Scholars Journal of Agriculture and Veterinary Sciences OPEN ACCESS
Abbreviated Key Title: Sch J Agric Vet Sci
ISSN 2348–8883 (Print) | ISSN 2348–1854 (Online)
Journal homepage: https://saspublishers.com

Flowering and Fruiting Phenology of Selected Indigenous Tree Species in Anferara Natural Forests, Southern Ethiopia

Aschalew Emire[1*], Sintayo Demise [1], Temesgen Giri[1]

[1]Oromia Agricultural Research Institute, Bore Agricultural Research Center, Bore, Ethiopia

DOI: https://doi.org/10.36347/sjavs.2024.v11i07.001 | **Received:** 14.02.2024 | **Accepted:** 19.03.2024 | **Published:** 01.10.2024

***Corresponding author:** Aschalew Emire
Oromia Agricultural Research Institute, Bore Agricultural Research Center, Bore, Ethiopia

Abstract **Original Research Article**

The Flowering and Fruiting Phenology of Selected Indigenous Tree Species were investigated in Anferara Natural Forests, for two years. Prior to Phenological study, by using key informant interview and focus group discussions the most important indigenous tree species were identified. Based on the preferences of the local communities, the following ten indigenous tree species included: *A. gumifera*, *A. adolfi-friedericii*, *C. africana*, *C. macrostachyus*, *E. capensis*, *M. ferruginia*, *P. falcutus*, *P. ferruginia*, *S. spinosa* and *P. africana* were selected for the phenological study. From each tree species selected from Anferara Natural forests, five mother trees were selected and a total of fifty mother trees were tagged for data collection. Based on the objective of this study, monthly the following parameters such as flowering time, fruiting time and seed collection time were recorded until the end of the study time. The findings of this study indicated that, the flowering and fruiting time of the examined tree species were concentrated with long dry season and rainy season of the study site. Based on the findings of this study, *A. gumifera, C. africana, C. macrostachyus, P. falcutus and P. africana* were flowered during main rainy season of the study site. However, the rest of indigenous tree species such as *A. adolfi-friedericii, E. capensis, M. ferruginia, P. ferruginia* and *S. spinosa* were flowered during long dry season of the study area. In terms of their fruiting time phenological study, the following tree species such as *A. gumifera, A. adolfi-friedericii, C. africana, C. macrostachyus* and *S. spinosa* were bearing fruit during main rainy season of the study site. However, the remaining investigated tree species were bearing fruit during dry season of the study site. Seed maturity and seed collection time of the studied tree species were more or less similar and after maturity time of their seeds, close supervision is very important to collect the matured and healthy seeds at proper time.

Keywords: Anferara natural forest, Flowering time, Fruiting time, Indigenous tree species Phenological study, Seed collection time.

INTRODUCTION

Plant phenology is the study of recurring life-cycle events including leaf information and fall, flowering, fruiting and seed dispersal (Morisette *et al*., 2009). The study of plant phenology provides knowledge about the pattern of plant growth and development as well as the effects of environment and selective pressure on flowering and fruiting behavior (Marques *et al*., 2004; Zhang *et al*., 2006). Phenological studies are also important to understand ecosystem process such as plant growth pattern, biomass production and plant water stress (Kikuzawa and Lechowicz, 2011).

Phenological study is very important for recurring biological events and explains the relationship between climatic factors and periodic phenomena in organisms (Moza and Bhatnagar, 2005; Yadav and Yadav 2008). Moreover, phenological patterns are basic for understanding biological processes and functioning of tropical trees and ecosystems (Tesfaye *et al*., 2011). Thus, an understanding of reproductive phenology and pollination biology are basic elements that should be considered in the conservation, management and exploitation of plant species (Peba and Tabla, 2007).

Phenological information is basic for understanding of biological processes and functioning of the forest ecosystem. The timing and duration of flowering and fruiting is crucial in understanding forest regeneration dynamics as the pronounced seasonality affects the reproductive output and performances such as seed production, germination, survival, and seedling growth (Augspurger, 1981). As well, restoration and rehabilitation of degraded forest lands for their biodiversity conservation, watershed protection, carbon

sequestration and other ecosystem services requires detailed knowledge of plant phenology (FORRU, 2006).

Phenological studies are also important in understanding species interrelations and their interaction with the environment. Variations in phenophases among individuals of the same species or different species have been linked to environmental perturbations (Suresh and Sukumar, 2011). Some of the climatic variables that affect these periodic phenological phenomena include rainfall,temperature, insolation and water stress (Borchert, 1983; Stevenson *et al*., 2008; Dutta and Devi, 2015).

Better knowledge of the phenological rhythms of tropical trees would help to improve forest management plans (Heinrich and Banks, 2006). However, lack of phenological information limits the understanding of the ecology and evolution of tropical plant species and communities (Newstrom *et al.*, 1994). Therefore, understanding of the relationships between phenology and climate would allow inferring the evolution of ecosystems under the foreseen modifications of climate, which is expected to be globally warmer and drier in tropical Africa (Malhi and Wright, 2004; Boisvenue and Running, 2006; Koenig, 2008).

