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ОРИГИНАЛЬНЫЕ СТАТЬИ

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REPRODUCTIVE PHENOLOGY OF *MILICIA EXCELSA*, *ANTIARIS TOXICARIA*, AND *POUTERIA ADOLFI-FRIEDERICII* IN SOUTH WEST ETHIOPIA

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Deforestation and degradation of natural forests pose a challenge for the forest sector in Ethiopia. Gathering scientific data on the reproductive biology of selected timber species has now become important to develop seed production areas and establish forest management regimes. In this regard, this study is aimed at determining the reproductive phenology of three indigenous tree species. The time of leafing, flowering, and fruiting in the three indigenous timber tree species has been recorded for three years in South West Ethiopia. This study was conducted in natural forests of the Benchi-Maji zone (Debub Bench district). We selected three prioritized species, *Milicia excelsa*, *Antiaris toxicaria*, and *Pouteria adolfi-friedericii*, based on the severity of their depletion and relative timber values in the area and in the country at large. Over 20 reproductively healthy, mature, and average mother trees >10 cm wide in diameter at breast height and with easily visible crowns, located at a distance of 100 m from one another, were selected out of each species and marked with marking ink. We conducted continuous observations and recorded data on leafing, flowering, and fruiting every 15 days (twice every month). The data was then analyzed using descriptive statistics. The result of this study indicates that the actual season when the seeds of *Milicia excelsa* are available for collection is once a year, from January to February. The results also showed that, for Antiaris toxicaria, the fruiting time is seasonal, and seeds become available for collection from early January up to the end of February. The fruiting time or the actual season when seeds of *Pouteria adolfi-friedericii* become available for collection is from May to June. Low-cost technologies (to establish seed production areas and domesticate the species) are recommended to be used for seed/seedling acquisition and distribution and preferable to reduce the destruction of the selected indigenous tree species.

Keywords: flowering, fruiting, phenology, seed production area, domestication.

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Ethiopia is becoming dependent on imported wood products, as the demand for timber, paper wood, and plywood keeps increasing every year (CSA, 2012). Even though there are many indigenous timber species, tree species used to cover the domestic demand are limited to exotic plants. However, economically important timber species like *Milicia excelsa, Antiaris toxicaria,* and *Pouteria adolfi-friedericii,* grow in natural forests or the gene pool, mainly in the southwestern parts of the country (Getachew Desalegn et al., 2011). *Pouteria adolfi-friedericii* is a plant species of the family Spotaceae. Locally in Ethiopia, it is known as *Guduba* or *Suduba* (Oromic), *Keraro* (Amharic). *Milicia excelsa* is commonly known as the African teak, or *Iroko*. It belongs to the family Moraceae and is locally known as *Gonji* (Benchgna), *sachu* (Oromic) in Ethiopia. *Antiaris toxicaria* is commonly known as the Sacking tree. It belongs to the family Moraceae and is locally known as *Tenji* or *Muka late* in Ethiopia. Natural forests in South West Ethiopia are the major source of making a living for people in the area who provide timber and non-timber forest products (honey, wild coffee, spices, and medicines).

However, in recent years associated with increased land use conversion to agriculture and monoculture plantations of coffee and tea, the deforestation rate has become aggravating (Tadesse Woldemariam and Masresha Fetene, 2007; Zelalem Amdie, 2007; Teshome Besufekad, 2012). Thus, domesticating timber species and establishing seed production areas that would serve for seed supply in the long term is crucial. So, it is becoming necessary to find innovative ways of maintaining/improving the genetic quality of these species by domesticating them in a wider scale of ecological and social environments and upgrading the seed supply by developing seed production areas (SPA). Such cases require information on phenology of targeted species to promote selected native timber species through species domestication, seed production area establishment, and setting forest management regimes.

