001; Tom-Dery et al., 2018). Humans consume its sweet pulp (Bvenura & Sivakumar, 2017; Maranz et al., 2004; Ugese et al., 2008) and the fallen ripe fruits can be fed to livestock (Orwa et al., 2009). Because of its high vitamin C content, daily consumption of up to 50g can provide the needed vitamin C supplement for both children and pregnant women (Honfo et al., 2014). Looking at its numerous uses, *V. paradoxa* is regarded as a unique resource for economic development especially in rural areas (Chidiogo et al., 2013).

V. paradoxa flowers develop in the axils of scale leaves, at the apices of dormant twigs (Sale et al., 2018). Inflorescences are borne at the end of a flowering twig, normally dense fascicle, 5-7.5 cm in diameter. The flowers are hermaphrodite, usually cross-pollinated, but can be self-pollinated. Insects, especially bees, are important for pollination. Flowering lasts 30-75 days and the fruits take 4-6 months to maturity which takes place during rainy season (Orwa et al., 2009).

Oni et al. (2014) reported that flowering in *V. paradoxa* took about 45.68 ±3.77 days while fruiting took about 145.87 ±7.86 days in Nigeria. Another research in Mali reported that *V. paradoxa* flowers for about 68 days in northern guinea and Sudan zones and 76 days in southern zone starting from November to May, whereas fruiting commences from January to August and usually takes about 86 days and 110 days in northern and southern zones respectively (Kelly et al., 2018).

In Cameroon, Nguemo et al. (2014) reported that *V. paradoxa* flowers from November to February in guinea savanna zone; while in Sudan savanna, the flowering is delayed till February, and it lasts till June. The leaves, however, fall between November and January.

The nature of phenological events such as flowering start date and flowering synchrony (Augspurger, 1983), and the relationship between these and other phenological events such as leaf shed may determine the reproductive success of *V. paradoxa* plant population (de Assis Pires et al., 2014; Hall et al., 2018; Rawal et al., 2015; Sale et al., 2018). Flowering synchrony directly determines the effective number of pollen donors through the density of flowering individuals and indirectly determine the patterns of pollen flow between trees (Delnevo et al., 2019; Murawski & Hamrick, 1992; Stephenson, 1983), encouraging either out-crossing or selfing, which ultimately influence the reproductive success of the plants (de Assis Pires et al., 2014; Hall et al., 2018; Ollerton & Lack, 1992; Poole & Rathcke, 1979; Rawal et al., 2015; Rodríguez-Pérez & Traveset, 2016). Synchronous trees are likely to receive pollen from more pollen donors than trees with asynchronous flowering which may experience a reduction in reproductive output, with the number of pollen donors and the selfing rate being similar to those of trees found in isolated fragments (Fuchs et al., 2003).

Phenological studies provide information on functional rhythms of plants and plants communities, where the timing of various phenological events may reflect biotic and/or abiotic environmental conditions. They are also important from the point of view of the conservation of tree genetic resource and forestry management as they determine reproductive success of species (Sale et al., 2018) and for better understanding of plants species and community level interactions. The aim of this research is therefore to study the phenology in *V*. *paradoxa* and determine the effects of some climatic conditions on some phenological events.

MATERIALS AND METHODS

Study Area

The study was conducted at the University of Ilorin, Nigeria, which lies between latitude 8°30´N and longitude 4° 33´E/ latitude 8.500°N and 4.550°E covering an approximate land mass of 5000 hectares. Ilorin is situated in a transition zone between the rainforest of the South and the Guinea savannah of the North, and it is characterized by both wet and dry seasons. Rainy season begins from April and last till October with annual rainfall of 990.3mm to 1318mm, while dry season begins in November and ends in April (Olabode et al., 2014). The relative humidity of the metropolis ranged between 28 and 57%, while daily temperature ranges between 15 to 36 °C (Adeniran et al., 2018).