In Ethiopia and other African countries information on phenological study of different tree species are critically lacking. This is particularly true for indigenous tree species found in Anferara Natural forests their reproductive phenological study is not yet conducted. Due to lack of phenological information in Anferara natural forests, biological process of the forests and proper time seed collection of the tree species are not yet identified. Therefore, in order to fill the above problem, the objective of this study was aimed to document the reproductive phenological patterns of selected indigenous tree species of Anferara natural forests, in Southern Ethiopia. Phenological information on the calendar of flowering, fruiting and other parameters gathered through this study could be used to anticipate proper timing for seed collection and seedling propagation for reforestation with indigenous tree species.

MATERIALS AND METHODS

Description of the study sites

Location

Anferara natural forest is found in Adola Rede district, in Southern Ethiopia. The study district is located at a distance of 475 km from Addis Ababa, the capital city of Ethiopia. The district is located at the coordinate between 5^0 44’10”- $6^0$12’38” North latitude and 38^0 45’10”-39^0 12’37” East longitude (Figure 1).

Climate

Adola Rede District is characterized by three agroclimatic zones namely humid, sub humid and dry arid zones. The district is found within an altitudinal range of 1500 to 2000 meters above sea level. The mean annual maximum and minimum temperature of the study district is 23 and 16°C, respectively. The rainfall pattern of the Adola Rede district is bimodal for lowlands and midland areas and mono-modal for high land parts.

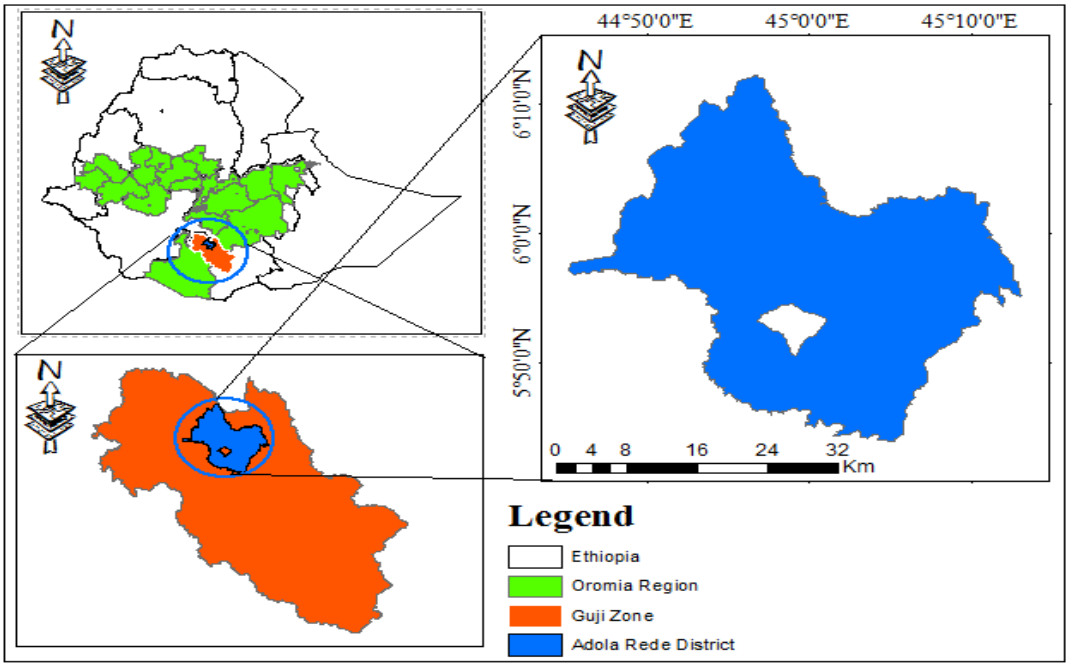

Figure 1: Location map of the study area

Soil and vegetation

The soil of the study area is Nitisols and orthcacrosols and it is dominantly brown soil. The vegetation type of the study district is characterized by forest, bushes and shrubs.The most dominant tree species found in the study area include; *Albizia gumifera* ,*Celtis africana, Cordia africana, Croton macrostachyus, Ekbergia capenis,Ficus sur, Millettia ferruginia, Podocarpus falcutus, Prunus africana, Strichynos spinosa* and others.

Agricultural activities

Rain-fed agriculture is a common practice for many farm households in this district. However, a semi-nomadic economic activity is also practiced as a means of livelihood by some of its dwellers. The farmers of the study district produce both in autumn and spring seasons. The traditional farming system of the study district is characterized by cultivation of major cereal crops such as teff, wheat, barley and maize, pulse crops such as haricot bean, common bean and chick pea and others such as fruits and vegetables. Farmers of the study district also engaged in the production of coffee as means of livelihood.