Phenology studies the effects of weather and climate on plant life stages, including flowering, fruiting, leafing, and defoliation. It also studies the timing for recurring biological events. In the case of plants, phenological events involve germination, flowering, fruit-

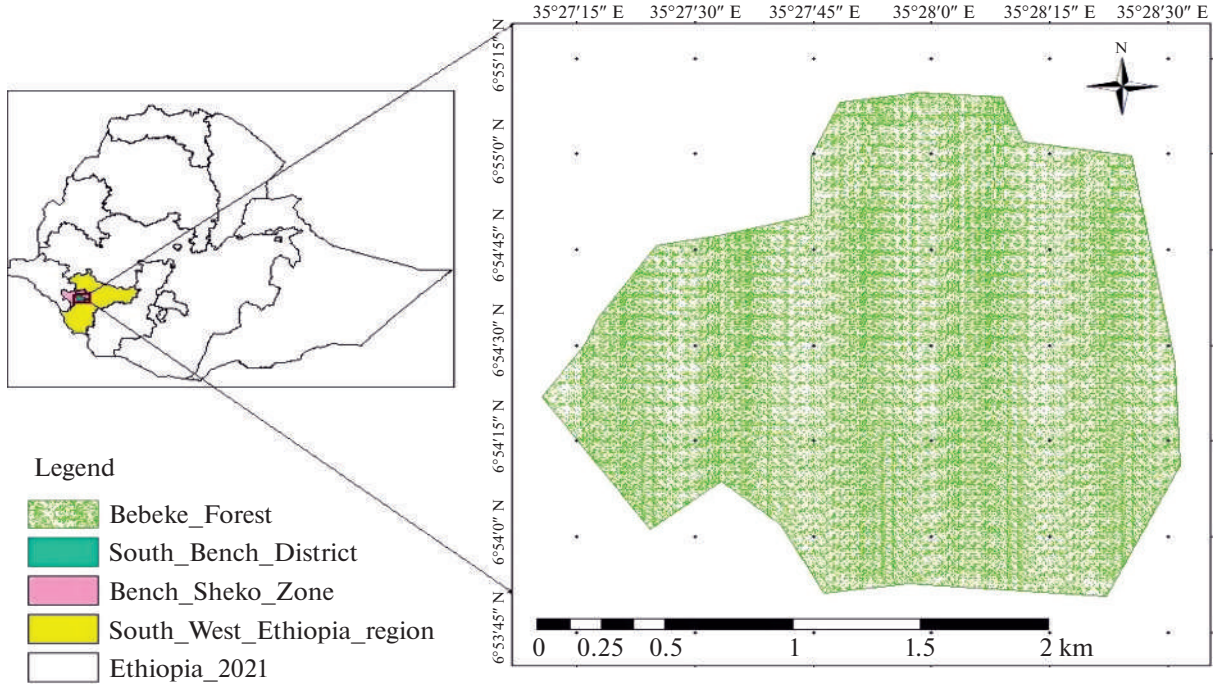

Fig. 1. Map of the study area.

ing, and leaf flushing. The season of these events has important effects on plant survival, reproductive success, and regeneration. Phenology of a species is aimed at examining the seasons when local climatic conditions may influence the behavior of the species in its natural habitat, as collecting the knowledge on seasonal manifestation of biological phenomena like leafing, flowering, and fruiting may effectively contribute to the development of strategies for the use and sustainable management of this species (Fobane et al., 2014).

The knowledge of phenological patterns is fundamental to have a good understanding of biological processes in trees, how they interact with other organisms, and ecosystem functioning in general. The time and duration of flowering and fruiting, for instance, have important consequences for a population's genetic structure and response to selection (Garrison et al., 2008; Hirao and Kudo, 2008). Trees grow when environmental conditions are appropriate. Thus, phenology stages are highly affected by environmental conditions like temperature and photoperiod. Seasonal duration or variations of flowering and fruiting are mainly determined by phenological behavior of trees (Singh and Kushwaha, 2006; Garrison et al., 2008; Hirao and Kudo, 2008).

This paper is aimed at documenting the phenology (timing of flowering and fruiting) of three indigenous tree species, namely *M. excelsa, A. toxicaria,* and *P. adolfi-friedericii,* that were selected based on the severity of their depletion and relative timber values. This study presents first-ever detailed studies on the phenology of leafing, flowering, and fruiting in *A. toxicaria, M. excelsa*, and *P. adolfi-friedericii* in the Benchi-Maji Zone, Ethiopia. The question this study answered was, "What are the duration, timing, and frequency of leafing, flowering, and fruiting in the three selected indigenous tree species at the study site?"

