Phenological Traits of Recalcitrant Seed-earing Trees in Bangladesh

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Abstract

Functioning and productivity of forest ecosystems vastly dependents on the phenological characteristics of the tree species. The study was carried out from June 2017 to December 2018 to explore the phenological traits of 74 recalcitrant seed bearing tree species of natural forests and plantations in Bangladesh. Data were collected from Chittagong University campus, Hathazari, Boalkhali, Hazarikhil, Dohazari, Rangamati, Kaptai, Ukhiya, Bandarban and Khagrachari through repeated field visits including review of published papers. The results showed that flowering, fruiting and seed maturity periods varied from species to species. The Seventy Four tree species belongs to 55 genera of 31 families. Maximum (39.19%) fruits were under the Berry category and minimum (1.35%) in Samara. The study revealed that flowering of maximum species occurred during March (54.05%) and fruiting in May (54.05%). The peak period for collecting viable recalcitrant seeds was found both in May and June (36.49% respectively). The study will be a ready reference with information on flowering, fruit initiation and seed collection time of 74 recalcitrant seed bearing trees of Bangladesh. The findings of the study may be useful to the nursery owners, foresters, and private plant growers for collection of seeds in right time and establishment of the plantations. This paper may also be a supportive document to the policymakers in taking decision on raising seedlings of recalcitrant seed bearing trees for mass plantations towards the greening program of the country.

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বন বাস্তুকারদের কাজ ও উৎপাদনশীলতা বৃক্ষপ্রজাতির ফেনোলজিক্যাল বৈশিষ্ট্যের উপর নির্ভরশীল। বাংলাদেশের প্রাকৃতিক বনাঞ্চল ও বাগানগুলির ৭৪ টি recalcitrant বীজ বৃক্ষ প্রজাতির ফেনোলজিক্যাল বৈশিষ্ট্য অন্বেষণ করার লক্ষ্যে জুন ২০১৭ থেকে ডিসেম্বর ২০১৮ পর্যন্ত এই গবেষণা করা হয়। গবেষণা পর্যালোচনাসহ বারবার মাঠ পরিদর্শনের মাধ্যমে চট্টগ্রাম ক্যাম্পাস, হাটহাজারী, বোয়ালখালী, হাজারিখিল, দোহাজারী, রাঙ্গামাটি, কাপ্তাই, উখিয়া, বান্দরবান ও খাগড়াছড়ি থেকে তথ্য সংগ্রহ করা হয়। ফলাফলে দেখা গেছে, ফুল ফোটা, ফুল ধারণ ও বীজের পরিপক্কতা সময় প্রজাতি থেকে প্রজাতি-তে বৈচিত্রময়। অধ্যয়নকৃত ৭৪ টি বৃক্ষ প্রজাতি ৩১ টি পরিবারের ৫৫ টি গোত্রের অধীনে পাওয়া যায়। সর্বোচ্চ ফল পাওয়া গেছে বেরি ক্যাটাগোরিতে (৩৯.১৯%) এবং সর্বনিম্ন সামারা-তে (১.৩৫%)। বর্তমান গবেষণায় প্রকাশ, সর্বাধিক প্রজাতির ফুল ফুটেছে মার্চ মাসে (৫৪.০৫%) এবং ফল ধারণ হয়েছে মে মাসে (৫৪.০৫%)। কার্যকরী recalcitrant বীজ সংগ্রহের জন্য সবচেয়ে উপযুক্ত সময়কাল পাওয়া গেছে মে ও জুন উভয় মাস (৩৬.৪৯% পর্যায়ক্রমে)। অতএব এই গবেষণায় বাংলাদেশের ৭৪ টি recalcitrant বীজ বৃক্ষ প্রজাতির ফুল ফোটা, ফল ধারণ, ও বীজ সংগ্রহ সংক্রান্ত প্রয়োজনীয় সকল তথ্য নিয়ে প্রস্তুত রেফারেন্স থাকবে। এই গবেষণার ফলাফল

বাগান স্থাপনের জন্য নার্সারী মালিক, বনরক্ষী, বেসরকারী বৃক্ষচাষীদের সহযোগী উপকরণ হবে। এই গবেষণাটি একটি সবুজ বাংলাদেশ গড়ার লক্ষ্য অর্জনে ব্যাপক অঙ্গণে বনায়ন করতে গাছের চারা উৎপাদনের ক্ষেত্রে নীতিনির্ধারকদের সহায়ক দলিল হবে।

Keywords: Flowering, Fruiting and seed maturity, Phenology, Recalcitrant seed, Forest and plantation tree species

Introduction

Phenology is the study of the timing of recurring biological events where it not only provides knowledge about plant growth but also supportive to the afforestation programs (Kumar *et al*. 2014, Nath 2012). In identifying the quality fruits and seeds, the knowledge of phenotypic or physical characteristics is an important factor (Cantín *et al*. 2010). Phenological traits can explain the evolution of plants including their flowering, fruiting, and seed maturity behavior influenced by the timing of biotic and abiotic events (Davies *et al*. 2013; Forrest and Miller-Rushing 2010, Khanduri 2014). Though it has a significant impact on individual species to whole ecosystems, it usually an overlooked aspect of plant ecology (Cleland *et al*. 2007, Omondi *et al*. 2016).

