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THE CIRCADIAN RHYTHMS: ROLE OF BIOLOGICAL CLOCK IN PLANT GROWTH AND DEVELOPMENT

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ABSTRACT: *Circadian (around the day) is a complex of two Latin words circa [around] and dies [day] they are endogenous and adjusted to the local environment by the daylight cues called Zeitgebers ZT (Germany for time giver) and the study of other biological rhythms is called chronobiology .most of metabolic and physiological processes in plants and animals including humans are going around an internal oscillator in a continuous period of 24h called circadian rhythm and is a diurnal rhythm this biological clock central loop is composed of the circadian clock components .in plants this circadian rhythm controls processes like photosynthesis , photoperiodism and photo protection by adjusting the crop with the environment that is why is referred to the master regulator of the plant life. Many researchers have proved that well understanding of the biological clocks can be useful in development of agricultural improved crops .in Arabidopsis as a model plant in plant breeding and development this biological clock has been used to identify some clock related genes which are responsible to the plant growth regulation, germination ,flowering ,biotic and abiotic stress responses and others studies have revealed that tissues and even every single cell is governed by circadian clock systems .in this review we are discussing our current understanding of the clock and its interactions with light and temperature signaling pathways, the history of clock research development, the circadian clock in Arabidopsis thaliana as a model plant ,its role during biotic and abiotic stresses ,plant hormones and homeostasis and our future perspectives about circadian research.*

KEY WORDS: circadian rhythm, plant metabolism, biological clock, homeostasis

INTRODUCTION

The circadian rhythm is an internal biological metronome that dictates a 24 hour activity pattern (lausanne) .the earth rotation on its axis has shown that the biological evolution has occurred in an environment that changes dramatically every day. The circadian rhythm has been widely observed in plants, animals, fungi and cyanobacteria (Fu Yu Hung).the core circadian clock is composed of TIMING OF CAB EXPRESSION1(TOC1)/PSEUDO RESPONSE REGULATOR (PRR5/PRR7/PRR9) , CIRCADIAN CLOCK ASSOCIATED 1(CCA1)/LATE ELONGATED HYPOCOTYL(LHY) and ZEITLUPE (ZTL) (Felipe Yon).TOC1 is highly expressed

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in the evening (dusk) and low expressed in the morning (dawn) while CCA1 and LHY are highly expressed in the morning and low expressed in the evening (Fu Yu Hung).these rhythms should persist in the absence of environmental time cues (light/dark or temperature) from cyanobacteria to humans time is endogenously measured and temporally regulated aspects of their biology. The circadian rhythms are defined by three parameters: periodicity, entrainability and temperature compensation, a true circadian rhythm persists in the absence of environmental time cues with a free running period of approximately 24hours. (C. R. McClung).endogenous circadian (24hour periodic cycles) systems seem to be a common feature of both eukaryotic and prokaryotic organisms they coordinate metabolism, enable organisms to adjust with the daily environmental changes and have a great role in photoperiodic measurements. The circadian system can be divided into three parts: oscillator, input pathways and output pathways. Oscillators is composed of interlocking positive and negative feedback loops of pacemaker elements and determine the period, phase and amplitude of the output rhythms it can be entrained by signals from the environment (temperature and light/dark changes) a strong temperature compensation capability is built in the system and allows the oscillator to function with aperiod close to 24hours .output pathways regulate wide range of physiological and molecular processes in plants(chlorophyll biosynthesis,starch metabolism,germination and growth,movement of leaves ,stomatal openning,photoperiodic flowering and gene expression(about 30% of the total genome) (Yuri Dakhiya).amplitude of circadian rhythm improves plant fitness under a particular environmental condition;temperature,drought and salinity that cause crop loss and severe limitations of crop land (Jack Grundy).all organisms are exposed to diel environmental rhythms such as the daily transition from light to dark and the daily fluctuation of temperature but organisms have developed sensors that enable them to sense and respond to these changes and maintain the internal balance or homeostasis(Nicky Creux).the central oscillator is a complex gene regulatory network of repressors and activators which form several interlocked feedback loops.

