Chapter

Climate as the Major Factor Controlling Phenology

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Abstract

The witnessed aberrance and irregularities in the timing of pheno-phases is an undeniable evidence of the reality of the climate change and hence proves the complete control of climate over phenology. In fact, some researchers mentioned the advance of blooming and the delay of defoliation to the mid of winter as well as the disappearance of many animal and vegetal species. This would visibly illustrates the impact of climate changes which became a factual reality. These facts a long with the rhythmicity of life under the climate control and seasonality makes the importance of this chapter unequivocal, and a backbone for this very book of "Agrometeorology". Accordingly, this chapter treats each phenophase from dormancy to fructification to cover all the plant life cycle. For each of which we focus on how climate is intimately controlling the biological processes of each life phase and how climatic elements are the strongest and first factor which induces plant to starts the appropriate phenophase according to the fitting season. Plant is indeed very sensitive to seasonal variation in climate elements which induces the transcription of specific genes to produce specific enzymes which to their turn are with specific act on specific cells and tissues. Hence there is a high harmony between plant physiological response and climate seasonality endorsed by the circadian clock which is merely created by the historical subjection of plants to the impact of climate. Nonetheless, the recent climate changes are seemingly to be against this natural harmony between phenology and climate. This should due to their erraticism which may cause damages to the ecosystem and available resources. Thence, this chapter within this book would be inspiring for some strategies of adaptation to the climate changes to avoid such a prejudice against crops by adjusting the agricultural calendar and planting dates to avoid coincidence of fragile phenophases (germination, flowering, and fructification) with climatic hazards.

Keywords: phenophase, climate change, agriculture, germination, fructification, food security

1. Introduction

The autumn is usually called fall due to the featuring fall of leaves during this season as a phenological phenomenon called defoliation. This would figure out how intimately related are seasons and phenology or in other words how strong is the repercussion of climate seasonal variation on the plants and animals successive and cyclic phenomena. Indeed, we almost notice seasons via phenological variation along with climatic one. This deep intimate co-occurrence between climate and phenology phenomena is very appealing for wonder and consequently to the exploration of the relations and mechanisms of these relations and how living beings respond to climate seasonal variations during their life cycles.

As a matter of undeniable fact, this chapter consists of a core and mandatory knowledge for the agriculture and farmers to make their crops safe and the most productive. Therefore, this chapter is likely to be the backbone for this very book of agro- meteorology and all disciplines within the same scope and the nature and life's scope.

Particularly, in the recent context of climate change. Indeed, Subrahmanyam and Murthy (in Ref. [1]) confirmed that global climate change is a reality, a continuous process that needs to be taken seriously. Many evidences have been gathered to depict that climate change is taking place. And although several species have responded to climatic changes throughout their evolutionary history, there is a concern as to how different ecosystems and populations will respond to this rapid rate of change.

The fact of the book being devoted to agro-meteorology imposes that this chapter should be more specified and oriented towards phenology of plants as to they are the subject of agriculture more than animals. This is also due to another fact that climate impacts plants more than animals. Accordingly, this chapter attempts to explain how climate factors affect and control each pheno-phase within the plant life cycle from dormancy and germination to fructification, after defining all of phenology, phonological phases, climate, climate factors, and climate seasonal variations.

2. Phenology

In general, Phenology is the observation and measurement of events in time [2].obviously, the word phenology is composed of the part "pheno" which refers to phenomena and "logy" which is commonly known to mean science or study, thus phenology is literally the study or science of phenomena. Practically, Phenology refers to the study the cyclic phenomena of living beings mainly plants and animals including insect and their succession in seasons as well as their timings [1, 3]. This is under the direct influence and control of climate and surrounding environmental conditions including the duration of sunlight, precipitation, temperature and other life-controlling factors [1]. The recent climate changes makes the deep mastery and comprehension of phenology worthwhile, because some unpredicted climate changes could cause many crop damages. Actually, the assessment of impacts of projected climate changes on natural ecosystems is not based on accurate scientific modeling or field studies at regional level [1], and It is well documented that plant and animal phenology is changing in response to recent climate warming in the Palearctic [3]; besides, global change, encompassing natural and anthropogenic changes to the Earth system at sub-annual to geologic time scales, has strong interactions with vegetation phenology [5]. Thus phenology is central and crucial as a background for the discipline of agronomy and mainly agro-meteorology to predict the eventual response of living being to the unpredictable climate changes and therefore probable agricultural damages.