Methods

To study the phenology of *V. paradoxa* population, thirty (30) shea butter trees were randomly selected from two distinct locations tagged and followed for their phenological events. The locations include a dense area, in which the tree stands are found in close and continuous canopy formation with their conspecifics and other tree species; and sparse area, in which trees occur far apart from one another. From each selected tree, eight (8) branches, two from each of the cardinal directions were selected, tagged and used in the research. From each selected branch, reproductive phenological events (flower buds sprout, blooming, and development of immature and mature fruits) and leaf phenological events (emergence of new leaves, leaf maturation and leaf shade) were observed and recorded from October 2014 to July 2015. Because reproductive phenological events take places at the apices of shoots in *V. paradoxa*, each event was estimated, at any given time, as the percentage of the total number of the apical shoots on the tagged branches (Denny et al., 2014), i.e.,

$$Q = \frac{n}{N} X\ 100 \qquad (1)$$

Here, Q= quantity (in percentage) of the occurrence of any event, n= number of apical shoots with flower-buds/flower or immature/mature fruits and N= total number of apical shoots.
Leaves phenological events, on the other hand, were estimated as the proportion of the total canopy cover at the time of data collection (Piepenbring et al., 2015), i.e.,

$$P = \frac{n}{N} X\ 100 \qquad (2)$$

Here, P = proportion (in percentage) of any event, n= number of young/mature leaves and N=total number of leaves. Phenological parameters estimated include: flowering start date, flowering finish date, flowering duration, peak flowering date, flowering synchrony, date of appearance of immature fruits, leaf fall start date and date of disappearance of 50% canopy cover. Flowering synchrony index was estimated as a percentage of the period when all the trees flower synchronously over the entire flowering period of the population (Omondi et al., 2016).

Data on climatic conditions were obtained from Baseline Surface Radiation Network (BSRN) Observatory, Department of Physics, University of Ilorin, Nigeria.

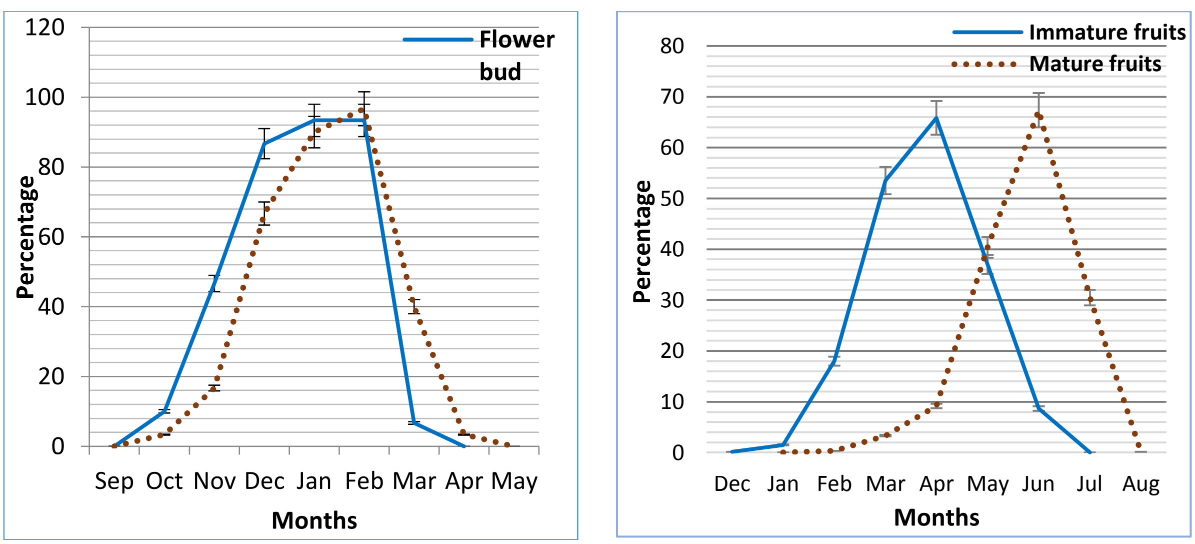
Date analysis

The data on phenological events were analyzed using Microsoft Excel® 2013 and the relationship between phenological events and climatic conditions was determined using PAST software. The results were presented in forms of charts using means and percentages.

RESULTS

Flowering and fruiting timing

The results of this research have revealed that the first flower buds in the population appeared on 28 October, and continuous till mid of March. Flower anthesis started from October also but persisted till April (Fig. 1a). Development of immature fruits commenced from December ending to June, while fruits maturity started from March ending to August (Fig. 1b).