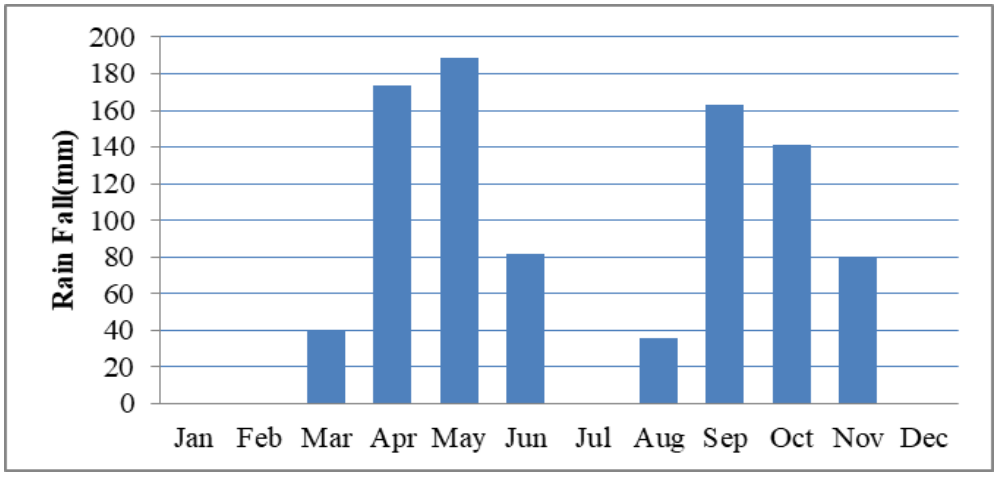

Figure 2: Mean monthly rainfall in mm for Adola Rede district, Southern Ethiopia

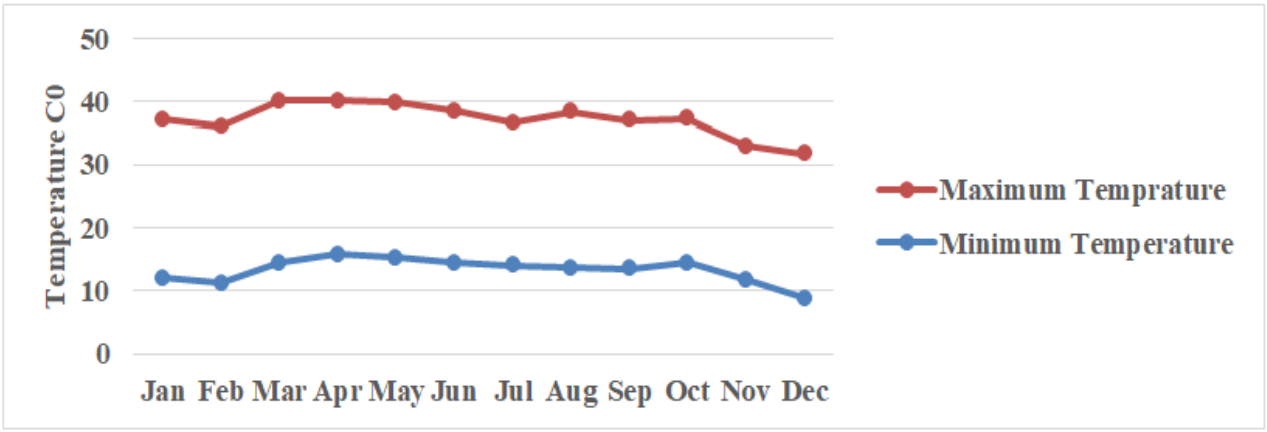

Figure 3: Mean maximum and minimum temperatures in ºC for Adola Rede district, Southern Ethiopia

Methods of Data Collection

Before phenological study of selected indigenous tree species of Anferara Natural forests was conducted, by using key informant interview and focus group discussions the most preferred tree species were identified. Based on the preferences of local communities of the study area, the following ten indigenous tree species such as *Albizia gumifera, Aningeria adolffi-friedericii, Cordia africana, Croton macrostachyus, Ekebergia capenis, Millettia ferruginia, Podocarpus falcutus, Polyscias ferruginia, Prunus africana* and S*trichynos spinosa* were selected for phenological study (Table 1 and Table 2).

For phenological observations of the selected indigenous tree species, individual trees which have >20cm diameter at breast height (DBH) were identified and tagged with a unique colour. From each tree species, five mother trees were selected and a total of fifty (50) individual trees were randomly selected and tagged for data collection. Reproductive phenological observations was made at monthly intervals for two years. Binocular

observations was made to check overlapping of events and tree branches.

Phenological observations was made on flowering and fruiting patterns. Moreover, phenological observations was based on phenological score such as 0 for no phenophase, 1 for less, 2 for moderate and 3 for high (Broadhead *et al*., 2003). Flowering phenophases categories include: 1) flower bud; 2) open flower; and 3) pollinating flower. Fruiting phenophases categories include:1) fruit bud; 2) immature fruit and 3) matured fruit.

Data Analysis

The data collected was summarized and analyzed by means of descriptive statistics. The illustrative tables and graphs were also used to summarize the data in precise form using the software programs such as Microsoft Excel. Spear man rank correlations was also performed to investigate correlations between monthly phenophase activity and environmental variables such as temperature and rainfall.

RESULTS AND DISCUSSION

Families of the Examined Tree Species

In this study phenological patterns of 10(ten) selected indigenous tree species classified under 8(eight) families were documented. The highest number of tree species were recorded under family of Fabaceae and Euphorbiaceae with 2 tree species.The remaining 6 families were represented by one species in each family (Figure 4).