The plant circadian rhythms

Circadian (circa “about”and dian “day”) rhythms are endogenous biological cycles with a continuous period of 24h (Alex A.R.Webb)and in the absence of external cues as the earth rotates on its axis every 24h with the position on the earth’s surface alternately faces toward or from the sun day and night these circadian rhythms allow plants to adapt to the environmental changes resulted from such earth rotation (Anjanabha Bhattacharya).All living things on earth encounter daily oscillations in environmental factors that the metabolism, physiology and behavior changes profoundly between day and night is obvious to even the most photosynthesis, flowering ,development and metabolism (Fiona E.Belbin),hypocotyl and root growth (Joelle De Caluwe).a diverse range of organisms has evolved an endogenous clock which permits anticipation of predictable fluctuation in environmental conditions arising from the daily rotation of our planet enabling organisms by different external inputs providing circadian rhythms with a periodicity of 24h that persist under constant conditions (Maria E.Eriksson).the resonance between endogenous clock and exogenous cycles affects performance as does naturally occurring clock variation. The clock drives temporal gene expression with physiological consequences like gas exchange from individual to ecosystem scales and

many aspects of plant development and its interactions with the environment at dawn ,the clock enhances the resistance to oxidative species produced during the light harvesting processes, provide plants with signals that govern stomata opening and control the mobilization of carbohydrates at dusk (Jin A KIm).the clock also causes hormonal waves influencing life history traits such as plant size at reproduction and floral development .the clock modulation for several hormones is characterized by the model plant (*A.thaliana*) (Hotta CT et al).and 30% of the transcriptome is clock regulated in day/night growing conditions.it rises to 80% in free running setting and this crucial role for the clock has been confirmed for other dicots while metabolic rhythmicity has been shown in monocot crops (Camela R.Guadagno).the circadian clock tunes both timing and capacity of sugar production via photosynthesis but at the same time sugar signals entrain the clock importantly ,plant nutritional status seems to feed back to the circadian clock .in Arabidopsis a clock component (CCA1) has identified as a putative master regulator in the nitrogen(N) regulated network (A. R. Michael J.Haydon).the rhythm to be called circadian must meet these critera:1.have continuous period of 24h every the clock must be at the same point at the same time (Svorc) 2.must be endogenous i.e. Persist in the absence of external periodic input ,in constant conditions within a period of 24h (R.P.Najjar) 3.must be entrainable it means can be adjusted to match the local time and rest by exposure to the external stimuli (light or temperature) .when an individual organism moved across the time zones the biological clock is adjustable to the local time and the organism will experience jet lag before entrainment of the circadian clock has brought it into sync with local time (Takanobu Higashi) 4.it must exhibit temperature compensation means that it maintains circadian periodicity over a range of physiological temperatures .the temperature coefficient (Q10) is used to measure temperature compensation if remains constant approximately 1 as temperature increases the rhythm will be considered to be temperature compensated (Michal Sorek).

