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The Effects of Global Warming on Plant Growth : A Systematic Analysis

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Abstract*: The impacts of climate change on plant phenology and distribution are reviewed here. Climate change is supported by several forms of information that may be used to reconstruct previous climates. These statistics originate from temperature measurements, glacier retreat, arctic sea ice loss, increasing sea levels, and worldwide precipitation. Additionally, actual facts have demonstrated that climate change has a broad variety of implications on life as we know it. Plant phenological features including flowering time, species richness and distribution, and assemblage composition are most affected by climate change. Plant species have expanded their ranges, become more species rich on alpine summits, and changed when they leaf out, flower, and fruit to adapt to the changing climate. Evolutionary adaptation may help natural populations cope with quick climatic change. The ability of species to profit from climate change may be affected by adaptive adaptations. Plant species may adapt to changing environments via phenotypic plasticity.*

Keywords: Phenology, Phenology, Plants, Ecosystems, Biodiversity, Adaptation

I. INTRODUCTION

Any change in the climate over time, whether brought on by human activity or natural variability, is referred to as climate change (IPCC 2007). The movement of heat into and out of the globe as well as the storage of heat in the atmosphere, land, ocean, and snow/ice are some of the processes that primarily control climate. In the end, the sun is the source of this heat. The oceans contain the majority of the heat stored at the Earth's surface, with the atmosphere containing just a relatively tiny portion of the total heat. Compared to the water, the heat flow into the atmosphere happens far more quickly. But since the ocean retains so much heat, variations in ocean temperature serve as a more accurate gauge of climate change than variations in air temperature.

To recreate previous climates, there are a variety of evidences supporting the reality of climate change from numerous sources. For example, temperature data over the last three decades have shown a about 0.6ºC global temperature increase (Hansen et al. 2006). According to Seiz and Foppa (2007), glaciers are thought to be among of the most sensitive indicators of climate change. The mass balance of snow inputs and melt outputs contributes to the measurement of glacier mass. The glaciers recede as the temperature rises unless there is an increase in snowfall to replenish the amount that has melted. The World Glacier Monitoring Service reports that glaciers are drastically declining globally. There were notable glacier retreats in the 1940s, and while conditions appeared stable or even increased in the 1920s and 1970s, the glaciers began to recede once more in the mid-1980s and have been doing so ever since.

The decrease of Arctic sea ice, both in terms of area and thickness, during the last several decades is another indication of the fast pace of climate change. According to satellite measurements, the average annual rate of decline of Arctic sea ice from 1979 to 2000 is presently 11.5 percent per decade (NSIDC 2013). An further indicator of climate change is the increase in sea levels and regional variations in precipitation. Over the last 40 years, the average worldwide sea level has risen at a pace of 1.8 millimeters per year, which is consistent with global warming. Relative to the last century, trends indicate that precipitation has declined in the Sahel, the Mediterranean, southern Africa, and parts of southern Asia, while it has risen considerably in eastern portions of North and South America, northern Europe, and northern and central Asia (IPCC 2007).

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Additionally, empirical data have shown that climate change has a wide range of effects on life as we know it. Phenological traits such plant blooming time (Walther et al. 2002, Parmesan 2006), breeding, and the arrival of migratory species (Both & Visser 2001) are a few of the most significant examples. Climate change also affects the distribution and richness of species as well as the make-up of assemblages (Root et al. 2003). When environmental circumstances change, a species' range may either remain the same or it may expand, decline, or move in response. Thus, the goal of this review study is to demonstrate how plant life cycles and distributions are affected by climate change, as well as how plants have evolved to withstand these effects.

Major causes of climate change

"Forcing mechanisms" or "climate forcings" are variables that have the potential to alter the state or condition of the climate (IPCC 2007). Climate forcing includes processes including fluctuations in solar radiation, shifts in the Earth's orbit, the formation of mountains and continental drift, and adjustments to greenhouse gas concentrations. Many feedbacks from climate change may either increase or decrease the original force. In response to climatic forcings, different elements of the climate system react differently. For example, the seas and ice caps react slowly, whereas other sections respond more rapidly.

One might categorize forcing methods as "external" or "internal." Internal forcing mechanisms, like the thermohaline circulation, are naturally occurring processes inside the climate system, but external forcing mechanisms, like variations in solar output, may be caused by humans or by natural processes (e.g., increasing emissions of greenhouse gases).