OBJECTS AND METHODS

Study site description. The study was conducted in the Debub Bench district of the Bench Maji zone that is, in turn, located in the Southern Nations, Nationalities, and Peoples' Region state (SNNPR). The specific localities of the study area are found at Bebeka (Abiy 4 and Abiy 5) (Fig. 1). It is located within 07°16′ N and 36°15′ E (Mihreiu, 2004). The mean annual rainfall is 2200 mm, while the mean annual temperature is about 25°C. The altitudinal range is from 1000 to 1350 m.a.s.l.

The vegetation type in the area is classified as the Afromontane moist transitional forest (Sebsebie et al., 2010). The forest in the area can be categorized as a natural (undisturbed) forest and a mixed natural coffee forest. There are areas of dense forests in the district that have been granted the status of high forests. They harbor many timber species, medicinal plants, and *coffee arabica* (Mirutse et al., 2009).

Data collection. Three indigenous tree species, namely *A. toxicaria*, *M. excelsa*, and *P. adolfi-friedericii* (formerly *Aningeria*), were selected for the study, because they are of significant ecological and economic importance in the Bench-Maji Forest. Reproductive phenology studies of the targeted species were carried out using the following methods. Over twenty (20) reproductively healthy, mature, and average mother trees >10 cm wide in diameter at breast height (DBH)

depending on the species average size, with easily visible crowns, located at a distance of 100 m from one another, were selected and marked using marking ink along sufficiently large transects.

Following this, we conducted continuous observations and recorded data on leaf phenology (leaf initiation and development of new leaves, maturity and shedding of leaves); flowering phenology (developing flower buds, flower initiation, peak flowering, and withering away/shedding); fruiting phenology (fruit initiation, fruit development, fruit maturation, drying of fruit and bursting out of fruit walls) every 15 days (twice every month). In addition, flowers and fruits that dropped from the trees were used as indicators of reproductive events and recorded as well. Data collectors were selected at respective sites; they completed a training course regarding the different phonological stages and the study format**.** Close supervision was conducted by researchers as well. Continuous observation and data recording were carried out as follows:

Descriptions of phenological stages used while collecting data

Vegetative Phenophases	Description
Leaf initiation	Dates when the first leaves have emerged
Leaf development	Dates when all emerged leaves are clearly visible but can still be partly folded. Leaves initiate from the flanks of the shoot apical meristem and develop into flat structures of variable sizes and forms (Singh and Kushwaha, 2006)
Leaf maturity	Dates when all emerged leaves are fully visible in their mature form
Flower bud development	Dates when the flower bud scales have opened to reveal the emerging flowers. The color of the flowers is distinguishable
Flower initiation	Dates when the meristem is committed to form a flower. Usually occurs early during active vegetative growth
Peak flowering	Dates when the first flowers are fully open. When open, the stamens can be seen among unfolded petals
Withering away/ Flower shedding	Dates when half or more of the flowers are completely open, or dates when most flowers have wilted or fallen off to form fruits
Fruit initiation	Dates when the first fruits emerge
Fruit development	Dates when all emerged fruits are clearly visible but can still be partly folded
Fruit maturation	Dates when the first fruits become fully ripe or drop seeds naturally from the plant. Ripening is usually signified by a change to the mature color, or by drying and splitting open (for dry fruits such as capsules)

Data analysis. The phenology data collected was checked, coded, and encoded by a computer and analyzed using descriptive statistics.

RESULTS AND DISCUSSION

Both flowering and fruiting were significantly influenced by temperatures and rainfalls. Flowering generally started in the beginning of the rainy season (Fig. 2). The peak fruiting period in *M. excelsa* was in the same month, and sometimes the latter was preceded by one month.

The peak fruiting periods for most species are the mid- to late dry season. Such peak fruiting periods during the dry season have been reported in dry tropical forests of Costa Rica (Frankie et al., 1974) and Cote d`Ivoire (Anderson et al., 2005). The peak flowering periods can be explained by influence of rainfalls on bud break after the dry season (Couralet et al., 2013). In the tropical climate, flowering periods are triggered by first rains in the rainy season with the transition being concentrated in the late dry to early wet season (Stevenson et al., 2008).

Flowering and fruiting time in *Milicia excelsa*. Different trees sprout leaves, flowers, and fruits at different times. The flowering and fruiting times are significantly seasonal. This phenological condition was observed throughout the year for different trees at different sites (Weru, 2012). The results of this study indicate that the actual season when seeds of *M. excelsa* become available for collection is once a year, from January to February (Table 1). The results also indicate that the species produce flowers twice a year but have a single seeding period each year. The flowering in *M. excelsa* takes place at the end of the dry season after this tree species have shed their leaves or while the new leaves emerge (Berg et al., 2002).

