1. **Title of the project**: *Study on Phenological Monitoring and Growth Stages of Selected Horticultural Fruit Trees*

Keywords: woody plants, ecology, developmental stages, fruit crops, climatic change, horticulture, seasons

2. **Objectives**
    a. Standardization of phenological monitoring methods to track tree phenology of horticultural fruit crops.
    b. To evaluate the response of tree phenology of horticultural fruit crops to changing climate.
    c. To evaluate the best management practice for manipulation of the climate change effect on horticultural fruit crops.

3. **Genesis and rationale of the project**: Researchers working on climate change predict that the rise of global temperature affects the life and ecosystems on the earth in various ways (IPCC 2007) and the most significant effect on the fruit tree crops would be the change in the phenology of growth and flowering (Chmielewski and Rötzer , 2001). And this change or shifts in phenology of flowering would affect the pollination as the flowering phenology of the fruit tree species and phenology of the pollinator shifts may not coincide (Rafferty and Ives. 2011). The horticultural fruit tree crops having highly economic and nutritional value and importance, the disruption of phenophases viz., leafing, flowering and fruiting would affect the availability and accessibility of the fruits in the markets. Hence, it is important to understand how the horticultural fruit tree crops are responding to their environment and how the phenology shifts are happening among the genotypes or varieties. As the response of some of the varieties and genotypes to changing climatic conditions varies, the study of the phenology of the fruit trees at the genotype and variety level needs to be undertaken. Therefore, the proposed study of phenological monitoring of selected fruit tree crops viz., Bael (*Aegle marmelos*), Jackfruit (*Artocarpus heterophyllus*) Jamun (*Syzygium cumini*) and Tamarind (*Tamarindus indica*) under the Chota Nagpur plateau climatic conditions is being undertaken owing to the importance of the selected fruit tree species based on their nutritional, economical and ecological aspects. The ultimate goal of the proposed project is documentation of how the stages of the tree's annual cycle are influenced by the environment and how these stages could be affected by climate change in the future and how we can manipulate the tree environment by management practices for better tree growth and development (leafing, flowering and fruiting) and fruit yield.

4. **Knowledge/Technology gaps and justification for taking up the present project**: The proposed study would give an insight into how the fruit tree phenology is changing according to the climate in both the long term and the short term at Chota Nagpur plateau conditions. As the phenology of any species is sensitive to environmental variation because of its linkage to most aspects of physiological and

ecosystem processes, the understanding of the tree phenology of the fruit crops and building a common phenological data sets of the selected fruit tree species viz., Bael (*Aegle marmelos*), Jackfruit (*Artocarpus heterophyllus*) Jamun (*Syzygium cumini*) and Tamarind (*Tamarindus indica*) could lead us to understand the climate change impact on people and ecosystems. The data sets so built would be made available for the public good for a variety of research and science applications, which would aid the scientists, the resource managers and others conducting phenological and ecological monitoring or research to consider the utilization of these datasets for building models for tracking the seasonal activity of trees and their pollinators.

5. **Critical review of the present status of the technology at national and international levels along with complete references**: Reza (2014) evaluated 75 bael germplasm during 2013-14 at the ARS, Burirhat, Rangpur, Bangladesh and observed that the flowering time of different germplasm was from 2nd week of April (AM Bur-47) to 1st week of June (AM Bur-73). However, Singhal et al. (2012) reported that in their study on Bael genotypes, the phenological events (leaf fall, leaf emergence, floral bud break, flowering and fruiting) are nearly in the same wild and cultivated trees. In order to test the hypothesis that the fruiting phenology of a plant community is affected by both fluctuating predation pressure and the seed preference of predators, Poesie et al. (2011) conducted an experiment on 17 jackfruit species in a tropical peat swamp forest in Central Kalimantan, Indonesia. In their experiment, they found that the species with preferred seeds produced their fruits when predator activity is restricted. With an understanding that the flowering, fruiting and phenology is fundamental for making sound decisions on genetic conservation and management of tree species, Pushpakumara (2006) studied phenology of jackfruit and found that the complete synchrony of the female flowering phase with the male phase of a given individual. However later, Lina and Protacio (2015) observed that the production of female inflorescence of jackfruit 'EVIARC Sweet' was not continuous and occurred between January to June and November to December. And they reported that with the application of paclobutrazol at 1g a.i. m^{-1} of canopy diameter increased female inflorescence production and were produced in the months of August and September resulting in off-season fruits. In Jamun under Lucknow conditions, it is observed that the period for panicle emergence was from 3rd week of February through 2nd week of March (Bajpai et al., 2012). Chavan et al. (1999) studied flowering phenology in *Tamarindus indica* L. and observed that flowering was observed from the last week of March to fortnight of June and reported that it requires 25 days for completion of the blooming of buds. Similarly, researchers Ebeid and Ali (2015) conducted phenological studies for Jamun and Tamarind during 2013/2014 and 2014/2015 in Egypt and observed that though the flowering continued throughout the year, the flower initiation started from late January to late May in mature trees and from late January to mid May for sapling tree species. Chmielewski and Rötzer (2001) investigated the impact of climatic changes on the plant development in Europe using phenological data of the International Phenological Gardens for the period 1969–1998 and observed that the warming in the early spring (February–April) by 1°C caused the

