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A REVIEW ON PLANT PHENOLOGY

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ABSTRACT

Plants are delicately adapted regularities to their surroundings and variation to the plant activity known as Phenology. The timing of reoccurring natural biological events that occur year after year provide an inevitable sign of the potential of climate change and vary the effects on plants. Plant phenology is regularly linked with climatic factors. Since plant phenology and climatic factors are frequently related, it is popular to have a better knowledge of the patterns and trends in plant phenology all through the world. Phenology shows the occasional appearance of life-cycle occasions. Phenology observes these vents and connect their seasonal variability to differences in the environment and the impact of temperature and dampness has been considered by numerous creators. Phenology right now gets plenteous consideration as the impacts of worldwide and territorial climate changes on vegetation are so clear. Complex intelligent between organ capacities and natural variables are basically capable for an assortment of species-specific phenological designs in tropical plants. This Review explores Plant Phenology responses due to Climate Change.

Keywords: Phenology, Climate Variability, Phenophase, Plant Response.

I. INTRODUCTION

Phenology is the study of how the environment, particularly seasonal changes in temperature and precipitation, affects the recurring events in the life cycles of plants. A specific phase of development, such as bud burst, blossoming fruiting, leaf-out, or senescence, can be referred to as phenophase.

II. WHAT IS PHENOLOGY?

When Carl Linnaeus established techniques for examining the connections among blooming and climate in the 1700s, he laid the groundwork for the field of phenology (Linnaeus et al., 2007). Charles Morren used the word "Phenology'' in the 1850s to refer to his observational research on annual blossoming (Morren et al., 1853).

Phenology is derived from the Greek term logos, referring to "to study" and phaino, which denotes "to appear, to come into view". Phenology is the scientific study of the timing of events in the life cycles of plants, animals, and microorganisms as well as how the environment influences those timings.

These life cycle events also known as Phenophases which take place in plants and include among other things such as, leaf budburst, first flower, last bloom, bud-burst, first mature fruit, harvest, and leaf shedding are examples of phenology, which has been defined as "the study of the timing of recurrent biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelationship within phases of the same or different species" (Badeck et al., 2004). Nonetheless, via impacting vegetative within and reproductive performances, the seasonal synchronization of phenology to climate may affect competitive interactions (Lechowicz & Koike 1995). As Over the years, the vegetative and reproductive cycles of plants have a rhythmic appearance. (Price et al., 1998).

III. WHAT IS PHENOPHASE?

In the yearly cycle of plant growth, Phenophase denotes discrete stages, especially in relation to seasonal events like blooming, leaf emergence, the various stages are important markers of how organisms adapt to environmental signals like temperature and photoperiod, and they are being studied more and more in relation to the effects of climate change on ecosystems. Schwartz observed that phenological shifts have been noted in a variety of species and geographical areas, and that a continuous pattern linking rising temperatures to early spring time events is the observation of phenological shifts (Schwartz et al., 2013). According to Polgar and Primack, this has major implications for ecosystem dynamics, including modified species interactions, altered species distributions, and altered productivity and biodiversity (Polgar and Primack 2011). Parmesan's (2007) work shows the need of introducing phenology into conservation and preservation efforts, as it is crucial for forecasting and overseeing natural reactions to climate change. To sum up, phenophases are essential to ecological dynamics, and research on them offers important new perspectives on how climate change affects ecosystem functioning and biodiversity.

Table 1: Sequence of Various Phenophase

Stage	Description
0	Development of buds, sprouting, and germination
1	Growing of leaves (main shoot)
2	Development of side shoots
3	Lengthening of the stem, rosette formation or development of the primary branch
4	Growth of sections of vegetative plants that can be harvested
5	Heading of the inflorescence (main shoot)
6	Flowering (main shoot)
7	Fruit development
8	Fruit and seed maturation or ripening
9	Senescence during the initial stage of hibernation

Table 2: Description of Various Phenophases

Stage	Description	Timeframe (Temperate Climate)	Reference
Vegetative Growth	Plants concentrate on developing larger, more complex leaves.	4-12 weeks	(Taiz *et al.*, 2015)
Seed Dormancy	A time when the seed undergoes physiological arrest, delaying early germination	Greatly varies (weeks to moths)	(Percival & Bandurski, 2014)
Germination	When a sed absorbs water, it emerges from dormancy and proceeds to grow roots and shoots.	2 – 10 Days	(Bewley *et al.*, 2013)
Seedling	As a young plant grows, its main root and shoot Systems develop and it forms real leaves.	2-4 weeks	(Salisbury & Ross, 2010)