Seed is a fundamental element of plant life cycle, while intact as a storehouse of genetic traits, necessary for regeneration, disperse, establish, and develop to maintain the species heredity (Nambara and Nonogaki 2012). It is the most important reproductive part for introducing a plant in any area and in establishing a plantation. Production of seeds in sufficient quantities will go in vain if plant producers do not know the seed collection time of the desired species (Hasnat *et al*. 2016). Seed quality is, therefore, of critical importance in determining many options and outcomes in producing seedlings (Aras *et al*. 2007). However, the basic knowledge of phenology is essential for anyone involved in seed collection and supply, both in order to identify fruits or seeds and to design processing procedures (Vidyarthi and Tripathi 2002).

The term ‘recalcitrance’ refers to seeds that undergo no maturation drying (Berjak *et al*. 1989, Radwan *et al*. 2014), as the final phase of development tolerate very little post-shedding desiccation and are often chilling-sensitive. Such seeds are not storable by applying any of the methods used for drying orthodox seeds (Berjak *et al*. 1989, Walters *et al*. 2013). By nature, recalcitrant seeds are short-lived, most commonly found in moist regions with an invariant climate. The seeds either germinate or eaten by animals in the wild (Berjak and Pammenter 2007, Lee *et al*. 2012). In addition, recalcitrant seeds are mainly fleshy seeds produced by woody plants of both the temperate zone and the tropics and generally forest trees of the families Araucariaceae and Dipterocarpaceae (Kozlowski and Pallardy 1997). However, mangrove plants are a special example of recalcitrant seeds, but the phenomenon is much more widespread and is seen in plantation species as well (Srivastava 2002).

A good, healthy, successful plantation depends on seed quality and seed quality primarily depends on the physical quality of fruits and seeds (Barracosa *et al*. 2007). However, the study of phenotypic characteristics of fruits and seeds of natural and planted tree species in Bangladesh is only at the pioneer stage (Vozzo 2002). Some researchers reported the phenological behaviors such as flowering, fruiting and seed collection time of different species (Alvim and Alvim 1978, Anwar

and Takewaka 2014, Borchert 2000, Hasnat *et al*. 2016, Jadeja and Nakar 2010, Kushwaha *et al*. 2011a;b, Motaleb and Hossain 2010, Nahar *et al*. 2010, Pezzini *et al*. 2014, Rahman and Islam 2015, Sheikh and Matin 2007), but studies on phenology of solely recalcitrant seeds has yet not been found. Therefore, the present study aimed to generate a physical feature and document with general information about the phenological characteristics of recalcitrant seeds of Bangladesh which will help the foresters and other stakeholders about the timing of flowering, fruiting, and seed maturity as well as information to collect desired fruits and seeds in time.

Materials and Methods

The study was carried out during June 2017 to December 2018 at Seed Research Laboratory of Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh. In the study, both primary and secondary data were collected. Natural, plantation and homestead forests of Hathazari, Boalkhali, Hazarikhil, Dohazari, Rangamati, Kaptai, Ukhiya, Bandarban, Khagrachari, and Chittagong University campus were visited repeatedly for primary data collection. Recalcitrant fruits and seeds of 74 tree species were collected from fields, and preserved in the Seed Research Laboratory after identification and verification. Flowering, fruiting and seed collection time were recorded for most of the species. However, few data on phenological behaviors were collected from field guides and existing research documents. The data were verified with the existing reports by different researchers (Ahmed *et al*. 2008;2009, Brandis 1906, Heinig 1925, Hasnat *et al*. 2014, Hasnat *et al*. 2018, Hasnat *et al*. 2019, Hossain *et al*. 2013, Hossain and Ahmed 2008, Hossain and Hossain 2014, Motaleb and Hossain 2010, Rahman *et al*. 2017, Uddin and Hassan 2010, Uddin and Hassan 2018) studied on natural, plantation and homestead forests.

Results

The study revealed that 74 tree species are belonging to 55 genera and 31 families. Maximum (12.16%) species were found in Anacardiaceae family followed by Myrtaceae (10.81%) and Dipterocarpaceae (8.11%) whereas 14 species found from 14 different families (Table 1).