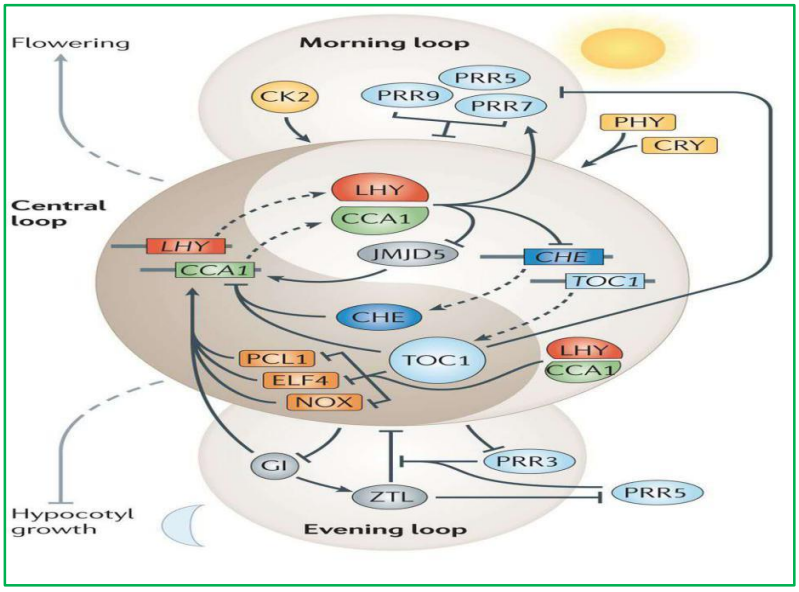

Figure 1.A regulatory network of the circadian clock

Historical research on circadian rhythms

The day night cycle represents one of the most important regular environmental changes that living organisms are exposed (Vallone D).circadian rhythms are present in all living organisms and responsible for almost all biological processes at molecular, cellular and behavioral levels (Lisa Wulund).In 1729 a French astronomer jean Jacques d'ortous de Mairan recorded the first observation of biological timekeeping after notifying that leaves of the Mimosa plant which was known to fold its leaves and leaflets closed at night and reopen during the day .when the plant placed in constant darkness ,de Mairan found that leaf opening and closing continued moving with a periodicity of 24h even to the place without light (Lisa Wulund).In 1751s Carl Linneaus designed a garden consisting of flowers that opened and closed their petals at specific but different times of a day by looking out the window and noting which species were open or closed one might tell the hour of the day (M.Johansson) in 1832, another Frenchman Augustin de Candolle has worked with mimosa and observed that in continuous dark the period length of the leaf opening and closing rhythm was not exactly 24h but approximately closer to 22-23 h (M.Johansson) though he did not prove it at the time .in 1929 ,Erwin Bunning has identified two variants of common bean that differed in their endogenous period length by three hours he crossed progeny exhibited period lengths ranging between the extremes of the two parents suggesting that this property of circadian rhythms is a genetically based polygenic trait(Bunning 1935) .in 1950s,Colin Pittendrigh has studied this circadian clock in fruit flies and Jurgen Aschoff in humans (Martha Hotz Vitaterna).twenty years ago the essential features of the circadian clock has been elucidated in the model plant (Arabidopsis thaliana) and the scientists proved that the biological clock is conserved with the rest of the plant kingdom however the study remains incomplete (Andrew J Tindall).

Circadian clock in Arabidopsis thaliana

In Arabidopsis as a model plant in agricultural research development, the circadian rhythm is associated with multiple important processes and maintained by multiple interconnect loops that generate robust rhythms (Fu-Yu Hung et al).the core circadian clock genes have been identified TIMING OF CAB EXPRESSION1(TOC1) which is dawn expressed and negatively regulates the expression of CIRCADIAN CLOCK ASSOCIATED 1(CCA1),LATE ELONGATED HYPOCOTYL(LHY) .CCA1/LHY binds to the promoter of TOC1 and represses the TOC1 expression (Fu-Yu Hung et al).the CCA1,PRR complex ,TOC1,ELF(EARLY FLOWERING complex) and LUX ARRHYTHMO(LUX) form multiple interlocked negative feedback loops (Akiva Shalit -Kaneh) and REVEILLE(RVE),LIGHT REGULATED WD(LWD),NIGHT LIGHT INDUCIBLE AND CLOCK REGULATED (LNK) that are positive regulators (Keisuke Inoue). LHY and TOC1 have also been shown to repress GIGANTEA (GI) expression and in turn GI induce CCA1 and LHY expression through unknown mechanism thus forming the core clock negative feedback loop (Reetika Rawat et.).The evening complex (EC) is formed by the Myb like transcription factor LUX ARRHYTHMO (LUX) which is also known as PHYTOCLOCK 1 and EARLY FLOWERING complex (ELF3/ELF4) two nuclear proteins with unknown biochemical function .the evening complex EC, CCA1 and LHY are reciprocally regulated with the EC indirectly promoting the expression of these two morning genes and in turn CCA1 and LHY repress the EC components (Reetika Rawat et.).