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Budding	Development of embryonic shoot or flower structures inside of designated nodes.	1-2 weeks	(Jablonski & Jackson, 2006)
Flowering	Flowers open and develop, revealing their reproductive organs to be pollinated.	1-4 weeks	(Fahey & Davies, 2001)
Fruiting	Development and ripening of fruit with seeds	Greatly varies (weeks to months)	(Lord & Strauss, 2009)
Seed Dispersal	Releasing and distributing the parent plant's seeds.	Varies according to the dispersion technique	(Van der, Pijl 1982)
Leaf Senescence	Leaves gradually deteriorate and die.	Varies according to the species and the surrounding conditions.	(Van der Pijl, 1982)

IV. WHY PHENOLOGY?

In the modern world, Phenology research is vital since it provides insight into how climate change affects ecosystems and human populations. Scientists may learn a great deal about how global warming is affecting the timing of crucial biological events by keeping an eye on phenological fluctuations. These Changes may have a domino effect on ecosystems, disturbing the delicate species balance and influencing food security and farming methods. Additionally, Phenology research can help to design conservation plants that are more successful by helping us predict and address the difficulties brought on by shifting environmental conditions. To put briefly, it offers significance information for recognizing, preparing and reducing the adverse effects of global warming on our surroundings and mankind.

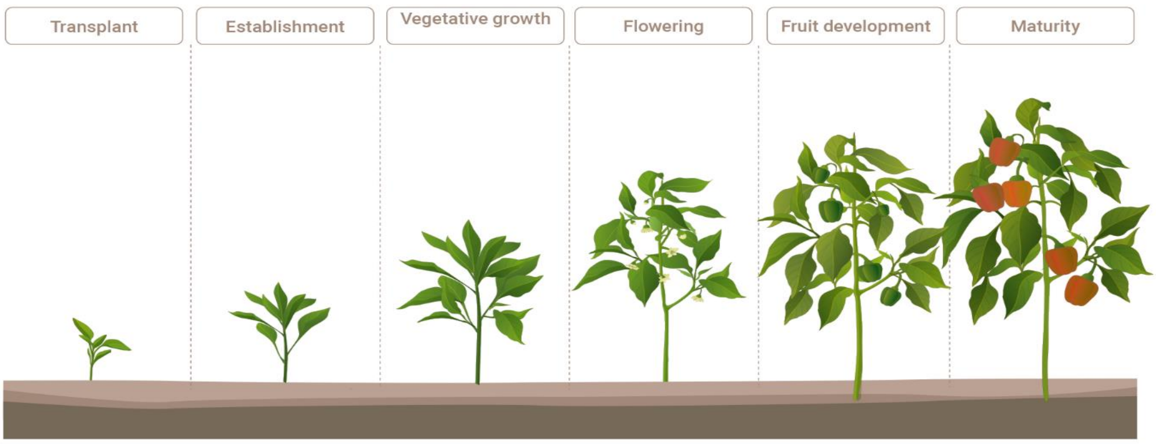
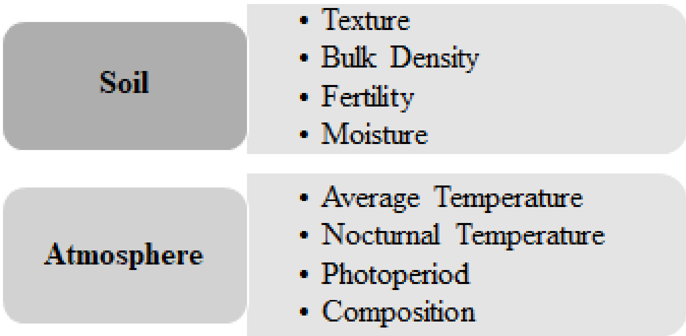


Figure 1: Various Phenophases of Plant

V. FACTORS AFFECTING PLANT PHENOLOGY



These interactions provide us with understanding of the general characteristics of plant growth and development as well as the consequences of the environment and how it affects the behavior of flowers and fruits (Zhang et al., 2006). The timing for various phenological events is significantly influences through abiotic conditions such as rain, temperature fluctuations, competition and the availability or absence of pollinators and herbivores (Kaur et al., 2013).

VI. PHENOLOGY DATA

There are Four sources account for all of Phenology data:

- Automated digital repeat Photography
- Satellite or Aerial Remote Sensing
- Ground based observations
- Historical plants held in museum collections (Schwartz et al., 1999).