Table 1. Flowering, fruiting and seed collection time of 74 recalcitrant seed-bearing tree species in Bangladesh

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
1	Annonaceae	*Annona reticulata*	Nona Ata	A	Oct-Nov	Jan-Feb	Mar-Apr
2		*Annona squamosa*	Sharifa	A	Mar-Apr	Oct-Nov	Jan-Feb
3	Anacardiaceae	*Bouea oppositifolia*	Miriam, Mailam	D	Nov-Jan	Jan-May	May-Jun
4		*Drimycarpus racemosus*	Kodi-barela	D	Sep-Nov	Mar-Apr	May-Jun
5		*Holigarna caustica*	Barela	D	Mar-May	May-Jul	Jun-Jul

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
6		*Lannea coromandelica*	Jial Bhadi	D	Mar-Apr	May-Jul	Jul-Aug
7		*Mangifera indica*	Aam	D	Jan-Feb	Apr-Jun	May-Jul
8		*Mangifera longipes*	Jangli Aam	D	Feb-Apr	Apr-Sep	Sep-Nov
9		*Mangifera sylvatica*	Uri Aam	D	Jan-Feb	Feb-Apr	May-Jun
10		*Semecarpus anacardium*	Beula, Bhela	D	May-Jun	Oct-Nov	Feb-Mar
11		*Swintonia floribunda*	Civit	D	Feb-Apr	Apr-May	May-Jun
12	Arecaceae	*Arenga pinnata*	Chini Tal	D	Mar-Apr	Jul-Aug	Dec-Jan
13	Apocynaceae	*Carissa carandas*	Karamcha	B	Mar-Jun	May-Oct	Sep-Nov
14		*Wrightia arborea*	Dud Kuruch	F	May-Jul	Jun-Nov	Sep-Jan
15	Araucariaceae	*Araucaria cunninghamii*	Araucaria	C	Jun-Jul	Sep-Oct	Dec-Jan
16	Boraginaceae	*Cordia dichotoma*	Bohal	D	Mar-Apr	Apr-Aug	Sep-Oct
17	Celastraceae	*Lophopetalum wightianum*	Raktan	C	Dec-Jan	May-Jun	Aug-Sep
18	Clusiaceae	*Garcinia acuminata*	Kuki	B	Sep-Oct	Mar-Apr	Jun-Jul
19		*Garcinia cowa*	Kau	B	Feb-Apr	Mar-Jul	May-Aug
20		*Garcinia xanthochymus*	Dephal	B	Mar-Apr	Apr-May	Apr-May
21		*Messua ferrea*	Nageshwar	C	Feb-May	Mar-Aug	Jun-Oct
22	Combretaceae	*Anogeissus acuminata*	Chakwa	P	Jan-Feb	Mar-Apr	May-Jun
23		*Terminalia bellerica*	Bohera	D	Mar-May	Jan-Feb	Jan-Feb
24	Datiscaceae	*Tetrameles nudiflora*	Chandul	C	Mar-Apr	May-Jun	Aug-Oct
25	Dilleniaceae	*Dillenia indica*	Chalta	D	May-Jul	Jul-Dec	Dec-Feb
26		*Dillenia pentagyna*	Hargaza	B	Feb-Apr	Apr-May	May-Jun
27	Dipterocarpaceae	*Anisoptera scapula*	Boilam	P	Dec-Jan	Mar-Apr	Apr-May
28		*Dipterocarpus alatus*	Dhullya Garjan	N	Dec-Jan	Jan-Apr	Apr-May
29		*Dipterocarpus costatus*	Baittya Garjan	N	Dec-Feb	Feb-Apr	Apr-May
30		*Dipterocarpus turbinatus*	Telia Garjan	N	Mar-Apr	Apr-Jun	May-Jun
31		*Hopea odorata*	Telsur	N	Mar-Apr	May-Jun	May-Jun
32		*Shorea robusta*	Sal	S	Mar-Apr	Apr-Jun	Jun-Jul
33	Euphorbiaceae	*Phyllanthus acidus*	Orboroi	D	Mar-May	May-Aug	Aug-Dec
34		*Phyllanthus emblica*	Amloki	D	Nov-Dec	Mar-Apr	Jan-Feb
35		*Trewia nudiflora*	Pitali	B	Mar-Apr	Apr-Jun	Jul-Aug
36	Fabaceae	*Gliricidia sepium*	Bashanta Manjuri	P	Jan-Mar	Mar-May	Apr-May
37		*Ormosia robusta*	Ormosia	P	Feb-Mar	May-Jun	May-Jun
38		*Pongamia pinnata*	Kerong	P	Apr-Jun	Feb-May	Apr-Jun