A B

Figure 1. Monthly reproductive phenological events of *V. paradoxa* in the study area

Flowering synchrony

The results further revealed that some trees started flowering early, some started late, but most of them started halfway between the two times. The highest percentage of the trees (53.3%) started flowering half way between early and late flowering trees, while 23.3% trees each flowered at the two extremes (Fig. 2). The result also showed that there is variation between the two locations with respect to flowering start dates. Trees in the sparse area started flowering earlier and finished sometime in the mid flowering period, while very few started flowering earlier in the dense areas and the flower persisted till the end of the flowering season.

Furthermore, the results indicated that there is high level of flowering synchrony in *V. paradoxa* in the study area. From November to March, all the trees are flowering, although some started before November and some continued flowering beyond March (Fig. 3). Therefore, of the 6 to 7 months flowering period in the population, all the trees flower synchronously for 4 to 5 months. Adding these two extremities and taking percentage gives 69.2% flowering overlap.

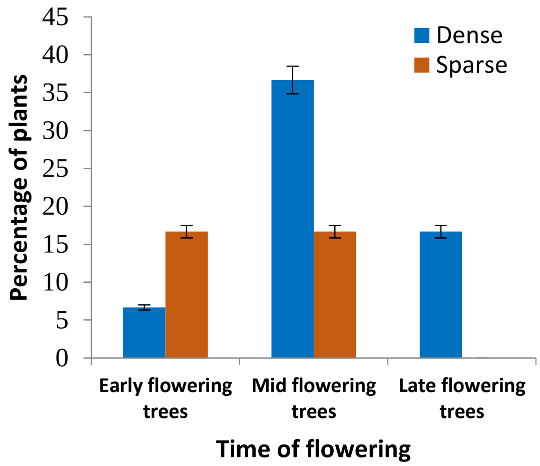


Figure 2. Floweing timing of *V. paradoxa*

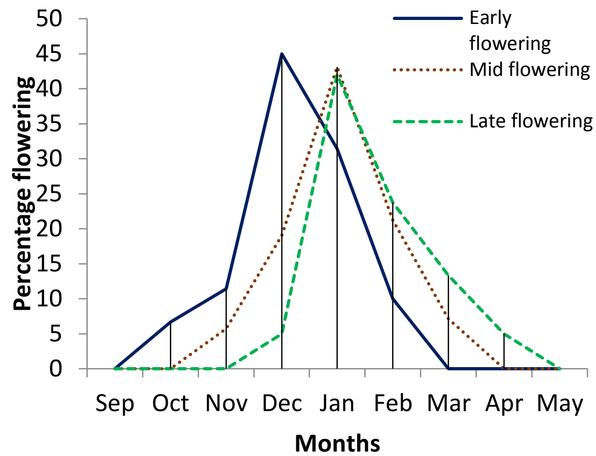


Figure 3. Level of flowering synchrony

Leaf phenology

Observations showed that *V. paradoxa* trees shed their leaves from November to March, and new leaves reemerged in April. Timing of leaf drop and the degree to which trees shed their leaves differed across trees and locations. Some trees shed their leaves completely while some retained reasonable amount of leaves throughout the season. Fig. 4 shows the monthly percentage of litter fall. In both the locations, the peak leaf shed occurred in February with 59% and 38% in sparse and dense areas respectively. Similarly, Fig 5 shows cumulative monthly disappearance of leaves. The overall seasonal leaf shed is higher in sparse areas (94.8%) than in dense area (53%).