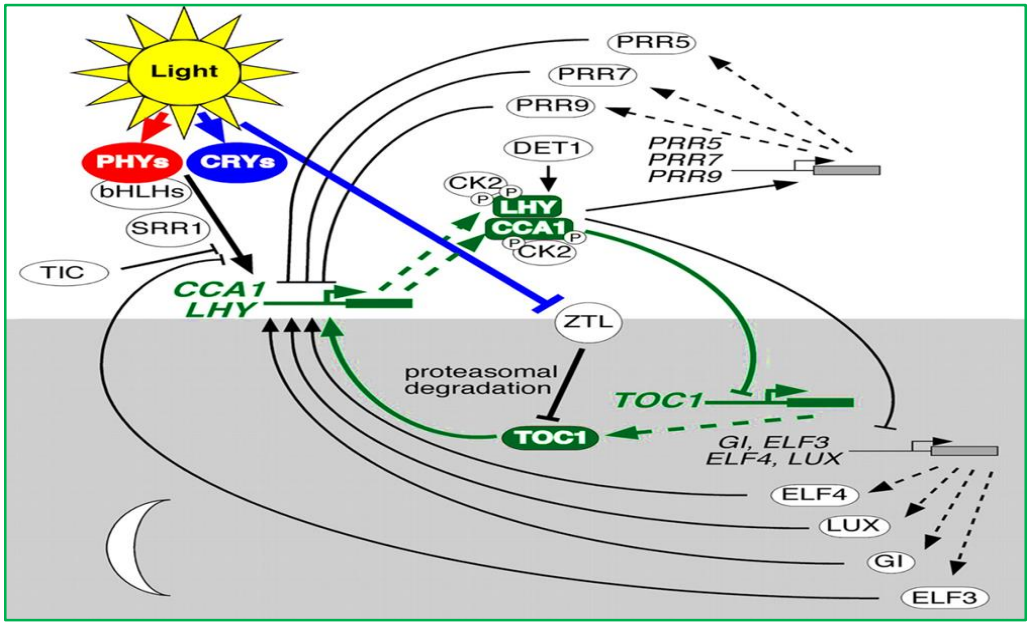

Figure 2.The molecular model of the Arabidopsis thaliana circadian oscillator, the white part (up) represent daytime and dark shaded part (down) indicates evening or night fall time. Genes are indicated by solid boxes, oval and oblong shapes indicate proteins, shaded lines indicate transcription and translation, solid lines indicate protein activity whereas positive action indicated by lines with arrowheads and lines ending with dashes indicate negative action .the core CCA1, LHY, TOC1 feedback loop is highlighted in green with thick lines and closed shapes while and phosphorylation of LHY and CCA1 indicated by circled P.

The circadian clock as master mind of plant life

Plant metabolism

Through photosynthesis plants are able to produce energy (mainly carbohydrates) then transported from source (green organs of the plants) to the sink organs during plant development. During the photosynthetic CO2 fixation drives the synthesis of sucrose and starch then during the night the stored sugars degraded and consumed until dawn .this action is day-night length and approximately 95% of starch in Arabidopsis is used with dawn (Jin A Kim).in Arabidopsis thaliana both sugar and starch are under the circadian rhythm where the compound rise to the maximum at the end of the light period and reduce to the dark period (Dieuwertje Augustijn).the circadian rhythm of net CO2 exchange in CAM (crassulacean acid metabolism) plants in a continuous light is considered as a time dependent generic model system to explore endogenous rhythmicity in a well understandable metabolic pathway (Uwe Rascher et al.).Circadian regulation of photosynthesis within chloroplasts may cause circadian modulation of a retrograde signal that alters mRNA splicing. A chloroplast protein proposed to associate CHLOROPLAST RNA BINDING (CRB) alters the circadian amplitude of CCA1 transcripts (Antony N.Dodd).RCA(RUBISCO ACTIVASE) and RUBISCO SMALL SUBUNIT (RCBS)

have a circadian profile of expression with a peak after dawn it has been shown that the distribution of RUBISCO within chloroplasts varies as a function of circadian time and this rhythm in rubisco distribution correlates with the CO2 fixation rhythm (Nasha Nassoury).GIGANTEA(GI) is necessary for the proper clock response to sugar and its own expression is modulated by sucrose and the endogenous clock entrained by photosynthetic cues (S. A. Sabrina E.Sanchez).it has been shown that metabolically active sugars (sucrose, fructose and glucose) are able to entrain and modify the phase of the core oscillator. Although the inhibition of photosynthesis modifies the pace of the clock, the normal period can be reestablished by the exogenous addition of sucrose. The clock gene PRR7 was shown to be an important link in the connection between sugar and the central oscillator, although CCA1 and LHY might also be implicated in the pathway. The study has shown that carbon-nitrogen metabolites are regulated by the natural light/dark cycle and carbon-nitrogen metabolic genes are natural light/dark cycle expressed (Haixing Li).

