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RESEARCH ARTICLE

Tropical Phenology: Individual-Level Phenological Study of Neem (Azadirachta indica A. Joss.) Occuring in Onitsha, Nigeria

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Abstract

An annual cycle phenological study of *Azadirachta indica* growing in Onitsha with tropical deciduous vegetation has been carried out to record and document the phenological activities of the species. The following phenological activities were observed: bud break (BB) (both vegetative and reproductive), leaf flushing (LF), inflorescence emergence (IE), fruit development (FD), and fruit ripening (FR). The initiation stages and the peaks in phenophases were recorded. A 2-digit scale was used to include the principal and secondary growth stages and this provided the basis for data collection. From the result of the study, the tree revealed two sub-annual cycles in both vegetative and reproductive activities, and both took place in the wet and dry season. There was no time lag between the onset of leaf-flushing and inflorescence emergence in *A. indica,* in the sub-annual cycles. The initiation of leafing and flowering in the species in the drought-laden dry season increased the rate of leaf fall and extended the duration of deciduousness more than in the wet season. Also Advance in fruit ripening was observed, and this took place in the drought-laden dry season. Thus, it was recommended that long-term phenological observation and documentation be carried out on the species for future references, especially in tracing the impact of climate change on the plant.

INTRODUCTION

Plants tend to exhibit rhythmic appearance of their vegetative and reproductive events over time. This phenomenon is termed phenology. The study of plant phenology provides knowledge about the pattern of plant growth and development as well as the effects of environment and selective pressures on flowering and fruiting behaviour (Zhang *et al*., 2006). The phenological activity of tropical trees is mostly influenced by seasonality in rainfall and drought, and this is evident on the seasonal duration of bud break (both vegetative and reproductive), leaf flushing, flowering, fruiting and leaf fall periodically observed in the tropics. Dry seasons within an annual cycle occur in most tropical regions, and many studies have shown correlation between tropical phenology and rainfall (Augspurger, 1981; Borchert, 1983; Reich and Borchert, 1984; Echereme *et al*., 2015; Echereme and Mbaekwe, 2015) demonstrating existence of annual patterns of plant vegetative and reproductive growth and development. The great majority of tropical plant species show some degree of periodicity in growth and reproduction whether or not the periodicity is annual (Longman and Jenik, 1987; van Schaik *et al*. (1993).

Phenological observations are some of the most sensitive data in identifying how plant species respond to regional climate conditions and to climate changes. Therefore, phenology has emerged recently as an important focus for ecological research (Schwartz, 1999). An understanding of the phenological patterns in different geographical regions and of factors underlying these patterns is important and assist conservation scientists in predicting consequences of perturbations such as typical climate events or global warming (Tutin and Fernandez, 1993).

Little is known about long-term phenological changes in plant behaviour in tropical forest trees. This is because most studies on plant phenology in tropical forests have been conducted to describe community-level patterns of phenological activities (Shoko, 2011; Anderson *et al*., 2005; Singh and Kushwaha, 2005; Singh and Kushwaha, 2006; Gurveen *et al*., 2013; Ebeid and Ali, 2013) with respect to diversity of the events under varying environmental factors. Leafing and flowering in some areas show irregular sub-annual or annual flowering patterns at the individual level, but continuous flowering at the population level is mostly seen. Therefore, for studies on selective forces for phenology, analyses at the individual level are essential (Janzen, 1978; Herrera, 1998). With the prospective importance of plant phenology in providing reference records to issues related to climate changes in the future, few studies, however, have focused on phenological observation of woody trees at individual levels in regard to this. This research was intended to determining the phenological calendar and providing baseline information on the individual-level phenology in *A. indica* growing in Onitsha.

Materials and Methods

Study Area

Onitsha district is located in southeastern part of Nigeria and lies between 6^0 10^I 0^{II} north latitude and 6^0 47^I 0^{II} east longitude. Total area of the district is 36.19 km with tropical deciduous rainforest vegetation. Natural vegetation occurs in narrow strips and patterns. Onitsha is in a tropical climate and experiences two seasons namely 1. Rainy season (March-October) with temperature ranges from 23.9^0 C to about 31.2^0 C and 2. Dry season (November-February), where temperature can reach 33.9^0 C (Echereme *et al*., 2015). During dry season, there is occurrence of cold-dry and dusty wind traditionally known as Hamattan, which blows from the Sahara Desert via Northern Nigeria to the study area from November to the mid February.