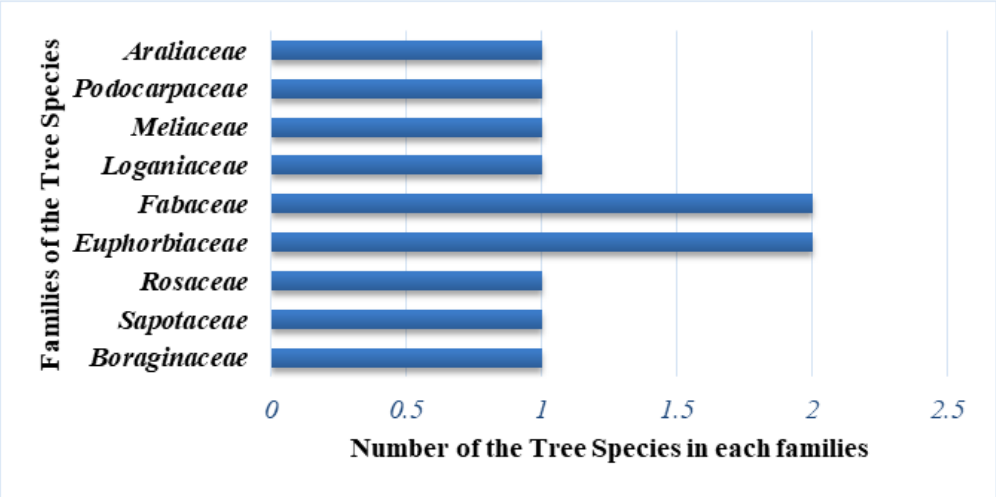

Figure 4: Taxonomy of sampled indigenous tree Species

Selection Criteria of the Studied Tree Species

The Anferara natural forests are very rich in terms of different tree species diversity. However, the current phenological study was only focused on 10(ten) selected indigenous tree species which have different values for local communities of the study area. Therefore, local communities living around Anferara natural forests were preferred the following indigenous tree species such as *Albizia gumifera, Aningeria adolffi-friedericii,Cordia africana,Croton macrostachyus, Ekerbergia capenis, Millettia ferruginia, Podocarpus falcutus, Polyscias ferruginia, Prunus africana* and *Strichynos spinosa* for flowering and fruiting phenological study.

Flowering Phenology of Selected Indigenous Tree Species

It was observed that from selected indigenous tree species their phenological patterns were studied for two years in Anferara natural forests, *Cordia africana* and *Croton macrostachyus* indigenous tree species were flowered in September and *Albizia gumifera* was flowered in October. The flowering time of *Podocarpus falcutus* tree was in November and *Prunus africana* indigenous tree was flowered from November-December (Table 2 and Table 3). This study showed that, the flowering period of the tree species began during the rainy season and their flowering phenophase lasted with a maximum of two months peak.

Moreover, the current phenological study showed that in both the years flowering intensity of the tree species were similar and their onset and peak flowering time were coincided with the rainy season of the study area. In support of this study, many research findings indicated that, there are a number of factors, which may influence the timing of flowering including rainfall, moisture, temperature and photoperiod (Kikim and Yadava, 2001; Anderson *et al*., 2005). Similarly, Torres *et al*., (2002) and Morellato *et al*., (2000) reported that flower production is influenced by temperature, day length, moisture availability, and internal physiological factors such as a specific balance of growth regulators.

The findings of the present study also agree with the reproductive flower phenology of different tree

species of tropical forests conducted in other countries. On their earlier phenological study, Anderson *et al*., (2005) and Sakai (2001) reported that flowering phenology of some tropical tree species were related with the humidity. Similarly, Getachew *et al*., (2011) indicated a significant positive correlation between rainfall and flowering for *Cordia africana* and *Syzygium guineense* indigenous tree species in a dry Afromontane forests, Southern Ethiopia. Furthermore, similar observations have also been reported by Bhat (1992) and Mishra *et al*., (2006) from the tree species of tropical moist deciduous forests of India. Therefore, based on the spearman correlation analysis results of this study, flowering patterns of *Albizia gumifera, Cordia africana,Croton macrostachyus, Podocarpus falcutus* and *Prunus africana* tree species were significantly correlated to mean monthly rainfall of the study area (Table 1).

Based on the findings of this study, *Ekerbergia capensis* was flowered in January, *Millettia feruginia* and *Polyscias ferruginia* were flowered in February and *Strichynos spinosa* and *Aningeria adolfi-friedericii* tree species were flowered in March (Table 2 & Table 3). This showed that, their flowering time was during dry season of the study area and their onset and peak of flowering periods coincided with the long dry season. In line with the present study results, a study in Northern Thailand tropical dry forest showed that peak flowering time of tree species were coincided with the beginning of dry season (Elliott *et al*., 1994). In support of this study, Singh and Singh (1992); Kikim and Yadava (2001) also reported that peak flowering period before rainy season and it has been argued that moisture, temperature and photoperiod seem to be responsible for flowering.

Moreover, in Rajasthan, India flower initiation of tropical dry deciduous forest trees were occurred during dry season (Yadav and Yadav, 2008). Flowering during the dry season reflects the availability of water by different sources, for example, through sporadic winter rains, absorption from soil and water stored in stem (Singh and Kushwaha, 2006). In favor of the current study, the studies of Berlin *et al*., (2000); Justiniano and Fredericksen (2000) in other semi-arid tropical forests also reported that flower peaks were concentrated in the dry season. Similarly, in Southern India, Krishnan (2004) studied reproductive phenology of endemic and non-endemic species. On his study findings reported that non-endemic species were flowered during the dry season.

Furthermore, in other dry tropical forests several studies have also reported that flower peaks were strongly concentrated in the dry season. In a dry Afromontane forest, southern Ethiopia,in Bolivian dry forests and in a cloud Forest on the Island of Maui, Hawaii, Justiniano *et al*., (2000); Berlin *et al*., (2000) and Tesfaye *et al*., (2011), on their former phenological studies indicated that flowering patterns of different tree species were correlated with dry season. Hence, from the current and previous phenological studies conducted in different parts of the country observed that, dry season flowering in tropical forests may be enhanced by the higher radiation. The findings of this study also indicated that, based on spearman correlation analysis results flowering patterns of examined tree species such as *Aningeria adolfi-friedericii, Ekerbergia capenis, Millettia feruginia, Polyscias ferruginia* and *Strichynos spinosa* were significantly correlated to mean monthly temperature of the study area (Table 1).