Internal influences

Ocean variability

Natural variations in the elements and interactions that make up the earth's climate system are what lead to internal climate variability. Examples of short-term changes (years to a few decades) that reflect climatic variability rather than climate change include the El Nino-Southern oscillation, the Pacific decadal oscillation, the North Atlantic oscillation, and the Arctic oscillation. However, changes to ocean processes, such thermohaline circulation, which takes place over longer periods of time, are crucial for the long-term redistribution of heat in the world's oceans as well as for the very slow and very deep flow of water.

External forcings

Solar radiation and volcanism

The global climate is impacted by both short- and long-term fluctuations in solar intensity. Solar variation is the shift in the sun's radiation output and spectral distribution over periods ranging from years to millennia. While there are periodic components to these fluctuations, the main solar variation is the roughly 11-year solar cycle, sometimes known as the sunspot cycle. With the previous three 11-year sunspot cycles, the total solar output has been estimated to have varied by around 0.1%, or 1.3 Watts per square meter (W/m2) (IPCC 2007). It is theorized that volcanic activity and fluctuations in the sun have influenced climate change. Eruptions have an impact on climate many times a century, and for a few years thereafter, they partly block solar radiation from reaching the Earth's surface, causing cooling. The second greatest terrestrial eruption of the 20th century, Mount Pinatubo's eruption in 1991, had a significant impact on the climate, whereas the first major eruption of the century happened in 1912 at Novarupta on the Alaska Peninsula. As a result, the temperature dropped by almost 0.5°C (0.9°F) worldwide. The area didn't have a summer in 1816 due to Mount Tambora's eruption in 1815 (Oppenheimer 2003).

Tectonic plate

The movement of tectonic plates, which reorganizes and creates topography over millions of years, may have an impact on both local and global patterns of climate and atmosphere-ocean circulation (Forest 1999).

The orientation of the continents shapes the seas, which in turn affects the circulation patterns within the oceans. Tectonic control over ocean circulation is shown by the development of the Panama Isthmus around 5 million years ago, which prevented direct mixing between the Atlantic and Pacific Oceans. This phenomena may have contributed to the ice cover in the Northern Hemisphere and had a significant impact on the ocean dynamics of the Gulf Stream today.

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About 300–360 million years ago, plate tectonics may have caused large-scale carbon storage and intensified glaciation (Bruckschen et al. 1999).

Human influence

Regarding climate change, experts generally believe that it "is largely irreversible" and that "climate is changing and that these changes are in large part (>90%) caused by human activities." The two most significant human activities are the removal of native plants and the release of greenhouse gases (IPCC 2007). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor (H_2O), and halocarbons (a class of gases including fluorine, chlorine, or bromine) are the most significant greenhouse gases in Earth's atmosphere (NAS 2001). The propensity of these greenhouse gases to absorb infrared light from the earth is a common characteristic. However, the greenhouse gases vary in the warming effect (radiative forcing) they have on the global climate system due to their various radiative qualities and lifetimes in the atmosphere (IPCC 2007).

The primary causes of the rise in global CO_2 concentration are land-use changes, such as the conversion of forests into agricultural land, and the combustion of fossil fuels. It is very probable that the use of fossil fuels and agriculture are the main causes of the observed rise in CH_4 concentration, while agriculture is the main cause of the increase in N_2O concentration (IPCC 2007). The primary source of gaseous water is ocean evaporation, while CFCs are man-made substances that are emitted into the atmosphere (NAS 2001).

The impacts of climate change on plants

Plant life activities, including germination, development, and reproduction, are closely linked to the environmental cues that the plant perceives. Consequently, variations in temperature and precipitation, particularly those that happen quickly or reach very high levels, have an immediate impact on species and may therefore have an impact on how competition between species develops (Sykes 2009). Global climate change is unlikely to be uniform in degree, and particular species and plant populations are likely to have different outcomes. For instance, general circulation models (GCMs) anticipate higher winter (and to a lesser degree summer) temperatures, particularly in northern latitudes (e.g., northern Europe), whereas other regions, such as southern Europe, see greater droughts and a drop in precipitation (IPCC 2007).