advancement of the growing season of 7 days. Also, Polgar and Primack (2011) in their Tansley review mentions that the leaf-out is generally earlier in warmer years than in cooler years and that the onset of leaf-out has advanced in many locations and further states that the changes in the timing of leaf-out will affect carbon sequestration, plant–animal interactions, and other essential ecosystem processes. The response of tree species to temperature and day length for determining the cessation of tree growth varies between species, with some groups thought to rely exclusively on photoperiod (Howe et al. 1996). Thus the analysis of phenology data of the fruit crops gains importance.

6. **Brief note on Proprietary/Patent Perspective (for projects related to technology development)/Ethics/Animal Welfare/Bio Safety Issues**: Data sets developed in the project are made available publicly (public domain) via the CC0 public domain dedication.

7. **Expected output**
    i. Documentation of phenology of the fruit tree species as influenced by seasonal and interannual variations in climate.
    ii. Standardized phenology monitoring methods to track fruit tree plants for science and resource management applications.
    iii. Addition of new knowledge regarding the time of shoot growth, flowering and fruit set, and the relationships between these events and carbohydrate utilization within the tree, etc., which will allow grower to plan management practices in relation to the events occurring within the tree.
    iv. Data and information on genotypic variability of fruit tree species in phenology with reference to photoperiod, rainfall, temperature etc.; C:N ratios, carbon sequestration and other essential ecosystem processes
    v. A phenology model for fruit tree species.

    A document with data and information related to the phenology of the fruit tree species as influenced by seasonal and inter-annual variations in climate at the genotypic level would be brought out along with a standardized phenology monitoring method to track horticultural fruit tree plants. The new knowledge generated with respect to the genotypic differences in the time of shoot growth, flowering and fruit set, and the relationships between these events and carbohydrate utilization within the tree etc. will be generated. Finally, with the help of tree phenological models for bael, jamun, jackfruit and tamarind will help growers to plan management practices in relation to the events occurring within the tree.

8. Expected Benefits in Economic Terms: The possible economic benefits include better growing and marketing of fruits in study, economic benefit to the growers and nutritional security through fruits to the people.

9. **Practical utility**: The proposed project would give an insight into how the stages of horticultural fruit tree's annual cycle are influenced by the environment and how these stages could be affected by climate change in the future and how we can manipulate the tree environment by management practices for the tree growth and development (leafing, flowering and fruiting).

10. **Technical program** (brief)
    a. Materials: About 20 available germplasm each of Bael (*Aegle marmelos*), Jackfruit (*Artocarpus heterophyllus*) Jamun (*Syzygium cumini*) and Tamarind (*Tamarindus indica*) at ICAR RCER RC Ranchi farms.
    b. Techniques/Methodology
        i. Published standard phenological monitoring methods would be used to record leafing, flowering and fruiting of the 20 germplasm lines of Bael (*Aegle marmelos*), Jackfruit (*Artocarpus heterophyllus*) Jamun (*Syzygium cumini*) and Tamarind (*Tamarindus indica*) by tagging 50 branches on four directions of the canopy.
        ii. Standard laboratory analysis methods would be used for C:N ratio analysis during the seasons of all the germplasm
        iii. Weather parameters from aWhere - Agronomic Data & Agricultural Data Management (www.awhere.com/) would be consulted for the weather data.
        iv. For digital documentation of the tree phenology, the online India Biodiversity Portal (http://indiabiodiversity.org/) would be utilised.
    c. Instrumentation
        i. Binoculars, lab glassware and chemicals
        ii. Special material
        iii. Analytical tools
        iv. Free and open source statistical analysis packages

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11. Activities and Outputs Details

Objectives	Activity	Month & Year		Outputs
		Start	End	
Standardization of phenological monitoring methods to track tree phenology of horticultural fruit crops	Designing the experiment with the help of published methods for phenological monitoring of tree species.	09/15	11/15	Standardized protocol for data recording on all aspects of tree phenology
	Daily recording of weather parameters of the experiment location.	09/15	09/20	Weather parameters database
To evaluate the response of tree phenology to changing climate	Periodic recording of phenological observations.	12/15	12/20	Leafing, flowering and fruiting dates of trees
	Periodic testing of stem	12/15	12/20	Season and tree wise

	C:N ratios			C:N ratio
	'Ionomics' of trees - measurement of the total elemental composition of tree branches.	12/15	12/20	Tree Ionomics
	Annual data analysis and interpretation	12/15	12/20	Processed data and Publications
To evaluate the best management practice for manipulation of the climate change effect.	Application of Plant Growth Regulators on Trees	12/16	12/19	Tree growth & development
	Development of tree phenological models	12/17	12/20	Tree phenology model