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
39		*Pterocarpus indicus*	Paduk	P	Mar -Apr	Apr-May	May-Jun
40	Flacourtiaceae	*Flacourtia jangomas*	Painnagula	B	Mar-May	Apr-Jun	Jul-Oct
41		*Hydnocarpus laurifolius*	Hiddigach	B	Jul-Sep	Aug-Dec	Dec-Feb
42	Lauraceae	*Cinnamomum verum*	Dalchini	B	Jan-Feb	Feb-Mar	Feb-Mar
43	Lecythidaceae	*Careya arborea*	Kumbi	C	Apr-May	May-Jun	Jun –Jul
44	Magnoliaceae	*Michelia champaca*	Champa	C	Mar-May	Apr-Jun	Jun-Jul
45	Meliaceae	*Azadirachta indica*	Neem	C	Mar-Apr	Apr-May	Jun-Jul
46	Moraceae	*Artocarpus chama*	Chapalish	D	Dec-Mar	Feb-Apr	May-Jun
47		*Artocarpus lachucha*	Barta /Dewa	D	Mar-Apr	Apr-Jun	May-Jun
48	Moringaceae	*Moringa oleifera*	Sajna	P	Oct-Dec	Dec-Feb	Dec-Feb
49	Myrsinaceae	*Aegiceras corniculata*	Kholshi	C	Mar-May	May-Aug	Jul-Aug
50	Myrtaceae	*Melaleuca leucadendrone*	Melaleuca	C	Mar-May	Apr-Jun	Jun –Jul
51		*Syzygium balsamea*	Buti-jam	B	Oct-Nov	Dec-Feb	Feb-Mar
52		*Syzygium cumini*	Kala Jam	B	Feb-Mar	Mar-Apr	Apr-May
53		*Syzygium firmum*	Dhaki Jam	B	Feb-Mar	Mar-Apr	Apr-May
54		*Syzygium formosum*	Paniya Jam	B	Dec-Jan	Jun-Jul	Sep-Oct
55		*Syzygium fruiticosum*	Puti Jam	B	Mar-Apr	Apr-Jun	Apr-Jun
56		*Syzygium jambos*	Gulab Jam	B	Mar-Apr	Apr-Jun	Apr-Jun
57		*Syzygium malaccense*	Jamrul	B	Feb-Mar	May-Jun	Aug-Sep
58	Oxalidaceae	*Averrhoa bilimbi*	Belamboo	B	Oct-Dec	Nov-Feb	Feb-Apr
59		*Averrhoa carambola*	Kamranga	B	Sep-Oct	Oct-Mar	Feb-Apr
60	Rhizophoraceae	*Bruguira gymnorrhiza*	Kankra	D	Dec-Feb	Feb-Mar	Mar-Apr
61		*Bruguira parviflora*	Rohinia	B	Jan-Feb	Apr-May	Jun-Jul
62		*Ceriops decandra*	Goran	B	Jan-Mar	Mar-Jun	May-Jun
63		*Rhizophora apiculata*	Bhora, garjan	B	Oct-Nov	Feb-Mar	Apr-May
64	Rubiaceae	*Haldina cordifolia*	Haldu	B	Apr-Jul	Jun-Dec	Dec-Feb
65		*Mitragyna diversifolia*	Phul Kadam	C	Aug-Sep	Oct-Nov	Jan-Feb
66		*Mitragyna parvifolia*	Puti Kadam	F	Nov-Dec	Dec-Jan	Jan-Feb
67	Rutaceae	*Aegle marmelos*	Bel	B	Apr-Jul	Jun-Dec	Sep-Dec
68		*Limonia acidissima*	Kotbel	B	Feb-Apr	Mar-Oct	Oct-Dec
69	Sapindaceae	*Schleichera oleosa*	Kusum	B	Mar-May	May-Oct	Oct-Nov
70	Sapotaceae	*Madhuca longifolia*	Mahua	B	Mar-May	Apr-Aug	Jul-Aug
71		*Palaquim polyanthum*	Tali	B	Mar-Apr	May-Jun	Jul-Aug

Sl. No.	Family name	Scientific name	Local name	Fruit type*	Peak flowering time	Peak fruiting time	Peak seed collection time
72	Sterculiaceae	*Firmiana colorata*	Udal	B	Mar-Apr	Apr-May	Apr-May
73		*Pterospermum semisagittatum*	Lana Assar	B	Apr-Jun	Jun-Aug	Jul-Aug
74	Thymelaeaceae	*Aquilaria malaccensis*	Agar	C	May-Jul	Jul-Sep	Aug-Oct

[Here, *A: Achene, B: Berry, C: Capsule, D: Drupe, F: Follicle, N: Nut, P: Pod, S: Samara]

The fruit types of the studied species were categorized into Achene, Berry, Capsule, Drupe, Follicle, Nut, Pod, and Samara. Maximum (39.19%) fruits were recorded under the Berry category followed by Drupe (24.32%) and Capsule (14.86%), whereas only 1.35% was recorded from Samara (Fig. 1).