The data collected in the past three years showed that the flowering and fruit setting time varied by 10 to 15 days within the same month each year. The fruiting time is fairly short in *M. excelsa*, as it takes place at a range of different days, but often occurs in January and February soon after the time shortly before new leaves appear or when most of the eaves fall. In the first year of phenological observation, the fruiting time started in mid-January, while next year the fruit setting or fruiting initiation occurred at the end of January and, during the third year, the fruiting shading occurred in late February.

Flowering and fruiting time in *Antiaris toxicaria*. Phenological observations of *A. toxicaria* in the past three years indicated that leafing, flowering, and fruiting may quite commonly vary from year to year and from tree to tree within a single population during the same year. The results also show that the fruiting time (when seeds are available for collection) in *A. toxicaria* is seasonal and occurs from the early January up to the late February (Table 2). In the first year of phenologi-

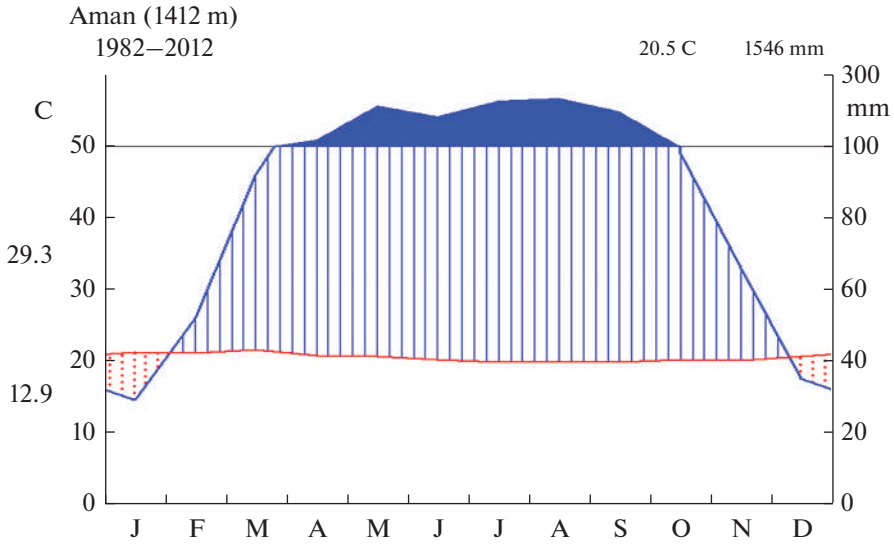

Fig. 2. Walter Climate diagram of Mizan-Aman produced using *R. 4.03.*

cal observation, the fruiting time occurred in mid-February; next year, the fruit setting or fruiting initiation phases occurred at the end of February, and during the third year, the fruiting shading occurred at the end of February. The fruiting duration in *A. toxicaria* is fairly short. Like *M. excelsa,* it produces flowers which set no fruit most of the time.

The phenological observation results indicated that, for the past three years, trees tend to lose their leaves in November, March, and June, but mostly in November, and flowering occurs in this period. This study was in line with *A. toxicaria* (Moraceae) – a new distribution record to the Eastern Ghats (Ravikumar and Sankar, 2009).

Flowering and fruiting of *A. toxicaria* in the past three years was almost similar as it did not extremely vary from year to year. The fruits of *A. toxicaria* are available for seed collection from February to March. The flowers ultimately produce fruit, while only a few trees can produce viable seeds. Some of the intra-population fruiting variations have been attributed to differences in attractiveness of inflorescences to insects during a particular flowering season. Fluctuations in the populations of sucking insects also play a significant role in determining the number of incipient fruits that abort in a given year.

Flowering and fruiting time in *Pouteria adolfi-friedericii.* The fruiting time, or the actual season when seeds of *P. adolfi-friedericii* are available for collection, ranges from May to June (Table 3). Both flower initiation and open flower stages in flowering phenology of *P. adolfi-friedericii* start during November and extend up to early May. The peak flowering time in *P. adolfi-friedericii* is November, while sporadic flowering is reported to occur all year round (Orwa et al., 2009). The fruiting time is seasonal and goes on from the early May up to June.