In general, plants react to the effects of climate change in three ways: first, by expanding their populations and growing faster (a positive response); second, by shrinking their populations and perhaps becoming extinct locally (a negative response); and third, by moving to new, more hospitable locations. Plant responses to the effects of climate change are primarily studied in two ways: phenology and range shifting (geographical distribution) (Sykes 2009).

Global distribution of plants

Climate affects the great variety of plant species and vegetation. Local environmental conditions like soil pH, nutrient status, water-holding capacity, slope, and aspect affect a species' presence or absence. However, intra- and inter-specific interactions including competition for light, water, and nutrients influence whether a plant is extant (Sykes 2009).

Because greenhouse gas emissions rapidly change the climate, they affect current and future vegetation patterns (IPCC 2007). Climate and land use change are the two biggest human-induced factors expected to affect biodiversity globally in 100 years (Sala et al. 2000).

Some species have altered their ranges due to climate change, according to many reviews (Lenoir et al. 2008, Chen et al. 2011, Pucko et al. 2011, Fei et al. 2017). Studies have demonstrated latitudinal shifts, although plant species range alterations are harder to detect. The northern limit of Holly (Ilex aquifolium L.), well-known for its association with winter temperatures, is strongly tied to the 0ºC isotherm. Holly has moved north with this isotherm during the past 50 years, taking up more climate along Sweden's southern coasts. Trees in the Scandinavian Alps have been observed to rise (Kullman 2001). Between 1962 and 2005, Vermont's northern hardwood-boreal forest ecotone top limits moved 91–115 meters upslope (Beckage et al. 2008). The dominant plant species' average elevation climbed by 65 m in southern California between 1977 and 2006–2007 via elevation gradient surveys. This rise was caused by regional warming and precipitation variability (Kelly & Goulden, 2008).

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Walther et al. (2005) showed that alpine summits had more species, showing that the European Alps' favorable environment has enlarged species ranges. More specialized alpine species may experience local extinction due to climate change-induced migratory species migrating uphill. Biome changes have occurred in the Mediterranean Mountains. Penuelas & Boada (2003) find that beech woodland (Fagus sylvatica L.) has moved upwards by 70 m since 1945, whereas holm oak (Quercus ilex L.) has replaced heathlands at lower elevations.

It appears tropical conditions are more complicated. However, Colwell et al. (2008) examined tropical elevation gradient climate change implications using Costa Rican plant data. They conclude that species from lower altitudes or lowlands may counteract biota upslope migrations on mountain slopes, as they do in higher latitudes.

In recent decades, some plant species have spread northward throughout Europe, perhaps due to warming temperatures. Thermophilic plant species have expanded in Western Europe during the last 30 years, whereas cold-tolerant species have decreased somewhat.

European alpine species have been replaced by alien species due to moisture availability (Fei et al. 2017), alien species invasion (Dainese et al. 2014), and climate change. Longer growing seasons and higher temperatures may have helped certain plant species ascend upland and compete with indigenous species. Sub-alpine plants and spruce and pine species may have climbed higher on summits in the Alps owing to climate warming during the last 60 years (Theurillat & Guisan 2001).

Mountainous areas on other continents have changed similarly. In Washington State's Olympic Mountains, sub-alpine forest has grown over higher-elevation alpine meadows owing to warming temperatures. The rise in air temperatures of 1ºC every decade over the last 30 years has led to increasing species richness. The Argentine Islands' populations of two native Antarctic flowering plants grew rapidly between 1964 and 1990, coinciding with a large Antarctic Peninsula warming. By boosting plant reproduction, warmer summer temperatures and longer growing seasons may have contributed to these species' rapid population expansion (Fowbert & Smith, 1994).

Phenology of plants

Plant phenology includes leaf emergence, fall, flowering, and fruiting (Chaturvedi & Raghubanshi 2016). Phonological pattern changes are bio-indicators of climate change since the environment substantially influences seasonal plant and animal occurrences. Plant phenological events including flowering, leaf emergence, fruit ripening, and leaf falling are visible. However, Japan's 801 AD bloom festival is the first known mention of cherry tree flowering (Anon & Kazui 2007).