The term of phenology was first introduced in 1853 by the Belgian botanist Charles Morren. It refers to the science that measures the timing of life cycle events for plants, animals, and microbes, and detects how the environment influences the timing of those events. Namely, it focuses on how environmental factors mainly climatic variables influence the phenol-phases to hence make a harmony between seasons and life cycle events including defoliation, plant dormancy, leaf budburst, blooming and first flower, last flower, first ripe fruit, and leaf shedding, and for animals this includes molting, mating, egg-laying or birthing, fledging, emergence from hibernation, and migration. Thus, phenologists record the dates when every event occurs, its duration and how environmental conditions such as temperature and precipitation affect its timing [2].

3. Climate and weather

The timing of phenological events can be quite sensitive to environmental conditions mainly climatic [2, 4, 5]. For example, an advance of leaf budburst and blooming for could be caused by warming an drought in spring and this could be for two weeks earlier than usual, whereas cold and moisture could exceptionally could equally delay them. Thus, weather and climate controls the timing of phenol-phases which vary among years [2]. Effectively, climate cyclic variations are the controlling variables of phenol-phases timing. In plants, bud-burst, leaf-expansion, abscission, flowering, fertilization, seedset, fruiting, seed dispersal and germination all take place in due season [6].

On the one hand weather is limited to a very short period of time from one day to less than week and it includes atmospheric conditions of a region, such as temperature, precipitation, humidity, wind, and sunshine. The climate of a region, on the other hand, concern a long period more than thirty years commonly defined as the conventional period for climatic studies. Climate consists of the generally-prevailing weather conditions for this period and in a large geographic region. For example, Santa Barbara, California is characterized by a Mediterranean climate – warm, dry summers and cool, moist winters. There are, however, daily and weekly changes in the weather that can rapidly change the temperature, sunshine, and wind conditions [2]. Nonetheless, there is no steady rhythm for all years particularly in the context of recent climate changes. This would not be tolerated by some species and therefore they are likely been extinguished and rarified in many regions.

4. Climate elements controlling phenology

Temperature, solar radiation, and water availability are assumed to be the key factors that control plant phenology [5]. However, not only these climatic factors. Indeed, temperature is an inevitable factor on which depends all the chemical reaction and mainly those occurring inside cells of living organism. In addition the temperature is both a characteristic of live and an indispensable condition to survive. Some biological functions and reaction may be inhibited or stopped by cold like in hibernation and dormancy. The solar radiation is unequivocally source of energy which is transformed from it luminous form to the chemical form (ATP) by the photosynthesis in the chlorophyll within plants. Furthermore, sun light is factor to fixate the calcium, to product vitamin and the duration of insolation which is called photoperiod determines the season of fall, season of bud bursting and blooming. Precipitations are source of water for crops. Water is indispensable for any form of life on earth. Indeed water is the solvent in all physiological solution in living organisms. As well as it transmits nutrients and regulates temperature of bodies of living beings.

In fact all the climate with its elements and their features including duration, frequency and intensity are influencing phenophases and living beings lives whence the elaboration of the discipline of bioclimatology.

5. Climate, overwintering and defoliation

In period of tough climatic conditions some plants and animals can no longer neither resist nor adapt to rude conditions of autumn and winter. Therefore, they adopt a specific strategy to survive. This is possible by pausing growth and development, which can occur in different organs like seeds and buds. This is known as dormancy which is controlled both by genetic and environmental factors. As the most studied dormancy, seed dormancy is an important adaptive trait in wild plants. The plant hormone abscisic acid plays a crucial role in the establishment and maintenance of dormancy, whereas gibberellins promote germination. The abscisic hormone (ABA) is specific to plants, and plays many roles for plant responses to stresses such as drought, salinity, cold and freezing tolerance, heat stress and heavy metal ion tolerance. Dormancy is a main determinant period in the plant life cycle. It has strong variation between species [7].

According to the predictability of climate, the dormancy may be preventive or consequential. Predictive dormancy is when plants can predict the onset of winter through the short photoperiod and the decrease of temperature, however when climate is unpredictable and has a sudden changes, the organism enter directly in consequential dormancy after adverse conditions. This last may cause a high rate of mortality before entering in consequential dormancy which is a protection strategy. Furthermore, the biological clock in many spices determine autonomously the period of the year for every phenophase.