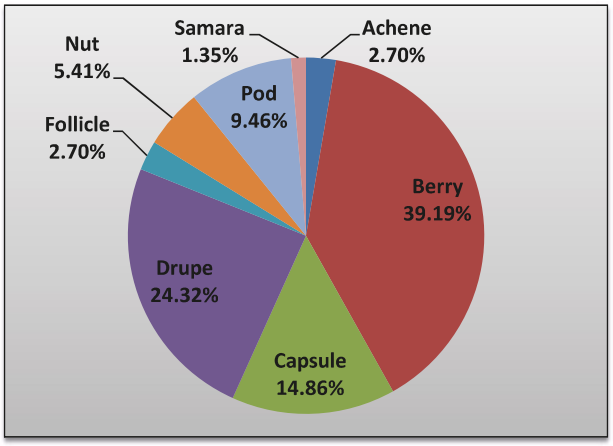

Figure 1. Fruits belonging to different categories

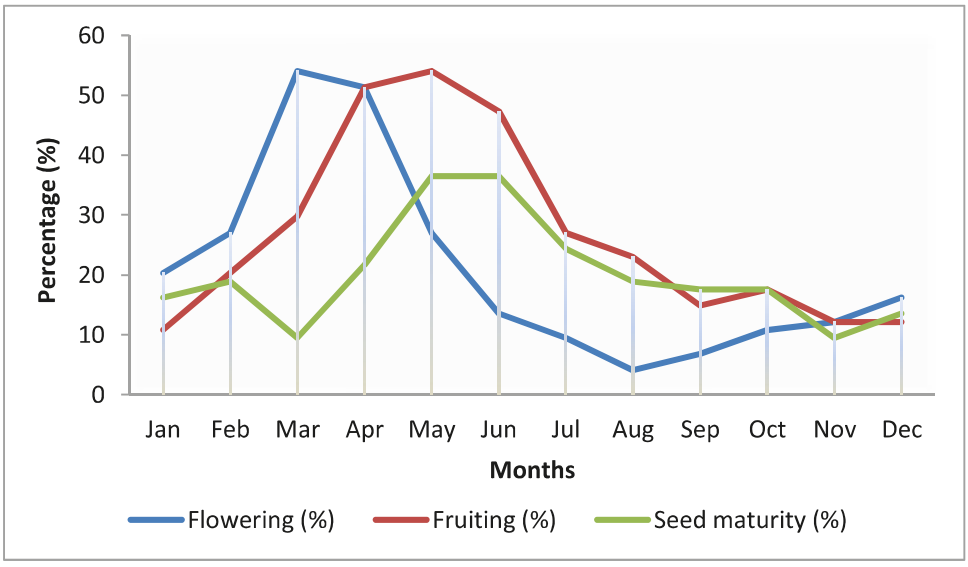

Figure 2. Time of flowering, fruiting and seed maturity of 74 recalcitrant seed-bearing tree species in Bangladesh

The graphical presentation of field observation revealed that flowering, fruiting and seed maturity occurred round the year. Visible flowering time was between January and May. Maximum trees (54.05%) bloomed in March and minimum (4.05%) flower blooming occurred in August. Results revealed that noticeable fruiting was found in April to June, fruiting of maximum species (54.05%) occurred in May, whereas minimum (10.81%) in January. The prominent seed collection time varied from April to July, maximum seeds (36.49%) were available for collection during May and June respectively, whereas minimum (9.46%) in March and November respectively (Fig. 2).

Discussion

Phenological behaviors, such as flowering, fruiting and seed maturity time of trees are very important as they are the indisputable factors of seed biology and regeneration process as well as forest dynamics (Dey 2006, Hasnat *et al*. 2016). The present study is in agreement with the findings of Hossain and Ahmed (2008), Kaur et al. (2013), Rahman *et al*. (2018), Schmidt and Jøker (2000), Singh and Kushwaha (2005), Upadhyay and Mishra (2010), Vashistha *et al*. (2009) where they studied different species from different regions of the world and revealed that phenological characteristics varied with time and species. In Bangladesh, Hasnat *et al*. (2016) recorded flowering, fruiting and seed maturity time of common 65 plantation tree species where they found the best time for collecting viable recalcitrant seeds was May and June that also supports the present findings. The same results found by Hasan (1971) that seeds of most of the tree species may be collected from May to June.

The present study also supported by the findings of Motaleb and Hossain (2010) where they reported that most of the fruits and seeds become available for collection from May to September. Seed collection time of some tropical and subtropical species represented by Schmidt (2000), which supports this study too. Findings from different researches (Bajpai *et al*. 2012, Bhat 1992, Kumar *et al*. 2014, Kushwaha *et al*. 2011a, Mishra *et al*. 2006, Singh and Kushwaha 2006) revealed that flowering and fruiting of most species occurred just before the rains that also supports the findings of the present study.