To document the records of phenological activity of *Azadirachta indica* growing in Onitsha, branches of the tree at all orders of arrangement including their lateral braches were marked for observation.

Criteria for Optimum Conditions

We ensured uniform conditions during the observations. The greenish-brown colour of the new leaves was a criterion for leaf flushing, and this clearly distinguished old leaves from the young developing ones. Flowering was marked with inflorescence emergence and development. Fruit ripening was marked with colour change from green to yellow fruits. We also achieved uniform conditions by observing the species at 1: 00 pm when the sun was high and behind the observers. This was to allow for optimum light conditions for colour vision. We also determined the peak monthly leafing, flowering, and fruiting. This was defined as the months with the highest manifestation of a particular phenophase.

Scale: Extended BBCH (*Biologische Budesantalt, Bundessortenamt and Chemsche Industrie*) scale of Meier (1999) based on Zadoks *et al*. (1974), by selecting 5 principal growth stages out of the 10 principal growth stages chronologically arranged according to their course of natural development, was used for data collection. The 5 principal growth stages used in the present study include: bud development (BD), leaf flushing (LF), inflorescence emergence (IE), fruit development (FD), and fruit ripening (FR) coded with ordinal numbers 0, 1, 6, 7 and 8 respectively, following their placements according to Zadoks *et al*. (1974). Since the principal growth stages were insufficient to reveal the short developmental changes in the course of time in the principal growth stages, secondary growth stages were introduced to fill these gaps. They were coded 0 to 9 where 0 denoted the start whereas 9 denoted the end in the primary growth stage. The mesostages between 0 and 9 (i.e., 1, 2, 3, 4, 5, 6, 7, and 8) were taken as percentage values of activity, thus 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% in the secondary growth stages. On the whole, the principal and secondary growth stages gave rise to 2-digit scale BBCHxy used in the phenological records. The letter ‘x’ denoted the principal growth stage while ‘y’ denoted the secondary growth stage, thus BBCH13 for example, represents 30% of the leaves developed, and BBCH69 represents end of flowering.

Results

The data below reveal the phenological activity of *Azadirachta indica* A. Joss.

Table I: Time-Dependent Phenophases of *Azadirachta indica* A. Joss.

DURATION	MONTH	MAR.		APRI.		MAY		JUN.		JUL.		AUG.		SEP.		OCT.		NOV.		DEC.		JAN.		FEB.	
	WEEK	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4	1-2	3-4
PRINICIPAL GROWTH STAGE																									
BUD BREAK (BB)	BBCH SCALE					01													10						
LEAF FLUSHING (LF)		96	97	*	*	*	13	*	18	*	*	*	*	90	92	*	93	96	*	13	19	*	91	*	95
INFL. EMERGENCE (EE)		*	*	*	*	09	*	69	*	*	*	*	*	*	*	*	*	*	09	69	*	*	*	*	*
FRUIT DEV. (FD)		*	*	*	*	71	79	*	*	*	*	*	*	*	*	*	*	*	*	71	79	*	*	*	*
FRUIT RIP. (FR)		*	*	*	*	*	*	81	85	89	*	*	*	*	*	*	*	*	*	*	81	89	*	*	*

Note: The asterisks (*) in the above Table denote absence of noticeable changes in the phenophases

The phenological activities of *A. indica* for the period of one annual cycle (March, 2013 to February, 2014) are shown in Table I. From the outset of the observation in March, 2013 the tree was met at deciduous state, having dropped 70% (BBCH97) of its leaves by this time (Table I). Leaf flushing started with bud break in May (BBCH01). Leaf flushing peaked 80% (BBCH18) by the end of June. Deciduousness was observed in September and peaked in November when approximately 60% (BBCH96) of the leaves dropped. Leafing activity resumed in the 3rd to 4th week of November (BBCH01) and peaked 80% (BBCH18) in December. Deciduousness was again observed in January to February when approximately 50% (BBCH95) of the leaves dropped. This shows that the time frame for leafing in each sub-annual cycle is approximately 2 months.