Table 1. The phenology of leafing, flowering, and fruiting in *M. excelsa* in Bebeka, South West Ethiopia

Phenological stage		Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Leafing	Sprouting (leaf initiation)												
	Mature (grown leaves)												
	Senescent shading												
Flowering	Flower initiation												
	Flower shading												
	Fruit initiation (setting)												
Fruiting	Fruit growing												
	Fruit ripping (maturity)												
	Fruit shading												

Table 2. The phenology of leafing, flowering, and fruiting in *Antiaris toxicaria* in Bebeka, South West Ethiopia

Phenological stage		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Leafing	Sprouting (leaf initiation)												
	Mature (grown leaves)												
	Senescent shading												
Flowering	Flower initiation												
	Flower shading												
Fruiting	Fruit initiation (setting)												
	Fruit growing												
	Fruit ripping (maturity)												
	Fruit shading												

Table 3. The phenology of leafing, flowering, and fruiting in *Pouteria adolfi-friedericii* in Bebeka, South West Ethiopia

Phenological stage		Month											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Leafing	Sprouting (leaf initiation)												
	Mature (grown leaves)												
	Senescent shading												
Flowering	Flower initiation												
	Flower shading												
	Fruit initiation (setting)												
Fruiting	Fruit growing												
	Fruit ripping (maturity)												
	Fruit shading												

CONCLUSION

The patterns of the fruiting phenology of the three selected indigenous tree species can be categorized as annual with two of the selected tree species (*A. toxicaria* and *M. excelsa*) producing fruit during the dry season, and one tree species (*P. adolfi-friedericii*) producing fruit in the rainy season. Recommendations: 1. Low-cost technologies for seed/seedling acquisition and distribution are a necessity; 2. Artificial regeneration of indigenous tree species through cuttings and air layering produces better results than using seeds, and matures in a shorter time.

Declaration of Interest Statement. No potential conflict of interest was reported by the authors.

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РЕПРОДУКТИВНАЯ ФЕНОЛОГИЯ *MILICIA EXCELSA*, *ANTIARIS TOXICARIA* И *POUTERIA ADOLFI-FRIEDERICII* В ЮГО-ЗАПАДНОЙ ЭФИОПИИ

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Обезлесение и деградация естественных лесов представляют собой проблему для лесного сектора Эфиопии. Сбор научных данных о репродуктивной биологии отдельных древесных пород в настоящее время приобрел важное значение для развития семеноводческих районов и установления режимов лесопользования. В связи с этим целью данного исследования является определение репродуктивной фенологии местных видов деревьев. Время листопада, цветения и плодоношения трех древесных пород регистрировалось в течение трех лет в Юго-Западной Эфиопии в естественных лесах зоны Бенчи-Маджи (район Дебуб Бенч). Были выбраны три приоритетных вида, *Milicia excelsa*, *Antiaris toxicaria* и *Pouteria adolfi-friedericii*, исходя из степени их истощения и относительной ценности древесины в данном районе и в стране в целом. Из каждого вида было отобрано более 20 репродуктивно здоровых, зрелых и средних материнских деревьев с диаметром на высоте груди >10 см и с легко различимыми кронами, расположенных на расстоянии 100 м друг от друга и помеченных маркировочными чернилами. Мы проводили непрерывные наблюдения и записывали данные о листопаде, цветении и плодоношении каждые 15 дней (дважды в месяц). Затем данные были проанализированы с помощью описательной статистики. Результаты этого исследования показывают, что фактический сезон, когда семена *Milicia excelsa* доступны для сбора, бывает один раз в год, с января по февраль. Результаты также показали, что для *Antiaris toxicaria* время плодоношения является сезонным, семена становятся доступными для сбора с начала января до конца февраля. Время плодоношения или фактический сезон, когда семена *Pouteria adolfi-friedericii* становятся доступными для сбора, – с мая по июнь. Для приобретения и распространения семян/саженцев рекомендуется использовать низкозатратные технологии для создания зон производства семян и одомашнивания вида, которые предпочтительнее использовать для сокращения уничтожения выбранных местных видов деревьев.

Ключевые слова: цветение, плодоношение, фенология, зона производства семян, одомашнивание.