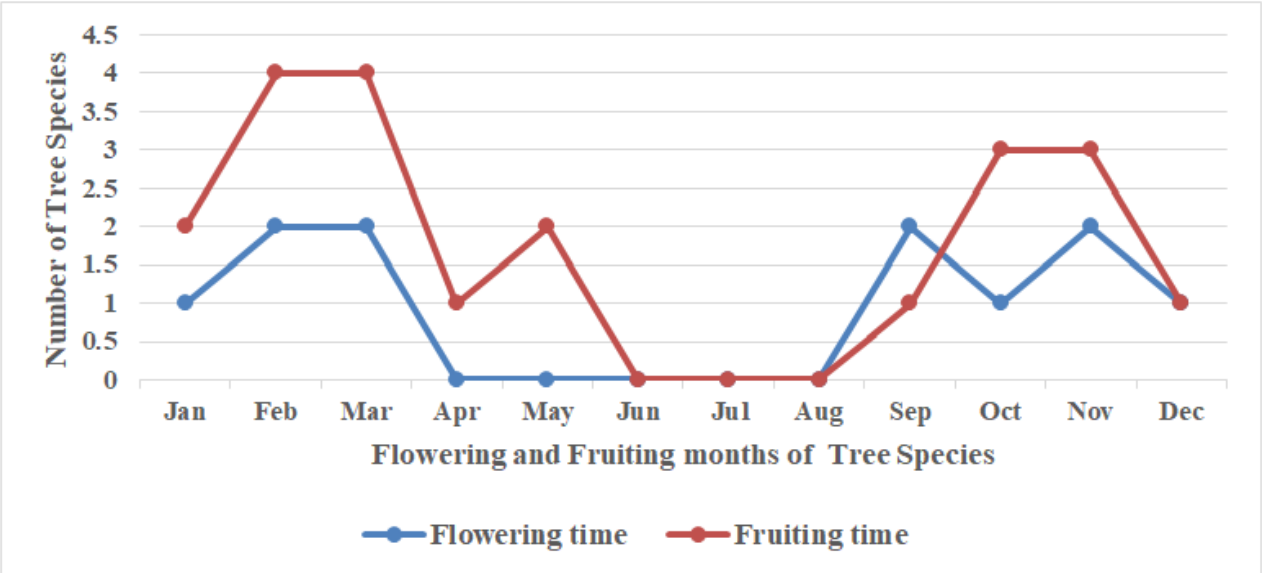

Figure 5: Number of tree species under study showing each phenophase

Table 1: Phenological patterns of Selected Tree Species in relation to temperature and rainfall environmental factors in Anferara natural forests, Southern Ethiopia

Tree Species	Spearman's rank correlation coefficients (r)			
	Flowering		Fruiting	
	Temperature(°C)	Rainfall(mm)	Temperature(°C)	Rainfall(mm)
Albizia gumifera	0.211 NS	0.851*	0.266NS	0.784*
Aningeria adolfi-friedericii	0.644*	0.265 NS	0.634*	0.311 NS
Cordia africana	0.225NS	0.831*	0.222NS	0.675*
Croton macrostachyus	0.292NS	0.785*	0.256NS	0.722*
Ekebergia capenis	0.656*	0.294 NS	0.678*	0.277 NS
Millettia ferruginia	0.787*	0.333 NS	0.751*	0.233 NS
Podocarpus falcutus	0.286 NS	0.872*	0.821*	0.323 NS
Polyscias ferruginia	0.835*	0.266 NS	0.711*	0.223 NS
Prunus africana	0.344 NS	0.796*	0.811*	0.267 NS
Strichynos spinosa	0.791*	0.311 NS	0.662*	0.315NS

Correlation is significant at the 0.05 level, NS: Non significant

Fruiting Phenology of Selected Indigenous Tree Species

As it is indicated in Table 2 and Table 3, fruiting phenology of majority of the studied indigenous tree species were lasted for two months. For instance, from selected tree species their reproductive phenological patterns were studied in Anferara natural forests: *Albizia gumifera, Cordia africana* and *Croton macrostachyus* tree species fruiting initiation to ripening lasted for two months and their months of fruiting time were from October to November (Table 2). Moreover, fruiting time of *Ekebergia capenis* and *Millettia ferruginia* tree species lasted for two months and their months of fruiting period were from February to March (Table 2 & Table 3). Fruiting patterns of *Podocarpus falcutus* indigenous tree was from December to January, *Prunus africana* from January to February and fruiting time of *Aningeria adolfi-friedericii* was from March to April (Table 2 & Table 3).

However, duration of fruiting patterns of *Strichynos spinosa,* tree species lasted for three months and its months of fruiting time were from March to May (Table 3). Likewise, fruiting patterns of *Polyscias ferruginia* examined tree species were lasted for three months from March to May (Table 3). According to Janzen (1967), fruiting extends for several more months because the fruits develop slowly to mature at the possible maximum rates through physiological processes.