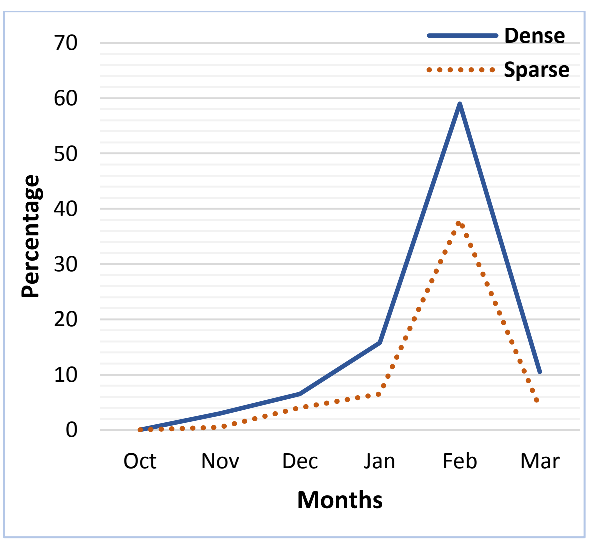


Figure 4. Monthly percentage leaf fall

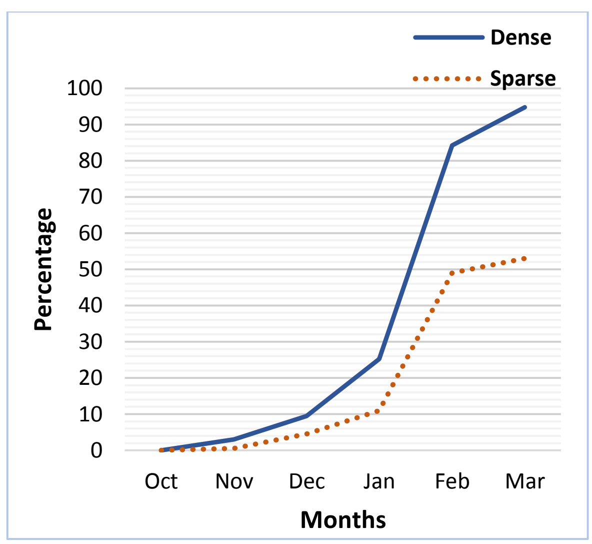


Figure 5. Leaves disappearance

Relationship between leaf drop and climatic conditions

Results showed relationship between leaf fall and climatic conditions. General linear model generated indicate positive relationship between leaf fall and temperature (fig 6A) and wind speed (fig 6B); whereas there was negative relationship between leaf fall and relative humidity (fig. 6C).