Mineral nutrients

Mineral nutrients are solutes that plants extract from the soil to fulfil diverse physiological roles such as energy storage, nutrition and signaling, osmotic potential among others. those include essential nutrients such as N, S, P, Mg2+and K^+, micronutrients and signaling like Ca^{2+} (L. J. Michael J.Haydon).in Arabidopsis thaliana the transcription translation loops (TTLs) begins at dawn with the accumulation of Myb like transcriptional regulators CCA1 and LHY which activate expression of PPR7/PPR9 and PPR7/PPR9 encode transcriptional repressors that in turn act on CCA1/LHY promotors (L. J. Michael J.Haydon). Nutrients demand follows circadian rhythmic pattern as a consequence of diel changes so they are needed in precise amount, deficiency affect plant growth while excess can lead to toxicity .during leaf senescence, plants remove the nutrients accumulated in leaves during the growing season by photosynthesis and nutrients uptake and relocate them to the newly developing leaves or seeds (Hyunmin Kim).we discuss about the role of the circadian clock in the transport of some minerals to the plant.

Nitrogen

There is a circadian regulation of transporters for N,P and S transcripts for chloroplast importers S and P peak around dawn consistent with increased demand for photosynthesis during the day time while transcripts for nitrate and ammonium uptake peak around dawn but the transcripts for nitrate loading through the phloem peak after dusk for source –sink movement of N during the night (A. R. Michael J.Haydon).Researchers have found that there a negative relationship between nitrate uptake and the internal concentration of substrate of nitrogen but other studies have suggested that nitrogen metabolites resulting from nitrate reduction may act as regulatory signals to control the rate of nitrate uptake by roots (Zongjian Yang).in Arabidopsis thaliana CCA1 has been identified as clock component and putative master regulator in the N regulated network therefore CCA1 bind to the promoter of N assimilation genes and alter their expression demonstrating direct regulation of N metabolism by the circadian clock (A. R. Michael J.Haydon).

Calcium

Calcium (Ca2+) is a highly abundant nutrient ion about 3% of leaf dry weight and can participate in cell signaling as a secondary messenger (S. A. Sabrina E.Sanchez).the concentration of cytosolic free calcium([Ca2+]cyt)in plants rhythmic regulated and is

peak around dusk (Michael et al).In 2007 ,Dodd et al proposed that circadian oscillations of [Ca2+]cyt originate from cADPR activated channels using transgenic plants and microarray experiments proved that GI,PRR5,PRR7 and CCA1 were controlled by cADPR (S. A. Sabrina E.Sanchez). ,most likely to be in ER or vacuole but he did not report any plants orthologues for ryanodine receptors thus cADPR activated channels in animal cells so the identity of elusive plant receptor or channel remains unknown (Michael et al).

Iron

It has been shown that plant circadian clock respond to the uptake and homeostasis of various mineral nutrients including Mg,Cu,N ,Fe and others (Sunghyun Hong). In plants Fe plays a major role in photosynthesis as it impacts CO2 assimilation and carbohydrates production but it promotes oxidative stress that may be toxic for cells (Yong-Yi Chen).it has been revealed that regulation of Fe homeostasis is associated with a circadian clock TIC(TIME FOR COFFEE) which expression the ferritin gene AtFer1 (Yong-Yi Chen). Ding et al., 2007 has identified TIME FOR COFFEE (TIC) a circadian clock component which regulate the expression of Fe homeostasis genes and Duc et al 2009 proved that TIC regulates Fe overload responsive genes such as FER1 (Sunghyun Hong). the study showed that in Arabidopsis thaliana the interruption of central circadian clock genes CCA1/LHY may lead to the reduction of Fe uptake and photosynthetic efficiency (Gang Xu).study showed that in Arabidopsis Fe dependent response change in a period of the circadian clock the period is long when the Iron level is low and shortens when the external level of Fe is low (Patrice A Salome).