From selected tree species their Phenological phenophase were studied in Anferara natural forests, *Albizia gumifera, Aningeria adolfi-friedericii, Cordia africana, Croton macrostachyus and Strichynos spinosa* indigenous tree species were bearing fruits during rainy season of the study area. Therefore, from spearman correlation analysis observed that their fruiting patterns were significantly correlated with the rainfall (Table 1). In support of this study, Gunter *et al*., (2008) indicated that there are a number of factors, which may influence the fruiting time of tree species including rainfall. Similarly, Singh and Kushwaha (2006) in their study results revealed that fruiting during the rainy season in tropical forests may have evolved to ensure dispersal of seeds when soil moisture conditions are favorable for seed germination, seedling growth and survival. Furthermore, in favor of this study, Getachew *et al*., (2011) in their study of Phenology of seven indigenous tree species in a dry Afromontane forests, in Southern Ethiopia reported that fruiting phenology of *Podocarpus falcutus, Croton macrostachyus, Pouteria adolfi-friederici, Polyscias fulva and Syzygium guineense* were significantly correlated with monthly rainfall.

On the other hand, fruiting phenophase of *Podocarpus falcutus* and *Prunus africana* indigenous tree species were during dry season of the study area. In favour of the current phenological study, dry season fruiting peaks have been reported from dry tropical forests such as Ethiopia (Tesfaye *et al.,* 2011), in Bolivian dry forests (Justiniano *et al*., 2000) and in Tai National Park, Cote d'Ivoire (Anderson *et al.,* 2005). The remaining examined tree species such as: *Ekebergia capenis, Millettia ferruginia* and *Polyscias ferruginia* beginning fruiting initiation at the end of dry season and their fruiting phenophases were completed during rainy season of the study area. In support of the present study results, Newston *et al*., (1994) and Janzen (1967) reported that fruiting towards the end of the dry season or during the rainy season in tropical forests may ensure the dispersal of seeds when soil moisture conditions are favorable for seed germination, seedling growth, and survival. Moreover, a like present study in Dry Afromontane Forests of Ethiopia, Teketay (1996) and Tesfaye *et al.,* (2011) indicated that seedling recruitment's were higher in the major rainy season than in the dry season.

Table 2: Flowering, Fruiting and Seed collection Phenological Patterns of Selected Indigenous Tree Species of Anferara Natural Forests, Southern Ethiopia

Months	**Phenological patterns of the tree species**				
	Albizia gumifera	*Aningeria adolfi-friedericii*	*Cordia africana*	*Croton macrostachyus*	*Ekebergia capenis*
January	-	-	-	-	FLT
February	-	-	-	-	FRT
March	-	FLT,FRT	-	-	FRT,SCT
April	-	FRT	-	-	-
May	-	SCT	-	-	-
June	-	-	-	-	-
July	-	-	-	-	-
August	-	-	-	-	-
September	-	-	FLT	FLT	-
October	FLT,FRT	-	FRT	FRT	-
November	FRT	-	FRT, SCT	FRT, SCT	-
December	SCT	-	-	-	-

Note: FLT=Flowering time, FRT=Fruiting time, SCT=Seed collection time

Seed collection time of the studied Tree Species

Collection of mature and healthy seeds from disinfected, vigor, healthy and disease free mother plants are essential for raising good quality seedlings. Therefore, it requires for the collector to determine when seeds are matured and time of harvest accordingly (Beniwal, 1987). The optimum time for seed collection is as soon as the seed is mature. For most types of tree species seed pods turn brown when the seed inside is mature. Therefore, tree seeds should be collected when they are mature and ripe, at proper seed collection time. As it is showed in Table 2 and 3, seed maturity and seed collection time of the majority of tree species their flowering and fruiting phenophases were investigated in Anferara natural forests are relatively similar. Based on the findings of the current phenological study, seed collection time of *Croton macrostachyus* and *Cordia africana* tree species were in November. *Prunus africana* and *Podocarpus falcutus* seed collection time were in February and for *Albizia gumifera* in December. Seed collection period of *Ekerbergia capensis* and *Millettia ferruginia* tree species were in March and April respectively. Seeds of both *Aningeria adolfi-friedericii* and *Strichynos spinosa* tree species should be collected in May and seed of *Polyscias ferruginia* tree species could be collected in June.

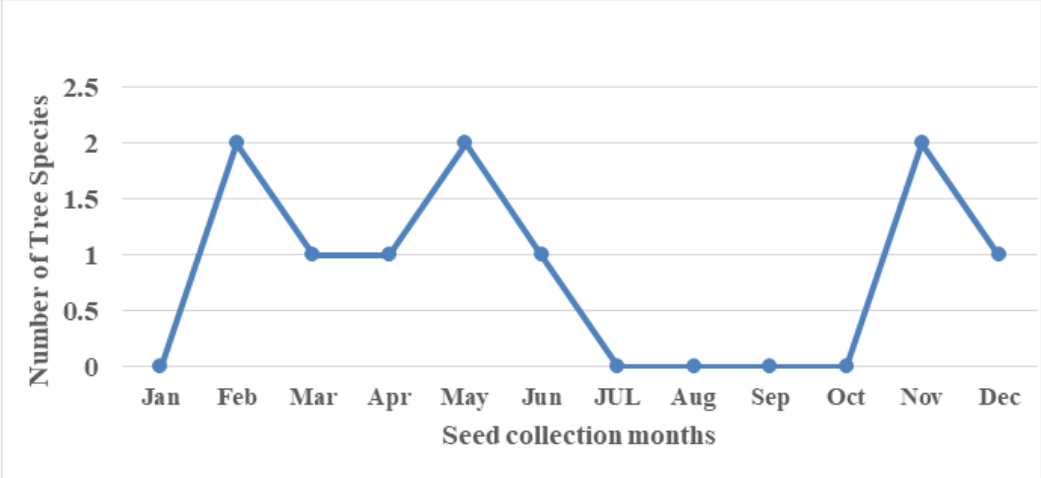

Figure 6: Month wise seed collection time of the examined Tree species

Table 3: Flowering, Fruiting and Seed Collection Phenological Patterns of Selected Indigenous Tree Species of Anferara Natural Forests, Southern Ethiopia