In soil, seeds dormancy is continually adjusted by a set of environmental signals (Figure 01). The time of the year is determined by signals related to the slow seasonal change and this may indicate how sensitive the plant sensors mainly in seeds are. The figure illustrates the range of environmental signals and how they can potentially inform the seed of the time [8]. As buried and incorporated into soil, seeds responds to a wide range of edaphic and physical conditions to inform about the time of year and its appropriateness to the germination as illustrated in the **Figure 1**. The nitrate is commonly known to have a very important role in informing plants about the surrounding environmental conditions.

For the evergreen plants like some trees such as conifers, the dormancy consisted of the sustained light quenching for the whole winter period by the

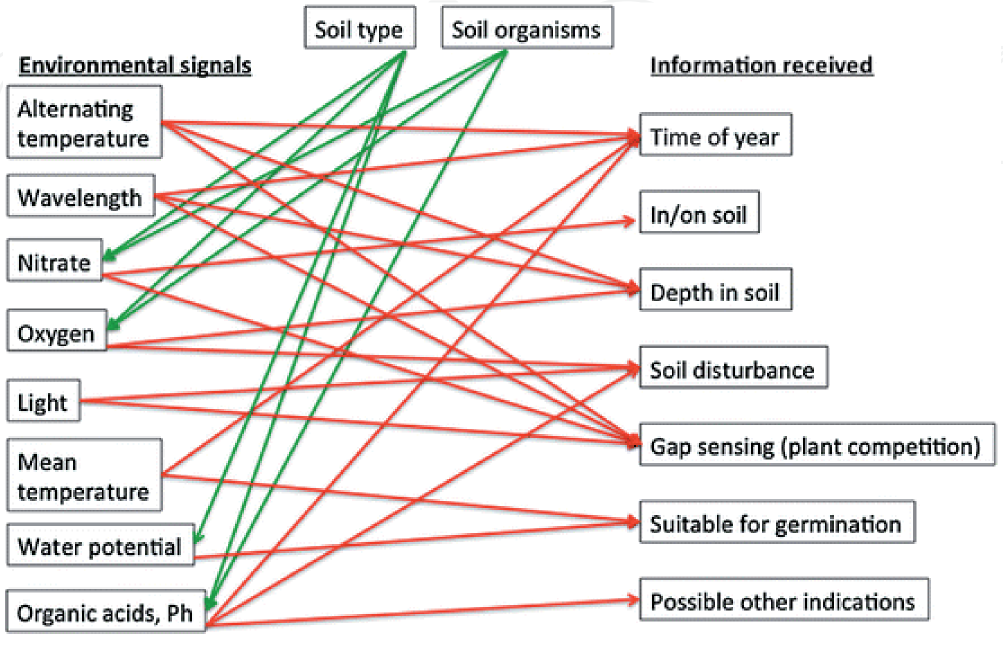

Figure 1.
Environmental signals controlling seeds dormancy and germination. ***Source:*** *Reference [8].*

xanthophyll-mediated non-photochemical antenna. This is a form of a protection for the evergreen foliage from photo-oxidative damage when photosynthesis is restricted or prevented by low temperatures during the winter. The molecular mechanisms of this cold acclimation are still unknown, it implies alterations in the photosystem II antenna. Photosystem I is also involved via its support of cyclic electron transport at low temperatures, and also by non-photochemical quenching of absorbed light irrespective of temperature. Processes like chloro-respiration and cyclic electron transport may also be important for maintaining the functional integrity of the photosynthetic apparatus of overwintering evergreens both during periods of thawing in winter and during recovery from winter stress in spring [9].

Defoliation (removal of leaves), on the other hand and for the deciduous plants, is the strategy to minimize or stop the photosynthesis in the overwintering period. Defoliation accelerates sink metabolism and hence remobilizes carbon and nitrogen reserves, leading to improved source-sink relations. Through removing lower and senescing leaves, plant can assure a greatest capacity of photosynthesis and carbon and nitrogen metabolism in despite of adverse conditions [10]. Hence, the defoliation consists of a balancing between the minimum of photosynthesis supplies in adverse conditions and the plant needs.