Flowers bloom during the most important season for plants. It influences seed ripening, dispersal, and pollination, especially if the pollinator is seasonal. Animals eat pollen, nectar, and seeds, therefore blooming time impacts them. An early blooming period may modify competitive interactions between species because food intake, root growth, and leaf expansion would be active sooner. These actions are essential for coexisting species niche differentiation. Thus, large blooming date changes may destabilize environmental equilibrium.

Several studies have examined how climate change affects phenology (Menzel et al. 2006, Bajpai et al. 2017). Leaf fall was delayed by 0.2 days and early leafing, flowering, and fruiting increased by 2.5 days between 1971 and 2000 (Menzel et al. 2006). North American lilac spring time was studied from 1900 to 1997. Despite regional disparities, spring temperatures increased by 5-7 days between 1959 and 1993 (Schwartz & Reiter 2000).

The national link between phenology and climate change has been widely explored. Fitter & Fitter (2002) found that 385 species' initial blooming dates rose by 4.5 days each decade in the UK in the 1990s. Four tree species, including Ginkgo biloba L., had their budburst advance by 5.6 days every ten years in four Japanese locations that have warmed the greatest in the previous 50 years (Doi & Katano 2007). The March temperature increase was thought to have caused these changes.

Lilac, apple, and grape perennials were studied in the 20th century for leaf emergence and flowering dates (Wolfe et al. 2005). The study indicated that Northeastern US spring phenology for these species had advanced by 2–8 days over 35 years. This may not always be true, but most studies have shown that temperature changes are the main culprit.

From the 1920s to the 1980s, phenological studies of four Eucalyptus species indicated strong correlations between temperature and rainfall and blooming (Keatley et al. 2002). However, the four species responded differently to

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temperature and rainfall. Under predicted summer rains and warmth, two species bloomed later and two species earlier. Generally, climate change has affected the timing of phenological events in many plant species.

Expansion of invasive plant species

Invasive plant species pose a serious danger to native ecosystems, natural resources, and controlled areas around the globe. Because invasive plant species may spread into new areas due to favorable climatic circumstances, it has been anticipated that climate change would exacerbate the negative effects of these plants. It has been demonstrated that invasive plants are more competitive with native species in higher CO_2 concentrations (Ziska et al. 2007). Additionally, a lot of invasive plants can spread quickly into disturbed areas, like recently burned sites, which may become more common as a result of climate change (Dukes & Mooney 1999, Yadav et al. 2016, Lone et al. 2019). Because invasive plant species outcompete native ones, natural ecosystems are under danger (Zavaleta 2000, Kumari & Choudhary 2016).

Variations in temperature and precipitation are likely to cause variations in the distribution of land area that is vulnerable to invasion. Increased precipitation has been linked to the spread of non-native grasses in the western United States (Martin et al., 1995), whereas in the southern United States, higher temperatures have been linked to the northward expansion of invasive species' ranges (Rogers & McCarty, 2000).

Climate change may increase the likelihood of invasion for some species in specific areas. As an example, invasive plants like tamarisk (Tamarix spp.) and yellow starthistle (Centaurea solstitialis L.) are expected to expand in response to climate change, while spotted knapweed (Centaurea biebersteinii (Jaub. et Spach) Walp.) and cheatgrass (Bromus tectorum (L.) Nevski) are expected to experience range shifts that result in both expansion and contraction (Bradley et al. 2009).

Invasive plants also pose a threat to human-managed systems, such as forests, rangelands, and agricultural lands. The effects of these plants on managed lands result in significant economic losses; the United States, for instance, spends billions of dollars annually on eradicating invasive plants (Pimentel et al. 2000). These invaders now inhabit tiny but non-dominant populations in many at-risk places, which presents a danger for fast growth in the face of climate change.

Adaptive features in plants for resisting climate change

Natural populations respond to climate change by adjusting their development and reproduction timing and geographic spread, which changes community composition and species interactions. Many natural populations' poor responses did not counteract climate change's pace and extent, putting them vulnerable to extinction. To avoid extinction, populations may be transferred to more hospitable locations, species features can be plastically adjusted, or organisms can evolve to endure severe circumstances (Williams et al. 2008).

Recent studies (Whitney & Gabler 2008, Stotz et al. 2016, Colautti et al. 2017) have shown that species that invade new areas and native species responding to biotic invasions undergo rapid evolutionary change, which may help counteract climate change.