Conclusion

Knowledge on phenological behaviors of trees, e.g. flowering, fruiting, and seed collection time is fundamental for any forestry programs. Recalcitrant seeds have short viability ranging from few days to weeks. Lack of proper information about the flowering, fruiting, and seed maturity traits of recalcitrant seed trees may delayed afforestation or reforestation programs and may lead to a failure of plantation establishment. The study elucidated the information on flowering, fruiting and seed collection time of 74 recalcitrant seed tree species from natural and plantation forests of Bangladesh. The information may be useful to government and non-government organizations, policymakers, extension officers, foresters, general nurserymen, and local plantation growers.

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References

Ahmed, Z.U.; Begum, Z.T.; Hassan, M.A.; Khondker, M.; Kabir, S.M.H.; Ahmad, M.A.T.A.; Ahmed, A.T.A.; Rahman, A.K.A. and Haque, E.U. 2008. Encyclopedia of flora and fauna of Bangladesh. *Asiatic Society of Bangladesh*, Dhaka.

Alvim, P.T. and Alvim, R. 1978. Relation of Climate Growth Periodicity. *In*: Tomlinson, P.B. and Zimmermann, M.H. (eds.). Tropical Trees as Living Systems. Cambridge University Press, Cambridge, UK. 445-464 pp.

Anwar, M.S. and Takewaka, S. 2014. Analyses on phenological and morphological variations of mangrove forests along the southwest coast of Bangladesh. *Journal of Coastal Conservation* 18(4): 339-357.

Aras, A.L.I.Y.E.; Akkemik, U. and Kaya, Z. 2007. *Hippophae rhamnoides* L.: fruit and seed morphology and its taxonomic problems in Turkey. *Pakistan Journal of Botany* 39(6): 1907-1916.

Bajpai, O.; Kumar, A.; Mishra, A.K.; Sahu, N.; Behera, S.K. and Chaudhary, L.B. 2012. Phenological study of two dominant tree species in tropical moist deciduous forest from the Northern India. *International Journal of Botany* 8(2): 66-72.

Barracosa, P.; Osorio, J. and Cravador, A. 2007. Evaluation of fruit and seed diversity and characterization of carob (*Ceratonia siliqua* L.) cultivars in Algarve region. *Scientia Horticulturae* 114(4): 250-257.

Berjak, P. and Pammenter, N.W. 2007. From *Avicennia to Zizania*: seed recalcitrance in perspective. *Annals of Botany* 101(2): 213-228.

Berjak, P.; Farrant, J.M. and Pammenter, N.W. 1989. The Basis of Recalcitrant Seed Behaviour. In: Taylorson, R.B. (ed.). Recent Advances in the Development and Germination of Seeds. *NATO ASI Series* (Series A: Life Sciences), vol. 187. Springer, Boston, MA. 89-108 pp. https://doi.org/10.1007/978-1-4613-0617-7_8.

Bhat, D.M. 1992. Phenology of tree species of tropical moist forest of Uttara Kannada district, Karnataka, India. *Journal of Biosciences* 17(3): 325-352.

Borchert, R. 2000. Organismic and environmental controls of bud growth in tropical trees. *In*: Viemont, J. D. and Crabbe, J. (eds.). Dormancy in Plants: from Whole Plant Behavior to Cellular Control. CAB International, Wallingford. 87-107 pp.

Brandis, D. 1906. Indian Trees. *International book distributor*, Dehradun.

Cantín, C.M.; Gogorcena, Y. and Moreno, M.Á. 2010. Phenotypic diversity and relationships of fruit quality traits in peach and nectarine [*Prunus persica* (L.) Batsch] breeding progenies. *Euphytica* 171(2): 211-226.

Cleland, E.E.; Chuine, I.; Menzel, A.; Mooney, H.A. and Schwartz, M.D. 2007. Shifting plant phenology in response to global change. *Trends in Ecology and Evolution* 22(7): 357-365.

Davies, T.J.; Wolkovich, E.M.; Kraft, N.J.; Salamin, N.; Allen, J.M.; Ault, T.R.; Betancourt, J.L.; Bolmgren, K., Cleland, E.E., Cook, B.I. and Crimmins, T.M. 2013. Phylogenetic conservatism in plant phenology. *Journal of Ecology* 101(6): 1520-1530.

Dey, T.K. 2006. Floristic composition of Chittagong Hill Tracks and Cox's Bazar Forests. *Useful Plants of Bangladesh* (In Bengali) 2nd edition. Chittagong. 966-969 pp.