6. Climate, germination and dormancy break

Whenever conditions are favorable, dormancy and overwintering become useless. Plants and seeds start anew their active lives. This starting is accomplished through germination in seeds characterized by the emergence of embryo from seed enclosing covers the endosperm, perisperm, testa, or pericarp. This metabolism is mainly activated by the seeds imbibition by water. This would incite the respiration metabolism to provide the necessary energy for the expansion of the embryo and after that the radicle through the covering tissues of the seed. The emergence of the radicle out of the seed indicates the germination completed and hence called the visible germination which ends up with the seeds germinated. Germination does not include the seedling growth [11].

In fact, not only water is the climatic factor inducing germination, there is also temperature and sunlight. However, the most essential environmental factor required for seed germination is water. Water availability acts following a specific model, the hydro-time model of germination [11].

While water availability and imbibtion of seed are indispensable to launch germination, temperature is important as well for germination and for all physiological functions both for animal and plants. In fact, the regulator role of temperature is commonly recognized in physiology as well as in germination. Indeed, temperature determines the germinability of seeds by determining its rate. It removes primary and secondary dormancy and temperature also induces the second dormancy [11].

Light is primarily responsible for the effect inducing germination after turning soil. As little as one millisecond of exposure to full sunlight can cause many seeds to germinate and produce seedlings. This principle may be utilized to reduce the use of herbicides in weed management programs. Hence, soil plays the role of light filter [11].

7. Climate and bud burst

Break in dormancy in many plants is triggered by temperature [1]. A sufficiently high temperature is indeed needed to make bud bursts. This would occur due the expansion of internodes and leaves formerly formed in previous season. This high temperatures is almost needed for the newly formed buds due to the apical meristem getting activity resumed. On the other hand, the burst of dormant buds is caused by the elongation of the internodes following to cell expansion [12]. The young buds are very sensitive to coldness and may be severely damaged if they burst early in winter. This probable damage of buds have an inevitable repercussion on the crop.

Although, almost factors controlling the phenology of bud burst are poorly understood, bud burst has a particular timing controlled by some climatic and non-climatic factors including:

- **Air temperature**: the temperature of the air affects with its values summation since the mid-winter as well as with its high values in the last part of winter. In fact, there is a correlation between the daily mean temperature and the number of buds bursting per day [12]. However, a need for chilling is indispensable for the bud burst and similarly for seedling.

- **Soil temperature (Root temperature):** there is a positive correlation between bud burst and temperature of the rhizosphere. High temperature (25°C) promotes the early bud burst unlike low temperature of about 12°C. This may explains how our ancestors where tricky as they irrigate plants with warm water to activate the bud burst when it delays. This also implies the importance of site selection and soil management. Indeed, drainage due to stony or calcareous quality of soil boost its spring warmth. In contrary, wet soils like clay soil which maintain cold due to their content of water are recommended to postpone bud burst in cool climates, therefore coincidence of new buds with tough condition is avoided and then chance of ripening is increased [12].

- **Photoperiod**: In a less degree, the photoperiod influences the bud burst. Some plant receptors could detects the spring arrival basing on the increase of it and then incites the bud burst. While long shilling duration advances the bud burst and short shilling postpones it, the long photoperiod may compensate for short chilling duration.

8. Climate and flowering

Blooming or flowering is a featuring phenophase which usually heralds the arrival of spring season. Flowering is controlled by environmental conditions and developmental regulation. The complexity of this regulation is created by an intricate network of signaling pathways [13]. The plant Arabidopsis is a model for the study of flowering mechanism due to the significant number of environmental factors involved in this process for many other species. In addition, the genetic material of this plant is well developed. Many factors influence the flowering such as photoperiod, growth regulators, insolation and sunlight, circadian clock regulation, temperature, and chromatin structure [13].

8.1 Photoperiod role in flowering control

One of the most important factors controlling flowering time in temperate regions is the duration of the daily light period, or photoperiod. Plant genes involved in sensing the photoperiod were identified by the molecular genetic approaches. These genes encode the proteins responsible of the flowering process and its regulation according the environmental conditions. Other genes encodes the components of light signal pathways and components of the circadian clock.