Evolutionary adaptation or human-mediated migration to suitable conditions may help fragile species survive (Hoffmann & Sgro 2011). Adaptive changes may affect species' ability to benefit from climate change-induced benefits such CO_2 enrichment's impacts on growth rate and seasonal conditions.

Climate change causes habitat destruction, fragmentation, and rapid species movement. That is, several research (Bajpai et al. 2012b, Chaturvedi et al. 2012, 2015, 2017, 2018) show that climate change occurs when many populations are already stressed by invasive species and disturbances. Invasions and fragmentation may alter gene distribution across landscapes and introduce new genotypes into populations via hybridization (Hoffmann & Sgro, 2011).

Populations and species grow in favorable climates, creating new contact zones between related lineages. This promotes inter specific hybridization and competition amongst taxa. Due to loss of variation and decreased fitness following combination, hybridization is frequently considered negative for conservation. However, hybridization may aid evolutionary adaptation. Molecular data suggests hybridization may have extended a species' climatic range. Hybridization increases genetic variety, which may accelerate population evolution. Darwin's finches, for example, depend on interspecies hybridization for much of their genetic diversity in morphology to adapt to their changing environment. When hybridizing species are adapted to different conditions, hybridization may assist them adapt to new ones (Donovan et al. 2010).

Plant species may adapt to changing environments via phenotypic plasticity. The range of phenotypes one genotype may exhibit depending on its environment. Some responses are inescapable owing to physical processes or resource limits, whereas others are adaptive plasticity, which increases genotype fitness. Climate change will cause adaptive and non-adaptive plant plasticity.

High genetic variability helps organisms adapt to new biotic and abiotic environmental changes, such as climate change. A plant's ability to sense environmental changes and create a plastic defense depends on genetic diversity. For instance, genetic variety in temperature sensor and vernalization transcription factor genes helps plant populations to adapt to temperature changes. Thus, flexibility may aid fast adaptation and cushion sudden climate change (Lande 2009).

II. CONCLUSION

Climate change affects plant life cycles and distributions globally. Most climate change studies examine plant phenology and range shifting, or geographic dispersion. Climate controls broad-scale plant distributions, but intra- and inter-specific interactions and local environmental conditions also affect them. Climate change has caused plant range shifts. Plant blooming, leaf emergence, fruit maturing, and leaf dropping are affected by climate change.

Climate change is expected to worsen the negative effects of invasive plant species because many of them spread quickly into disturbed areas and are more competitive than native species under higher CO_2 concentrations. Invasive plants outcompete native ones, threatening forests, rangelands, and farms.

Interspecies hybridization has given Darwin's finches much of the genetic variation in form they need to adapt to changing surroundings. Hybridization improves population adaptability and evolutionary potential. When hybridizing animals are initially adapted to different environments, it may make habitat adaptation simpler. Plant species may adapt to changing environments via phenotypic plasticity. The ability of natural populations to tolerate climate change is enhanced by high genetic variety. A portion of these genetic differences control a plant's ability to detect environmental changes and respond with plasticity.

REFERENCES

[1]. Anon Y & Kazui K (2007) Phenological data series of cherry tree flowering in Kyoto, Japan, and its application to reconstruction of springtime temperatures since the 9th century. International Journal of Climatology 28: 905–914.

[2]. Bajpai O, Dutta V, Chaudhary LB & Pandey J (2018) Key issues and management strategies for the conservation of the Himalayan Terai forests of India. International Journal of Conservation Science 9(4): 749–760.

[3]. Bajpai O, Dutta V, Singh R, Chaudhary LB & Pandey J (2020) Tree Community Assemblage and Abiotic Variables in Tropical Moist Deciduous Forest of Himalayan Terai Eco-Region. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, Online available. [DOI: 10.1007/s40011-019-01161-2]

[4]. Bajpai O, Kumar A, Mishra AK, Sahu N, Behera SK & Chaudhary LB (2012a) Phenological study of two dominant tree species in tropical moist deciduous forest from the northern India. International Journal of Botany 8(2): 66–72.

[5]. Bajpai O, Kumar A, Mishra AK, Sahu N, Pandey J, Behera SK & Chaudhary LB (2012b). Recongregation of tree species of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. Journal of Biodiversity and Environmental Sciences 2(12): 24–40.