Flowering activity occurred twice in the yearly cycle of development. Inflorescence emergence began in May, 2013 (BBCH60) marked with initiation of bud elongation and flowering peaked in the 2nd week of June (BBCH69) (Table I). Second flowering started in November and peaked in the 1st week of December.

Fruiting phenology followed flowering phenology immediately. Ten per cent (10%) (BBCH71) fruit development was observed at the end of flowering in the 1st week of June and stopped in the last week of June. Fruiting resumed in the 1st week of December with 10% (BBCH71) occurrence observed and ended in the 2nd week of December (Table I).

Fruit ripening occurred twice as well, but with a slight deviation in the time frame in the 2nd sub-annual cycle to the 1st sub-annual cycle. The first ripening started in the 1st week of July when approximately 10% of the fruits ripened (BBCH81) and ended in the 2nd week of August (BBCH89) covering a time frame of 1 month and 2 weeks, whereas the second sub-annual ripening advanced by 2 weeks as ripening here started by the end of December, 2013 to the 1st week of January, 2014 covering a period of 1 month (Table I).

Discussion

From the one year phenological observation of the species under study, it was observed that all the phenophases repeated their appearances in the course of time (i.e. an annual cycle), thus corroborating Menzel (2002) that plants show recurring biological events over time. The phenophases showed periods of early development to late/final development in the principal growth stages of the studied species. Following the observed trend in the phenological activity in *A. indica*, it can be inferred that vegetative and reproductive phenology in *A. indica* occurred twice in a yearly cycle. This is in concord with Barwick (2004) as he observed that *A. indica* has the tendency to shed its leaves twice a year followed by flowering and fruiting. A number of studies on phenology of different tropical ornamental trees from different parts of India have been undertaken which include *A. indica*. Bhat and Murali (2001) observed that blooming period in *A. indica* is characterized by scattered inflorescence followed by fruiting for approximately 2 months. This completely rhymes with the present study as flowering and fruiting in *A. indica* lasted for approximately 2 months in both sub-annual cycles of development. The leafless period observed during the drought-laden dry season (January to February, 2014) is an indicative that the tree has re-adjusted its physiological functions to conserve water by the process of deciduousness. This is in line with Bullock (1995) who concluded that the leafless period is an adaptation to avoid water stress, and water stress affects flowering time in tropical forest trees. Also, the flushing of leaves in *A. indica* was observed occurring almost simultaneously with inflorescence emergence. This is in line with Singh and Kushwaha (2006) as they observed that in <2-months-deciduous and 2-4months-deciduous species, both leafing and flowering activities begin relatively close in time, and this could possibly be due to slower resource-use rate (reflected by longer leaf flush period) and greater tolerance to water stress (suggested by short leafless period) than the >4-months-deciduous tree species (having a short leafless period and longer leaflessless period). This is in line with the present study as the area of study falls within this category, having 4 months of dry season and longer wet season duration, and this justifies the short time lag between leafing and flowering in *A. indica*.

In the case of the advance in ripening in the 2nd sub-annual cycle, it can be speculated that the harmattan with its characteristic dry and dusty wind hastened the ripening process reducing the time by approximately 2 weeks from the 1st sub-annual ripening duration.

Conclusion

From the annual cycle observation and documentation of phenological activities in *Azadirachta indica* growing in Onitsha, the tree reveals two sub-annual cycles in both vegetative and reproductive activities, and both take place in the wet and dry season, thus leaf flushing and flowering in *A. indica* are independent of soil's seasonal moisture content. There is no time lag between the onset of leaf-flushing and inflorescence emergence in *A. indica* in the sub-annual cycles. However, the initiation of leafing and flowering in the species in the drought-laden dry season increases the rate of leaf fall and extends the duration of deciduousness more than in the wet season. Advance in fruit ripening observed in *A. indica* can be attributed to increase in drought in the dry season. Since climatic factors can influence the phenology in *A. indica*, it is imperative that long-time phenological observation and documentation be carried out on the species for future references. This necessitates establishment of meteorological station close to the study area for integration of climatic data, especially for tracing the impacts of climate change on plants in the area.

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