The **Figure 2** illustrates the relations among factors, genes, and processes involved in flowering phenology relating to the photoperiod. The effect of photoperiod on flowering consists of a balance between genes which promote the flowering in green color in the **Figure 2** and in red color those which repress the flowering. All these genes are incited by the sunlight. While Repressive effect is represented by the perpendicular arrows, and overexpression of genes is illustrated but e small upright arrows, the promotion is represented by arrows between genes. Similarly, interaction between proteins is indicated by simple lines. The expression of genes controlled by circadian clock is noted by arrows from it whereas arrows to the clock are for the process of lengthening the period by the gene [13].

8.2 The role of the circadian clock and the central oscillator in flowering

Biological Phenomena are almost systematic and have standard rhythm, timing and cyclicity. These are all controlled and adjusted by the biological clock or the circadian clock. This rhythmicity is at all living beings and in every division of time from one second to one year. The genes controlling the circadian clock have been identified by scientist as to be the gene (per, frq, clock, tau) [14].

The period of circadian clock is almost one day without being affected by transition between day and night, dark and light. This clock is observed in all functions and biological elements from stomat, CO2 assimilation, and gene transcription to the clearly observable phenophases like defoliation, bud burst and flowering. This rhythmicity and circadian are believed to be created by the cyclicity of environmental phenomena and hence underwent a selection pressure. Indeed this circadian clock serves the harmony between environment with it climates and the phenology and therefore permit to living beings to efficiently anticipate their environment changes in particular periodic variations or more appropriately the

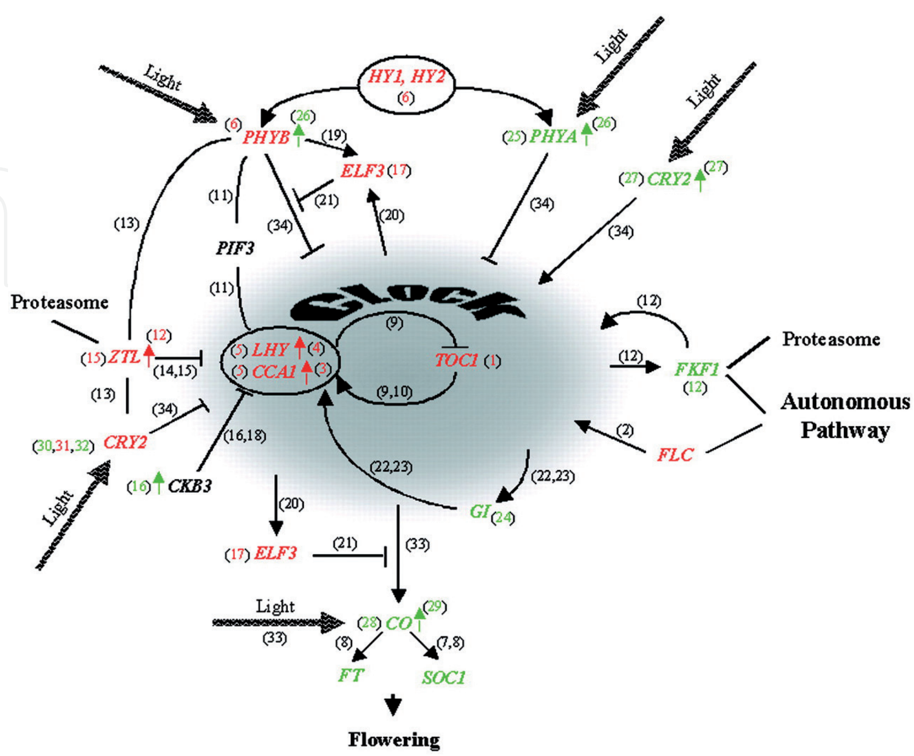

Figure 2.
Signaling pathways involved in the regulation of flowering by photoperiod in Arabidopsis ***source:*** *Reference [13].*

seasonality of climatic elements including temperature, insolation by its intensity and photoperiod, humidity, precipitations [14]. This implies the constant quality of this circadian clock and meanwhile poses a problem of adaption to the unexpected climates changes. Thus, many vulnerable species may have been extinguished due to this effect.

Three outstanding interrelated types of this rhythmicity are characterized in the circadian clock including the input pathways which are relating to the daily cycle of light and dark and adjusting the clock mechanism to it. Secondly, a central oscillator which is responsible to keep the mechanism of 24 hours' time. And output pathways for specific process as the thirds category of this circadian clock [13].