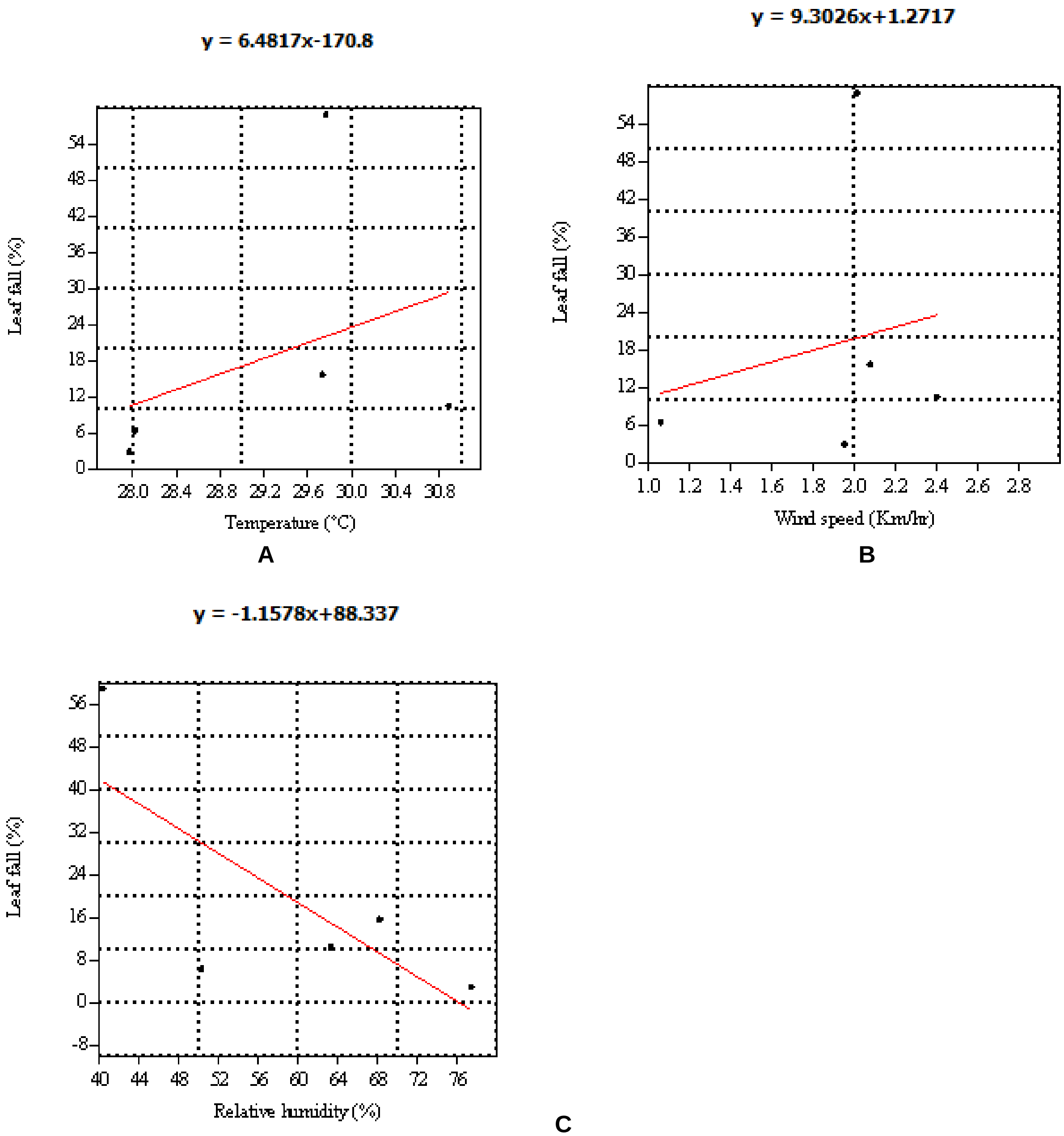


Figure 6. Relationship leaf fall and (A) temperature, (B) wind speed and (C) relative humidity

DISCUSSION

This study has revealed that some trees started flowering before others. However the entire *V. paradoxa* population in the study area produce flower from October ending to the middle of March. A similar research in Mali shows that *V. paradoxa* flower from November to May (Kelly et al., 2018). Similarly, Nguemo et al. (2014) reported that *V. paradoxa* flowers from November to February in guinea savanna zone; while in Sudan savanna, the flowering is delayed till February, and it lasts till June. The little variations in flowering start and finish dates may be attributed to genetic variation in the population as reported by Sale & Morakinyo, (2017) or the age of the trees themselves. However, regardless of when a tree starts flowering, most trees take about two and a half months to complete flowering. This is in line with the work of Kelly et al. (2018) who reported that *V. paradoxa* trees take about 68 days to complete flowering in northern guinea and Sudan zones of Mali.

The research reported that fruiting in *V. paradoxa* in the study area commenced from December ending all through to August. This agrees with the work of Kelly et al. (2018) and Nguemo et al. (2014) who reported that the fruiting period in *V. paradoxa* is from January to August in Mali.

The result has revealed that trees in the sparse areas started flowering earlier than those in the dense area. This could be attributed to the fact that those in the sparse areas have more access to solar radiation, wind and even insects pollinators as there may be no competition. This indicated that space is required for early flowering in *V. paradoxa* plant since trees in the disturbed area are found solitary with zero completion for light and space (Sale et al., 2018).

Furthermore, some trees started flowering early, some started late, but majority of the trees started sometimes halfway between the two extremities. This is what bring about the high level of synchrony and it can enhance and encourage outcrossing (Ollerton & Lack, 1992; Poole & Rathcke, 1979) which in turn could bring about improved fruitfulness as observed by Sale et al. (2018).

The results reported that *V. paradoxa* shed their leaves from November to March. This is perhaps due to the fact that those months form the core of dry season in the study area, and by April, all the trees produced new leaves. This means there was no enough water for the trees to sustain their leaves from November to March and therefore the leaves are shed for the trees to survive the stress. This does not agree with the work of Nguemo et al. (2014) who reported that leaves shed between November and January. The leaves sprout in April due to commencement of rain. Similar findings was also reported by Okullo et al. (2010).

The variation in the timing and degree of leaf shed across different trees could be attributed to genetic variation within the population or even age as older trees may have longer root to reach more water than younger ones, and therefore the old ones may tend to sustain more leaves or delay shedding.

Trees also differed in the degree to which leaves are shed in different locations. Trees in dense area seemed to shed larger percentage of leaves than those in the sparse area, with some of the trees in the sparse area not shading their leaves completely. This is perhaps due to the facts that in the sparse areas there is little competition for water around the rhizosphere, therefore the trees have access to enough water to retain certain percentage of their leaves.

The results of the relationship between leaf fall and climatic conditions revealed positive linear relationship with temperature, wind speed and rainfall; and negative relationship with relative humidity. This is because temperature and wind speed increase dehydration in both the soil and plants which in turn cause more leaf shed. Wind speed also increase the mechanical leaf shedding. Relative humidity, on the other hand, does exactly the opposite of wind speed and temperature.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article

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