Copper

Copper is a cofactor that involves in redox pathways and has an effect on thicking of the circadian clock two Myb transcription factors CCA1/LHY have been identified to participate in the core circadian clock of Arabidopsis and showed that excess of external Cu decreases in a dose dependent manner the expression level of CCA1 and LHY (Ana Perea-Garcia).the transcriptional regulation of COPT2(plasma membrane Cu transporter) is under circadian control and COPT2 expression is oscillated under day/night with around 24h and entrained even in the absence of external cues COPT2 expression peaks around dawn while COPT1 peaks at 21.5h several hours before dawn (Ana Perea-Garcia et al).the study has shown that the expression of CCA1/LHY mRNA levels decrease as endogenous content of Cu in Arabidopsis increases and showed that Cu homeostasis could affect the cellular circadian system (Nuria Andres-Colas et al).

Plant hormone pathways

Circadian clock helps plant to adjust with the external environment it regulates phytohormones (IAA, ABA, JA, SA,cytokinin, ethylene, GA,Brassinosteroids) synthesis and signaling pathways to generate daily rhythms in hormone activities which fine tune a range of plant processes and enhance plant adaptation to the local conditions (L.Harmer). Auxin(IAA) induced genes are clock regulated and circadian clock modulate auxin signaling .transcriptional responses to endogenous and exogenous auxin are regulated in a circadian rhythmicity therefore plant growth in response to exogenous auxin enter the plant by the clock (Michael F Covington).Thimann stated that plants are sensitive to auxin and its sensitivity varies according to the day time .more than a half of genes induced by

auxin is clock regulated and both auxin and clock regulated genes show peak expression during a 4h window in the middle of the subjective day (Michael F Covington).JA is known as hormone that induce leaf senescence the study showed that EC composed by ELF4/ELF3/LUX located at hub position to mediate circadian regulation on JA(Jasmonic acid) induced leaf senescence (Yan Wang).TIC was identified as nuclear regulator for proper circadian function from the middle to late subject night . In 2015 Zhou et al. found that SA(salicylic acids) signaling was identified as the cause of circadian clock reinforcement without circadian period change instead of boosting circadian amplitudes of few circadian core component via NPR1 (Jingjing Zhang et al) .SA mediated immune response is influenced by circadian via regulatory control of CCA1 on expression of defense genes (Yan Wang). Auxin and gibberellin pathways are responsible for diurnal growth control therefore interruption of GA biosynthesis genes delays rhythmic growth. Auxin pathway and response are regulated by PIF4/PIF5 while GA responsive genes are not (Kazunari Nozue).alteration of PIF4 expression has been reported to change GA sensitivity that make GA pathway a mediator of PIF4 controlled by daily growth rhythms it also has revealed that GA and BR pathways are regulated by the circadian clock since the GA/BR regulated genes are enriched for circadian regulation (Kazunari Nozue).the time of day specific and photoperiod dependent modulation of hormone signaling network contribute in PIF4 mediated control of diurnal and seasonal growth of the plant (Yuichi Nomoto).cytokinin is a histone kinase like (HK) receptor that phosphorylated at the histone residue then transfers the phosphoryl group to the conserved Asp residue in the fused receiver domain.cytokinin functions as a putative internal signal to affect the circadian oscillator genes CCA1/LHY so in turn CCA1/LHY are needed for cytokinin signaling.phyB,ARR4 and the oscillator can act as signaling to integrate light and cytokinin signals to regulate physiological processes associated with those two signals (Binglia Zheng et al).research has revealed that carotenoids are the precursors to the ABA and over expression of CLA1 or PSY increases the levels of carotenoids and ABA and the transcription of the circadian clock regulated ABA genes NINE-CIS-EXPOXYCAROTENOID DIOXYGENASE(NCED3) and ABSICIC ACID DEFIENT2(ABA2) are accumulated during the subjective morning (Michael F Covington et al).Seung et al.2012,Liu et al.2013 and Legnaioli et al.2009 have researched and proved that ABA is connected with the circadian clock and its synthesis involves clock regulated genes and involve different steps i.e.TOC1 binds with ABAR promoter gene (ABAR) which is a putative ABA receptors, ABA induces TOC1 expression in a gated fashion ABAR closing elegant feedback loop(ABA-CLOCK-ABA).ethylene production is controlled by light entrained clock CCA1 and TOC1 .the main control point for ethylene production is the synthesis of the precursor ACC ,it has been shown that the rhythmic emanation of ethylene correlated with ACS8 transcript level so the light controls accumulation of that transcript and negative feedback regulation of that gene through ethylene signaling is highly imposed on endogenous circadian regulation (Simon C.Thain et al).