8.3 The role of the vernalization on flowering

As a commonly used technique, vernalization is used since a long history of agriculture. First discovered for plants which were planted in spring, then they needed some cold to germinate and to pass from vegetative life to productive life. Indeed, vernalization is almost related to flowering and fructification in particular. And it is defined as subjection of seeds and seedlings to coldness or chill in order to promote and hasten the growth and the flowering of plants.

In fact, plants are very sensitive to their environment and constantly adapting to the environmental variations by for example dormancy or overwintering during adverse conditions period which is a strategy to withstand them. However, in spite of its toughness, winter cold is in the other hand mandatory and indispensable for plant growth and flowering whence the principle of vernalization. This vernalization is also an adaptive trait to prevent flowering before the spring arrival with its favorable conditions. Genetically, vernalization is merely the inhibition of genes which repress flowering particularly in Arabidopsis and cereals [15].

Exposure to low temperatures for several weeks will often accelerate flowering. Susceptibility to this treatment can differ markedly between varieties of a species. Therefore winter seasons is likely to an inevitable period in the plants life cycle because without long exposure to cold plants do not flower not pass to the reproductive and productive phase of their life. During winter plants are in vegetative growth phase with the minimum of activities [13].

Figure 3 illustrates process, mechanism and all involved factors and genes in the flowering phenomenon, especially promotion of this flowering process is indicted in blue and the red color illustrates the components and genetic interaction which repress flowering including FLC (Flowering Locus C) and its relatives pointed as FLC clade. It inhibits the expression the flowering genes or properly named the floral integrator genes which are FD, FT, and SOC1 (Suppressor Of CONSTANS1). The photoperiod pathway passes by CO (CONSTANS) to induce the FT which is a protein working as a mobile signal of flowering. In the floral meristem, FT in partnership with FD protein activate SOC1 as well as SAP (sepalat), FUL (fruitful), and AP1 (apetatalata1) which are known as the floral meristem identity genes and which induces the floral meristems that will develop into flowers. Accordingly, Flowering locus C (FLC) and photoperiod pathway are antagonist.

In the one hand, Autonomous pathways genes partially determine the expression of FLC. In the other hand, the prolonged winter and cold further repress the FLC remodeling of chromatin. In addition, flowering is promoted by the plants hormones class of gibberellin which activates SOC1 along with the floral meristem-identity gene LEY (LEAFY) [15].

As illustrated by **Figure 4**, vernalization, which repress FLC expression, along with the autonomous pathway genes induce flowering [13].

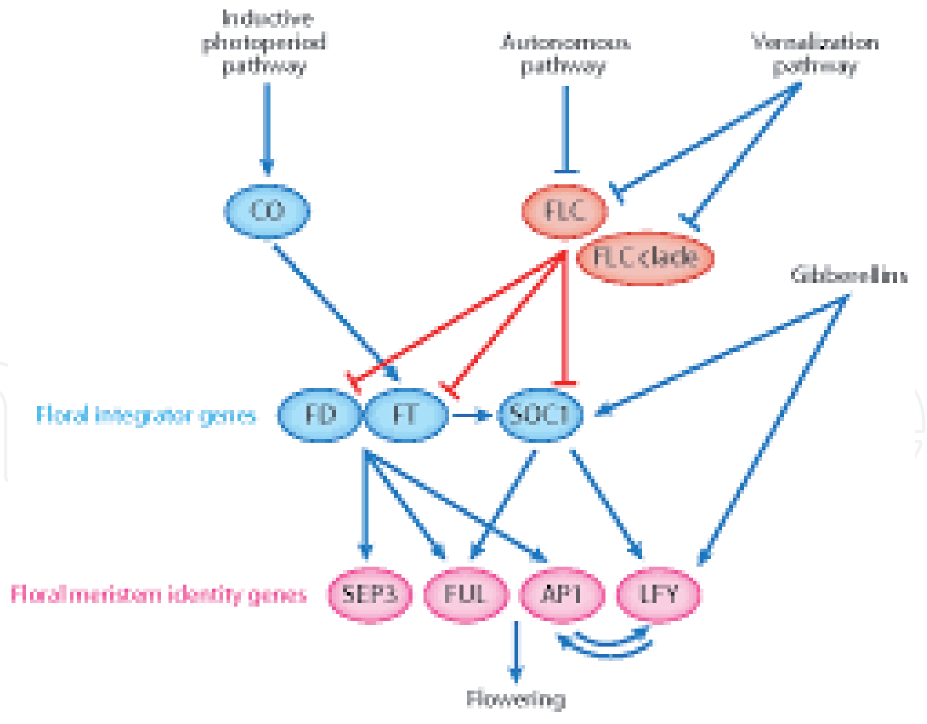

Figure 3.
Outline of flowering pathways in Arabidopsis source: Reference [15].