Months	Phenological Pattern of the tree species				
	Millettia ferruginia	*Podocarpus falcutus*	*Polyscias ferruginia*	*Prunus africana*	*Strichynos spinosa*
January	-	FRT	-	FRT	-
February	FLT, FRT	SCT	FLT	FRT, SCT	-
March	FRT	-	FRT	-	FLT, FRT
April	SCT	-	FRT	-	FRT
May	-	-	FRT	-	FRT
June	-	-	SCT	-	FRT, SCT
July	-	-	-	-	-
August	-	-	-	-	-
September	-	-	-	-	-
October	-	-	-	-	-
November	-	FLT	-	FLT	-
December	-	FRT	-	FLT	-

Note: FLT=Flowering time, FRT=Fruiting time, SCT=Seed collection time

CONCLUSION AND RECOMMENDATION

From Anferara natural forests, ten most important indigenous tree species were selected by local communities and their reproductive phonological study was conducted for two years. The study results showed that, flowering and fruiting phenological patterns of the selected indigenous tree species were concentrated with dry and rainy season of the study area. In terms of flowering phenophase, *Albizia gumifera, Cordia africana, Croton macrostachyus, Podocarpus falcutus* and *Prunus africana* indigenous tree species were flowered during rainy season. However, the rest of indigenous tree species such as *Aningeria adolfi-friedericii, Ekebergia capenis,Millettia ferruginia, Polyscias ferruginia* and *Strichynos spinosa* were flowered during dry season of the study site.

Fruiting phenological patterns of the studied indigenous tree species also correlated with dry and rainy season of the study area. From the examined indigenous tree species, *Albizia gumifera, Aningeria adolfi-friedericii, Cordia africana, Croton macrostachyus and Strichynos spinosa* were bearing fruits during dry season of the study area. However, the remaining studied indigenous tree species such as *Podocarpus falcutus, Prunus africana, Ekebergia capenis, Millettia ferruginia* and *Polyscias ferruginia* beginning fruiting initiation during the dry season. The current investigation carried out in phenological study of selected indigenous tree species of Anferara Natural forests showed that majority of the tree species seed shade was take place immediately after peak fruiting maturity time. Therefore, by close supervision seed collection before dispersal can be planned based on the results of this study. The findings could be helpful to those stakeholders informing them about right time of seed collection of most important indigenous tree species of the Anferara natural forests. Moreover, it helps the researchers to understand the change in phenological trends in the near and long-term as well with respect to change in global climate.

Acknowledgments

The authors are thankful to Oromia Agricultural Research Institute for financing the study and Bore Agricultural Research Center for provision of the necessary facilities for research work. The authors would like to acknowledge local communities living around the Anferara natural forests for the support during phenological field data collection.

REFERENCE

- Anderson, D., Nordheim, V. E., Moermond, C. T., Gone, B. Z., & Boesch, C. (2005). Factors influencing tree phenology in Tai National Park, Cote d´Ivoire. *Biotropica*, 37, 631-641.
- Appaji, N., Hebbalalu, S. S., & Yelugere, L. K. (2014). Phenology of a tropical dry deciduous forest of Bhadra wildlife sanctuary, southern India. *Ecological Processes*, 2014, 3, 1.
- Augspurger, C. K. (1981). Reproductive synchrony of a tropical shrub: experimental studies on effects of pollinator and seed predators on *Hybanthus pruniformis* (Violaceae). *Ecology 62*, 775-788.
- Beniwal, B. S. (1987). Phenological study of trees in Arunachal Pradesh, India. *The Indian Forester*, 113, 779.
- Berlin, E. K., Pratt, K. T., Simon, C. J., & Kowalsky, J. (2000). Plant phenology in a Cloud Forest on the Island of Maui, Hawaii. *Biotropica*, 32, 90-99.
- Bhat, D. M., & Murali, K. S. (2001). Phenology of understorey species of tropical moist forest of Western Ghats region of Uttara Kannada district in South India. *Curr Sci*, 81, 799-805.
- Boisvenue, C., & Running, S. W. (2006). Impacts of climate change on natural forest productivity; evidence since the middle of the 20th century. *Global Change Biology*, 12, 862-882.
- Borchert, R. (1983). Phenology and control of flowering in tropical trees. *Biotropica*, 15, 81-89.