Forrest, J. and Miller-Rushing, A.J. 2010. Toward a synthetic understanding of the role of phenology in ecology and evolution. *Philosophical Transactions of the Royal Society B: Biological Science 365* (1555): 3101–3112.

Hasan, S.M. 1971. Problems of seed supply for the plantation program in Bangladesh. *Forest Dale News* 4(1): 8.

Hasnat, G.N.T.; Hossain, M.K. and Hossain, M.A. 2016. Flowering, fruiting and seed maturity of common plantation tree species in Bangladesh. *Journal of Bioscience and Agriculture Research* 7(1): 583-589.

Hasnat, G.N.T.; Hossain M.A. and Hossain M.K. 2018. Rehabilitation of degraded landscape by improving germination of Raktan (*Lophopetalum wightianum*) - a native threatened tree species of Bangladesh. *Bangladesh Agriculture* 8(1): 23-31.

Hasnat, G.N.T.; Hossain, M.A. and Hossain, M.K. 2019. Pre-Sowing treatments accelerate germination percent for restoration of fourteen threatened tree species in Bangladesh. *Journal of Tropical Forestry and Environment* 9(2): 36-45.

Hasnat, G.N.T.; Hossain, M.K.; Bhuiyan, M.K. and Alam, M.S. 2014. Effect of pre-sowing treatments on germination and initial growth of seedlings of Kusum (*Schleichera oleosa*). *International Journal of Usufructs Management* 15(1): 3-9.

Heinig, R.L. 1925. List of Plants of Chittagong Collectorate and Hill Tracts. *The Bengal Government Branch Press, Darjeeling, India*. 84 pp.

Hossain, M.A.; Hossain, M.K.; Salam, M.A. and Rahman, S. 2013. Composition and diversity of tree species in Dudhpukuria-Dhopachori wildlife sanctuary of Chittagong (South) forest division, Bangladesh. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* 4(2): 1447-1457.

Hossain, M.K. and Ahmed, F.U. 2008. Biponnoprai Brikkha Projatir Nursery Manual (Bangla version). Arannayk Foundation, Banani, Dhaka-1213, Bangladesh. 95 pp.

Hossain, M.K. and Hossain, M.A. 2014. Biodiversity of Chunati Wildlife Sanctuary: Flora. Arannayk Foundation and Bangladesh Forest Department, Dhaka, Bangladesh. 176 pp.

Jadeja, B.A. and Nakar, R.N. 2010. Phenological studies of some tree species from Girnar reserve forest Gujarat India. *Plant Archives* 10(2): 825-828.

Kaur, G.; Singh, B.P. and Nagpal, A.K. 2013. Phenology of some Phanerogams (trees and shrubs) of Northwestern Punjab, India. *Journal of Botany* 2013:1-10. http://dx.doi.org/10.1155/2013/712405.

Khanduri, V.P. 2014. Annual variation in floral phenology and pollen production in *Lagerstroemia speciosa*: an entomophilous tropical tree. *Songklanakarin Journal of Science and Technology* 36(4): 389–396.

Kozlowski, T.T. and Pallardy, S.G. 1997. Growth Control in Woody Plants. *Academic press*, *San Diego*. 643 pp.

Kumar, V.; Patel, R.; Singh, S.K.; Desai, B.S. and Chourasia, S. 2014. Studies on phenological characteristics of different forest trees of South Gujarat, India. *Plant Archives* 14(2): 1015-1021.

Kushwaha, C.P.; Tripathi, S.K. and Singh, K.P. 2011a. Tree specific traits affect flowering time in Indian dry tropical forest. *Plant Ecology* 212(6): 985-998.

Kushwaha, C.P.; Tripathi, S.K.; Tripathi, B.D. and Singh, K.P. 2011b. Patterns of tree phenological diversity in dry tropics. *Acta Ecologica Sinica* 31(4): 179-185.

Lee, A.K.; Slovin, J.P. and Suh, J.K. 2012. Dehydration intolerant seeds of *Ardisia* species accumulate storage and stress proteins during development. *Horticulture, Environment, and Biotechnology* 53(6): 530-538.

Mishra, R.K.; Upadhyay, V.P.; Bal, S.; Mohapatra, P.K. and Mohanty, R.C. 2006. Phenology of species of moist deciduous forest sites of Similipal biosphere reserve. *Lyonia* 11(1): 5-17.

Motaleb, M.A. and Hossain, M.K. 2010. Phenology of native tree species in Tankawati Natural forest, Chittagong (South) Forest Division, Bangladesh. *Indian Journal of Tropical Biodiversity* 18(1): 67-71.

Nahar, K., Ahamed, K.U., and Fujita, M. 2010. Phenological variation and its relation with yield in several wheat (*Triticum aestivum* L.) cultivars under normal and late sowing mediated heat stress condition. *Notulae Scientia Biologicae* 2(3): 51-56.