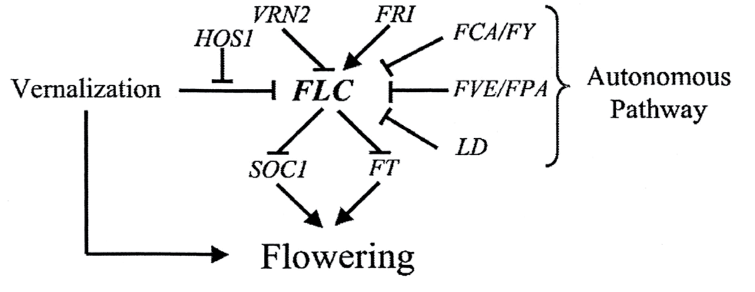

Figure 4.
*The effects of Vernalization and the autonomous pathway on flowering time, emphasizing the central role of FLC **source:** Reference [13].*

9. Climate and fructification

The making of a fruit is a developmental process unique to plants. It requires a complex network of interacting genes and signaling pathways which consists of series of reaction launched by an environmental signal such as light, photoperiod, and temperature. Generally, fructification goes through three stages which are first the set of fruit which follows the pollination of flowers. Then the fruit development stage and finally the fruit ripening which received the most attention of researcher of the field. This is due its importance in commercialization an economy since it the quality of fruits is the most attractive feature for the customer. In fact the process of ripening activates a series of biochemical reactions that make the fruit edible and desirable to the consumer [16].

A detailed illustration of this process is provided by the following **Figure 5**. It is merely a scheme of activating the ripening related genes to be expressed into enzymes charged each of which by one or more of the various ripening pathways such odor, color or softening. This whole process is controlled and adjusted by hormonal and environmental signals. It is to be noted that ethylene as a plant hormone plays a major role in this process of ripening and fruit development [16]. Indeed,

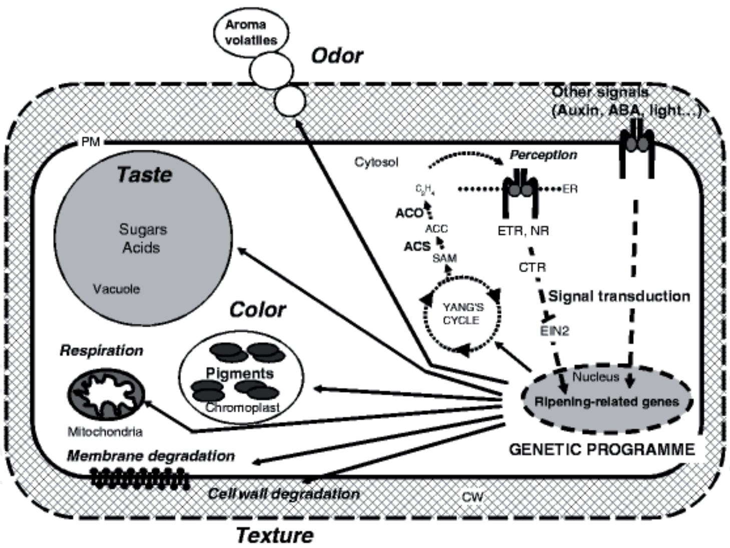

Figure 5.
Schematic representation depicting the molecular mechanisms controlling the ripening of climacteric fruit **source:***Reference [16].*

fruits whose ripening is related to ethylene and a respiration increase are called climacteric fruit, such as tomato, apple, pear, and melon. In the other hand, the non-climacteric are featured by no ethylene associated with the increase and peak of respiration during the ripening phase. It is to note that sales men uses this ethylene to preserve fruits during transportation or deposit for long-period by picking fruits prematurely and when ready for exposition for sale they use ethylene to induce ripening. Similarly, it is used to advance flowering before the adverse periods.