- Broadhead, J., Ong, C. K., & Black, C. R. (2003). Tree phenology and water availability in semi- arid agroforestry systems in Kenya. *Forest Ecol Manag*, 180, 61-73.
- Dutta, G., & Ashalata, D. (2015). Phenology and population structure of six tree species in tropical forest of Assam, northeast India. *Tropical Ecology*, 56, 343-399.
- Elliott, S., Baker, P. J., & Borchert, R. (2006). Leaf flushing during the dry season: the paradox of Asian mon-soon forests. *Global Ecology and Biogeography*, 15, 248-257.
- Forest Restoration Research Unit (FORRU). (2006). How to Plant a Forest: The Principles and Practice of Restoring Tropical Forests. Biology Department, Science Faculty, Chiang Mai University, Thailand.
- Heinrich, I., & Banks, J. C. G. (2006). Variation in phenology, growth, and wood anatomy of Toona sinensis and Toona ciliata in relation to different environmental conditions. *International Journal of Plant Sciences*, 167, 831-841.
- Janzen, D. H. (1967). Synchronization of sexual reproduction of trees within the dry season in Central America. *Evolution*, 21, 620–637.
- Justiniano, M., & Fredericksen, T. (2000). Phenology of tree species in Bolivian dry forests. *Biotropica*, 32, 276-280.
- Kikim, A., & Yadava, P. S. (2001). Phenology of tree species in subtropical forests of Manipur in north eastern India. *Tropical Ecology*, 42, 269-276.
- Kikuzawa, K., & Lechowicz, M. J. (2011). Ecology of leaf longevity. Ecological Research Monographs, Springer, Berlin.
- Koenig, R. (2008). Critical time for African rain forests. *Science*, 320, 1439-1441.
- Krishnan, R. M. (2004). Reproductive phenology of endemic understorey assemblage in a wet forest of the Western Ghats, South India. *Flora-Morphology, Distribution and Functional. Ecology of Plants, 199*(4), 351-359.
- Malhi, Y., & Wright, J. (2004). Spatial patterns and recent trends in the climate of tropical rainforest regions. Philosophical Transactions of the Royal Society of London Series. *Biological Sciences*, 359, 311-329.
- Marques, M. C. M., Roper, J. J., & Salvalaggio, A. P. B. (2004). Phenological patterns among plant life-forms in a subtropical forest in southern Brazil. *Plant Ecol*, 173, 203-213.
- Mishra, R. K., Upadhyay, V. P., Bal, S., Mohapatra, P. K., & Mohanty, R. C. (2006). Phenology of species of moist deciduous forest sites of Similipal biosphere reserve. *Lyonia*, 11, 5-17.
- Morellato, L. P., Talora, D. C., Takahasi, A., Bencke, C. C., Romera. E. C., & Zipparro, V. B. (2000). Phenology of Atlantic rain forest trees: a comparative study. *Biotropica*, 32, 811-823.
- Morisette, J. T., Richardson, A. D., Knapp, A. K., Fisher, J. I., Graham, E. A., Abatzoglou, J., Wilson, B. E., Breshears, D. D., Henebry, G. M., Hanes, J. M., & Liang, L. (2009). Tracking the rhythm of the seasons in the face of global change: phenological research in the 21st century. *Front Ecol Environ*, 7, 253-260.
- Moza, M. K., & Bhatnagar, A. K. (2005). Phenology and climate change. *Current Science*, 89, 243-244.
- Nanda, A., Suresh, H. S., & Krishna Murthy, Y. L. (2015). Leafing phenology of tropical forests of Bhadra wildlife sanctuary, Karnataka, India. *Applied Science Reports*, *12*(1), 33-40.
- Newstrom, L. E., Frankie, G. W., & Baker, H. G. (1994). A new classification for plant phenology based on flowering patterns in lowland tropical rain-forest trees at La-Selva, Costa-Rica. *Biotropica*, 26, 141-159.
- Peba, S. L., & Tabla, P. V. (2007). Phenology and pollination of Manilkarazapota in forest and homegardens. *Forest Ecology and Management*, 248, 136-142.
- Sakai, S. (2001). Phenological diversity in tropical forests. *Population Ecology*, 43, 77-86.
- Stevenson, P. R., Castellanos, M. C., Cortés, A. I., & Link, A. (2008). Flowering pattern in a seasonal tropical lowland forest in western Amazonia. *Biotropica*, 40, 559-567.
- Singh, K. P., & Kushwaha, C. P. (2006). Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Annals of Botany*, 97, 265- 276.
- Singh, J. S., & Singh, V. K. (1992). Phenology of seasonally dry tropical forest. *Current Science*, 63, 684-688.
- Suresh, H. S., & Sukumar, R. (2011). "Vegetative phenology of tropical montane forests in the Nilgiris, South India". *Journal of the National Science Foundation of Sri Lanka*, *39*(4), 33.
- Teketay, D. (1996). Seed Ecology and Regeneration in Dry Afromontane Forests of Ethiopia. Ph.D. Thesis, Swedish University of Agricultural Sciences, Umeå, Sweden.
- Tesfaye, G., Teketay, D., Fetene. M., & Beck, E. (2011). Phenology of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Tropical Ecology*, 52, 229-241.
- Torres, E., Iriondo, J. M., & Perez, C. (2002). Vulnerability and determinants of reproductive success in the narrow endemic Antirrhinum microphyllum (Scrophulariaceae). *American Journal of Botany*, 89, 1171-1179.
- Yadav, R. K., & Yadav, A. S. (2008). Phenology of selected woody species in a tropical dry deciduous forest in Rajasthan, India. *Tropical Ecology*, 49, 25-34.
- Zhang, G., Song, Q., & Yang, D. (2006). Phenology of *Ficus racemosa* in Xishuangbanna, Southwest China. *Biotropica*, 38, 334-341.