Nambara, E. and Nonogaki, H. 2012. Seed Biology in the 21st Century: Perspectives and New Directions. *Plant and Cell Physiology* 53(1): 1–4. https://doi.org/10.1093/pcp/pcr184

Nath, N. 2012. Phenological study of some tree species of Sri Surya pahar of Goalpara district, Assam. *Indian Journal of Fundamental and Applied Life Sciences* 2(1): 102-104.

Omondi, S.F.; Odee, D.W.; Ongamo, G.O.; Kanya, J.I. and Khasa, D.P. 2016. Synchrony in leafing, flowering, and fruiting phenology of *Senegalia senegal* within Lake Baringo woodland, Kenya: Implication for conservation and tree improvement. *International Journal of Forestry Research* 2016:1-11.http://dx.doi.org/10.1155/2016/6904834

Pezzini, F.F.; Ranieri, B.D.; Brandão, D.O.; Fernandes, G.W.; Quesada, M.; Espírito-Santo, M.M. and Jacobi, C.M. 2014. Changes in tree phenology along natural regeneration in a seasonally dry tropical forest. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology* 148(5): 965-974.

Radwan, A.; Hara, M.; Kleinwächter, M. and Selmar, D. 2014. Dehydrin expression in seeds and maturation drying: a paradigm change. *Plant Biology* 16(5): 853-855.

Rahman, M.R.; Hossain, M.K.; Hossain, M.A and Haque, M.S. 2017. Floristic Composition of Madhupur National Park (MNP), Tangail, Bangladesh. *Bangladesh Agriculture* 7(1): 27-45.

Rahman, M.R.; Hossain, M.K.; Mariam, H.; Rahman, M.A. and Mezan-Ul-Hoque, M. 2018. Procuring quality seeds and seed orchard establishment in Bangladesh: miles to go. *International Journal of Usufructs Management* 19: 70-85.

Rahman, M.M. and Islam, S.A. 2015. Phenophases of five mangrove species of the Sundarbans of Bangladesh. *International Journal of Business, Social and Scientific Research* 4: 77-82.

Schmidt, L. 2000. Guide to Handling Tropical and Subtropical Forest Seed. Danida Forest Seed Center, Krogerupvej 21, DK – 3050 Humleback, Denmark. 511 pp.

Schmidt, L. and Jøker, D. 2000. Seed Leaflet (*Swietenia mahagoni* L. Jacq.). Danida Forest Seed Centre, Krogerupvej 21, DK-3050 Humlebaek, Denmark. 1 p.

Sheikh, A.H. and Matin, A.M.M. 2007. Seed morphology and germination studies of *Dalbergia sissoo* Roxb. at nursery stage in Bangladesh. *Journal of Agriculture and Biological Sciences* 3(1): 35-39.

Singh, K.P. and Kushwaha, C.P. 2005. Emerging paradigms of tree phenology in dry tropics. *Current Science* 89: 964-975.

Singh, K.P. and Kushwaha, C.P. 2006. Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Annals of Botany* 97(2): 265-276. doi: 10.1093/aob/mcj028

Srivastava, L.M. 2002. Plant Growth and Development. *Academic Press, San Diego*. 774 pp. https://doi.org/10.1016/B978-012660570-9/50160-X

Uddin, M.Z. and Hassan, M.A. 2010. Angiosperm diversity of Lawachara National Park (Bangladesh): a preliminary assessment. *Bangladesh Journal of Plant Taxonomy* 17(1): 9-22.

Uddin, S.N. and Hassan, M.A. (eds.) (2018). Vascular Flora of Chittagong and the Chittagong Hill Tracts (Vol. 2). Bangladesh National Herbarium, Ministry of Environment, Forest and Climate Change, Government of the People's Republic of Bangladesh, Bangladesh. 1-1060 pp.

Upadhyay, V.P. and Mishra, P.K. 2010. Phenology of mangroves tree species on Orissa coast, India. *Tropical Ecology* 51(2): 289-295.

Vashistha, R.K.; Rawat, N.; Chaturvedi, A.K.; Nautiyal, B.P.; Prasad, P. and Nautiyal, M.C. 2009. An exploration on the phenology of different growth forms of an alpine expanse of North-West Himalaya, India. *New York Science Journal* 2(6): 29-41.

Vidyarthi, R.D. and Tripathi, S.C. 2002. A Text book of Botany. S. Chand and Company Ltd., New Delhi.

Vozzo, J.A. 2002. Tropical Tree Seed Manual. *Agriculture Hand book* 721. Washington DC, USA: USDA Forest Service.

Walters, C.; Berjak, P.; Pammenter, N.; Kennedy, K. and Raven, P. 2013. Preservation of recalcitrant seeds. *Science* 339(6122): 915-916.