VII. HOW TO STUDY PLANT PHENOLOGY?

(1) Standardized observation Techniques: For studying phenology in plants across many environments, use standardized procedures designed by organizations like the USA National Phenology Network (USA-NPN).

(2) Phenological observations: A key methodology is the direct investigation of plant phenophases like Blooming, Leaf emergence, Fruiting and Leaf falling. To study these phenomena, researchers frequently travel to the field on a regular basis (Schwartz, M.D., & Reiter, B.E.2000).

(3) Considering Climate Change and Environmental Variables: Recognize the possible impact of climate change and other environmental variables on phenology, along with the fact that phenological patterns are distinct to a certain place.

(4) Creating Phenological Networks: Gathering observational data systematically over long periods of time from multiple places is necessary to establish phenological networks. The study of regional and worldwide trends in phenology is made easier by such networks.

(5) Remote Sensing: Techniques like satellite imaging and aerial photography offer valuable data for examining broad patterns of phenology over a longer period of time (Richardson & Hollinger, 2007).

(6) Phenocams: They are automated cameras that are programmed with particular software to capture images of crops on a regular basis. Phenological occurrences across time can be characterized by analysis of these photos (Richardson et al., 2018).

(7) Herbarium Specimens: Researchers can identify prior phenological changes and compare them with present data by looking at preserved plant specimens in herbaria (Willis et al., 2008)

(8) Genomic Studies: Genes regulating phenological features and their response to environmental stimuli are identified by genomic mapping, genome-wide association studies (GWAS) and transcriptomics, which explore the genetic foundation of plant phenology. (Wilczek et al.,2009).

(9) Interviews & Surveys: To obtain traditional knowledge and observations of phenology, interviews and surveys with farmers, tribal members and local residents should be conducted (McCarter & Gavin, 2014)

VIII. APPLICATIONS OF PLANT PHENOLOGY

Phenomenology is valuable for research on climate change as well as for a wide range of scientific fields, including human health, forestry, agricultural, and biodiversity (Rumi et al., 2005). Likewise, it can support serval environmental and economical industries.

a) **Phenology in knowing the structures and functions of ecosystems:** Individual phenology plays a key role in figuring out the composition and function of ecosystems (Cleland et al., 2007). Phenology has a major effect on the distribution and abundance of species. In particular, phenology determines competitive interactions within and between species and even across trophic levels, as well as the fitness and reproductive success of both plants and animals.
b) **Phenology in medicine and health:** The use of phenology in the medical field is exemplified by the pollen forecasting technique. Due to the longer pollen season and its detrimental effects on the health and well-being of allergy sufferers, as well as increased healthcare expenses, spring has arrived earlier than usual in moderately temperate zones (Beggs, 2004). The pharmaceutical companies, scientists, doctors who specialize in allergic treatment, individuals with allergies, and authorities in matters of health and the environment may all utilize pollen predictions for a range of goals, including medication prevention and health promotion.
c) **Phenology in agriculture and forestry:** Understanding phenology and floral morphology serves as essential for studying breeding systems, especially when it comes to pollination. This applies to both agriculture and forestry. Reproductive biology studies are necessary for restoration and reintroducing it, and they will aid in the development of ways to protect the genetic potential of rare species. As a result, research on reproductive phenology assists in the formulation of plans to protect endangered species' genetic potential, which is essential for restoration programs.
d) **Phenology's application to tourism and leisure:** As tourism gains popularity, it is viewed as a means of promoting growth and reducing poverty. Activities like birdwatching, spring wildflower displays, and fall tree color are examples of phenology-driven activities that able to forecast when these kinds of occurrences would happen. When they experience in particular phenophases, like the first leaf, flowering, or leaf coloration, many plants have immense aesthetic value. So, according to (Zexing et al., 2015), there is a strong correlation between plant phenology and seasonal properties of the environment.

IX. CONCLUSION

Plant Phenology depicts how ecosystems react to shifting climatic circumstance. Researchers may learn more about how climatic variability and change affect ecosystem dynamics, human populations, and biodiversity through investigating the timing of plant life-cycle events. Plant phenology is researched in a variety of conditions and geographical areas using standardized observation techniques, remote sensing technology and historical data sources. The multidisciplinary benefit of phenology study is demonstrated by the range of sectors in which it is applied, from ecology and agriculture to medicine and tourism. Phenology learning will be especially important in directing conservation efforts, regulating agricultural practices, and minimizing the effects of climate change on both natural and human systems as long as it continues in changing climatic circumstances.

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