Table 1.stress responsive hormones synthesis and signaling by the core circadian components in Arabidopsis thaliana.

Hormone	Gene ID	Gene name	Function	TOC1t arget	PRR5 target	PRR7 target
JA	AT1G17420	LOX3	JA biosynthesis	Y		
JA	AT1G72520	LOX4	JA biosynthesis			
JA	AT3G45140	LOX2	JA biosynthesis			
JA	AT1G19180	JAZ1	Repressor of JA-responsive genes			
JA	AT1G70700	JAZ9	Repressor of JA-responsive genes	Y		
JA	AT5G11270	OCP3	JA signaling	Y		
JA	AT1G25540	PFT1	Regulator of JA responses		Y	
JA	AT1G80840	WRKY40	JA-responsive transcription factor			
JA	AT3G06490	MYB108	JA-responsive transcription factor		Y	
JA	AT1G52890	ANAC019	JA-responsive transcription factor			
ET	AT4G11280	ACS6	ET biosynthesis			
ET	AT5G03280	EIN2	ET signaling			
ET	AT5G47230	ERF5	ET-responsive transcription factor			
ET	AT1G53170	ERF8	ET-responsive transcription factor	Y		

ET	AT4G39403	PLS	Negative regulator of ET signaling		
ABA	AT5G13630	ABAR	Putative ABA receptor		
ABA	AT5G59220	PP2C:HAI1	Catalytic subunit of ABA receptor		Y
ABA	AT3G11410	PP2CA/AHG3	Catalytic subunit of ABA receptor		Y
SA	AT2G41010	CAMBP25	Regulation of SA biosynthesis		
SA	AT1G20020	LFNR2	Regulation of SA biosynthesis	Y	
SA	AT3G56710	SIB1	Regulation of SA biosynthesis		

The role of plant circadian clock in biotic and abiotic stresses response

Like all other living organisms, plants are living in a stressful environment (biotic and abiotic) so plant needs to live with these diverse stresses with less or no effects so to perform this ,they develop transcriptome and metabolism to adjust with unsuitable conditions. Many studies have been done to check the mechanism by which plants can overcome stresses.one of those mechanisms is circadian clock (Alfredo Sanchez).approximately 80% of transcripts cycle in Arabidopsis thaliana are diurnal light dark or temperature cycles and 30-40% of these oscillations persist upon transfer to constant conditions (Jack Grundy et al).

Abiotic stress

Measures such domestication and breeding have been applied to increase plant adaptability with environmental oscillation; circadian clock was identified as the key to improve fitness (Meina Li et al).drought, high/low temperature and salinity are most common abiotic stresses that plant can face. In Arabidopsis thaliana, Approximately 50% of genes responsive to cold ,heat, water and salinity stress has been shown circadian rhythmic this circadian rhythm has been found in expression of abiotic stress responsive genes in soybean and barley (Emily J.Blair et al).TOC1 forms a regulatory feedback loop with the ABA pathway and PRR7 negatively controls drought responsive genes through a TOC1 independent mechanism moreover,TIC mutants show an enhanced tolerance to drought .Kolmos et al in 2014 stated that GI(GIGANTEA) is the molecular link between the clock and the triggered responses though PRR7 might also involve in this mechanism. CBF/DREB1(C-REPEAT BINDING FACTOR/DEHYDRATION-RESPONSIVE ELEMENT-BINDING) is the family of genes responsive to cold stress. and PRR5/PRR7/PRR9 directly repress genes in the clock output pathway including CDF(CYCLING DOF FACTOR) genes which involve in flowering time control and

CBF/DREB in cold stress response (Norihito Nakamichi et al).CBF can also activate the expression of the COR (COLD-REGULATED) genes involve in drought tolerance and are circadian clock regulated CBF1 binds to the LUX promoter to regulate its expression and provides molecular mechanism for the feedback loop ,the central oscillator also modulated by high temperatures by regulation of alternative splicing of the clock component or direct transcriptional regulation of them.HsfB2b(heat shock factor) and FBH1(FLOWERING BASIC HELIX-LOOP-HELIX1) respectively bind with PRR7 and CCA1(Grundy et al.2015).