10. Climate change and phenology

The obvious delay of defoliation and advance of blooming along with the appearance of butterfly in autumn and disappearance of many species of plants, insects and animals in many regions unequivocally indicate the climate change and warming, and triggered the scientific research and investigation in this respect [17]. In a context of global climate change being a reality, a continuous process that needs to be taken seriously, and a subject which continues to be a topic of hot debate at global conventions, world summits and international conferences and symposia [1] . Indeed, plant phenology is strongly controlled by climate and has consequently become one of the most reliable bio-indicators of ongoing climate change [18]. Thus, aberrations and anomalies in phenology are repercussions of climatic ones and hence are unequivocal and undeniable evidence of the climate change fact and the fact of their occurring irregularly. This may help to assess and predict ongoing and future significant impacts of climate changes on plants and the whole ecosystems. Effectively, it is largely noticed the disappearance of many vulnerable and hyper-sensible species because of the climatic stress, the unpredicted change of weather, and inability of these species neither to withstand adverse conditions nor to adapt. However if erraticity of weather and climate persist, plants would adapt and a new ecotypes will appear. Indeed, the first response to climate changes is through changes in plant phenololgy and phenophase with their timing and durations and this would have a potential impact on the available resources [1].

Accordingly, long phonological records generate authentic data to study the effect of climate change on phenology and the whole ecosystem, environment and nature future. This may includ parameters such as advance or delay in the appearance of leaf, leaf fall, and timing of opening of flowers, and blooming which can be recorded right at the field site for a long period to form a long time series valid and reliable for the scientific analysis and deductions. For instance, increase in level of carbon dioxide in the atmosphere and consequent global warming may have a profound effect on the flowering time of plants [1].

Accordingly, it was highly recommended to work actively in terms of implementation of the climate change scientific findings in the field of the field of agriculture to both preserve and increase crops. Namely, it was proposed to adjust and reconsider the agricultural calendar according to the recent climate changes to avoid damages related to climate hazards. Indeed, planting dates should be judiciously set in such a way that fragile phenophases (e.g. germination, fruiting) do not come across hard climatic periods [17, 19].

11. Climate change phonological impacts and food security

The climate changes are commonly known as frustrating and alarming when first talked about in the first years of the past century and when they first came into existence among scientific community. All scientist talked about inundation by the sea level rise, drought, desertification, natural resources depletion as climate change aftermaths in a very dramatic way as it is the certain end of life on this planet. In fact, climate changes are constantly with clear and remarkable impacts mainly on living beings and foremost plants due their sessile life style directly exposed to climate influences. Furthermore, this created an intimate relation between plants life and climate or the entire surrounding environments.

Thus, plant's life and physiology is utterly dependent to its environment and mainly the climate.

As the plant is the first source of food for all other living beings, the food security is therefore subject to climate changes impacts. Indeed, since all phenol-phases are interrelated and related to climate seasonality and variation, the fructification as the final one is inevitably impacted by the climate changes and consequently crop quantity and quality. This uncovers and emphasizes the direct impact of climate changes on the food security.

Food is basically from cereal crops whose growth and development are dependent to the day length and growing degree days (GDDs) and they are responsive to climatic factors in specific seasons [20].

The global warming hinders the crop growth and development and mainly causes a shift in phenological development of crops and affects their economic yield [20]. This is due to the fact that the rise of temperature and warm winters are indeed against vernalization which, as previously posited, mandatory for flowering and fructification. This implies that there would be only vegetative life and neither reproduction nor production for plants. Hence, the impact of climate changes is decreasing production in favor of phonological and only vegetative plants.

As climate warming is global and unavoidable phenomenon, the unique solution for food security in this context consists of an adaptive strategy and agronomic management through breeding of climate-adapted genotypes and increasing genetic biodiversity [20]. This is to say that we should make use the field of genetic engineering to develop local species, or more properly and appropriately use more adapted species brought from already temperate regions. This last alternative is more recommended to avoid transgenic organisms and crops whose use as food is unsecure.

12. Conclusion

This chapter is a mandatory background knowledge for everyone interested on nature particularly on plants starting from agricultural professionals to simple farmers, amateurs and herborists. This chapter provides a solid basis for agro-meteorology, and agronomy.

Therefore it is an inevitable part for this very book of agro-meteorology. Actually, the controlling of climate to plant phenophases was emphasized to prove the importance of its knowledge to predict and prevent the probable damages due the climate changes.

For more emphasis, the last two titles were devoted to the impact of climate changes on phenology and consequently on food security.

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