[6]. Bajpai O, Kushwaha AK, Srivastava AK, Pandey J & Chaudhary LB (2015). Phytosociological status of a monotypic genus Indopiptadenia: A Near Threatened Tree from the Terai-Bhabar Region of Central Himalaya. Research Journal of Forestry 9(2): 35–47.

[7]. Bajpai O, Pandey J & Chaudhary LB (2017). Periodicity of different phenophases in selected trees from Himalayan Terai of India. Agroforestry Systems 91: 363–374.

[8]. Beckage B, Osborne B & Gavin DG (2008) A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. Proceedings of the National Academy of Sciences of the USA (PNAS) 105: 4197–4202.
[9]. Both C & Visser ME (2001) Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. Nature 411: 296–298.
[10]. Bradley BA, Oppenheimer M & Wilcove DS (2009) Climate change and plant invasion: restoration opportunities ahead? Glob Change Biology 15: 1511–1521.
[11]. Bruckschen P, Oesmann S & Veizer J (1999) Isotope stratigraphy of the European Carboniferous: proxy signals for ocean chemistry, climate and tectonics. Chemical Geology 161(3): 127–163.
[12]. Chaturvedi RK & Raghubanshi AS (2014) Species Composition, Distribution and Diversity of Woody Speciesin tropical dry forest of India. Journal of Sustainable Forestry 33(8): 729–756.
[13]. Chaturvedi RK & Raghubanshi AS (2016) Leaf life-span dynamics of woody species in tropical dry forests of India. Tropical Plant Research 3(1): 199–212.
[14]. Chaturvedi RK, Raghubanshi AS & Singh JS (2011) Effect of small scale variations in environmental factors onthe distribution of woody species in tropical deciduous forests of Vindhyan Highlands, India. Journal of Botany 2011: Article ID 297097 [DOI:10.1155/2011/297097]
[15]. Chaturvedi RK, Raghubanshia AS & Singh JS (2012) Effect of grazing and harvesting on diversity, recruitment and carbon accumulation of juvenile trees in tropical dry forests. Forest Ecology and Management 284(2012): 152–162;
[16]. Chaturvedi RK, Raghubanshia AS, Tomlinson KW & Singh JS (2017) Impacts of human disturbance in tropicaldry forestsincrease with soil moisture stress. Journal of Vegetation Science 28(5): 997–1007.
[17]. Chen I-C, Hill JK, Ohlemüller R, Roy DB & Thomas CD (2011) Rapid range shifts of species associated with high levels of climate warming. Science 333: 1024–1026.
[18]. Colautti RI, Alexander JM, Dlugosch KM, Keller SR & Sultan SE (2017) Invasions and extinctions through the looking glass of evolutionary ecology. Philosophical Transactions of the Royal Society Biological Science 372: 20160031. [DOI: 10.1098/rstb.2016.0031]
[19]. Colwell RK, Brehm G, Cardelu CL, Gilman. AC & Longino JT (2008) Global warming, elevational rangeshifts, and lowland biotic attrition in the wet tropics. Science 322: 258–261.
[20]. Dainese M, Kuhn I & Bragazza L (2014) Alien plant species distribution in the European Alps:influence of species‟ climatic requirements. Biological Invasions 16: 815–831.
[21]. Doi H & Katano I (2007) Phenological timings of leaf budburst with climate change in Japan. Agricultural and Forest Meteorology 148: 512–516.
[22]. Donovan LA, Rosenthal DM, Sanchez-velenosi M., Rieseberg LH & Ludwig F (2010) Are hybrid species more fit than ancestral parent species in the current hybrid species habitats? Journal of Evolutionary Biology 23: 805–816.
[23]. Dukes JS & Mooney H.A (1999) Does global change increase the success of biological invaders? Trends in Ecology & Evolution 14: 135–139.
[24]. Fei S, Desprez JM, Potter KM, Jo I, Knott JA & Oswalt CM (2017) Divergence of species responses to climate change. Science Advances 3: e1603055. [DOI: 10.1126/sciadv.1603055]
[25]. Fitter AH & Fitter RSR (2002) Rapid changes in flowering time in British plants. Science 296: 1689–1691. Forest CE (1999) Paleoaltimetry incorporating atmospheric physics and botanical estimates of paleoclimate.