Biotic stress

Phytohormones play great importance in the response to various biotic stresses Jasmonates (JA) and salicylic acid (SA) are among those hormones. JA defends plant against herbivores (Silvia Nitschke et al), (Claire Bendix et al) and SA against pathogens.JA and SA signaling pathways are connected but in an antagonistic way. (Claire Bendix et al) Studies have revealed the role of core circadian clock in the regulation of these hormones and their control responses and JA/SA accumulation patterns follow a circadian profile but in opposite phases .in Arabidopsis thaliana JA signaling rhythmic controls the susceptibility to the botrytis cinerea and necrotrophic fungal pathogen(Ingle et al .2015).TIC has been shown to be involved in the regulation of the JA receptor COI1(CORONATINE-INSENSITIVE1) and MYC2 ,bHLH transcription factor that induces the transcription of JA-responsive targets therefore TIC might represent the molecular link between the core oscillator and JA ,SA signaling responses also depend on the functional clock.SA biosynthesis and accumulation are regulated by a core clock component CHE(CCA1 HIKING EXPEDITION) Zheng et al.2015 and bind with the promoter element of ICS1(ISOCHORISMATE SYNTHASE 1) which is a major gene involved in SA biosynthesis and positively regulates its expression (Mayank Sharma).

Circadian clock as a manager of plant life

The endogenous circadian oscillator is essential for perceiving and coordinating environmental cues such as day/night, temperature and abiotic stress responses within physiological processes (Kathleen Greenham et al).agricultural traits like flowering time and light responses have been studied in various crop species and shown to be regulated under the circadian rhythm (teacher).the process controlled by the clock, the molecular structure and diverse components of core oscillator are conserved in many different green lineages including angiosperms and gymnosperms. Bendix et al,.2015, the significant role played by the pacemaker in plant performance has been described in tomato Muller et al.2015 proved that the circadian clock helps plant to respond to simultaneous environmental challenges that a sessile plant would not avoid and theses responses are integrated into dynamic metabolic and physiological networks which are essential for plant growth and reproduction (K. G. McClung).there is a big connection between plant early development processes such as leaf polarity establishment where REVOLUTA (REV),the transcription factor is involved and lateral meristem initiation or vascular development which regulate the expression of the senescence promoting transcription factors WRKY53 in a redox dependent manner during early senescence. apart from autophagy and transcriptional response to the reactive oxygen species JA and SA contribute much in biotic and abiotic stresses and this shows big connection between

autophagy and stress control .in Arabidopsis thaliana at least ¼ of genes change their expression and transcription factors for senescence regulation .it has been shown that the periods of clock related genes and of core clock genes shorten in the old leaves compared to the younger leaves and this is regulated by clock oscillator TOC1 (Ulrike Zentgraf).the core oscillator EC that regulating circadian output (He Huang et al) is composed by three proteins ELF3,ELF4 and LUX ,the mutations in EC component lead to natural and pronounced JA induced senescence which shows that EC negatively induce senescence .

Future perspectives

Scientist have involved in the research on the circadian rhythms but much effort need to be put in this field .the circadian clock has a very complex importance in the coordination of transcriptome in natural conditions in naturally occurring plants and crop species however how plants respond to the daily and seasonal changing environment and how the circadian clock coordinate the transcriptome in order to adjust plant in such changing and stressful environment need further knowledge. The knowledge about molecular aspect of circadian clock regulation in plants is derived from manipulation of the central oscillator in the laboratory but it is hard to predict the phenotype after perturbation of the central loop of the endogenous clock (Paige E.Panter et al).researchers need much knowledge about the clock work requirement to predict how the plant will behave in the field under certain unfavorable environmental conditions. Recorded data about circadian clock behavior in a set ups resembling natural phenomena such as light/dark cycle and temperature are still limited.in changing environment and climate change with limited resources the role of biological clock must be fully understood to improve adaptability of the living organisms in such challenging environment .furthermore this will enlarge the research on how the plants can withstand the diverse stresses (e.g. light/dark,temperature,water,nutrition,acidity/salinity etc...) While striving to increase production to ensure food security in the highly growing population on the globe.

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Conflict of interest

We declare that there is no conflict of interest

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