Information in Plants

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Abstract — *Information in plant leaves is determined by the morphology and by the physiological activity of a plant leaf. The information I sent by a plant leaf can be connected with the luminescence spectra emitted by the leaf. The quantity of information I being emitted is specific for a plant species. Obtaining the information I can help us to increase our knowledge about response from plant concerning living environmental conditions and changes in its morphology and physiology.*

Index Terms — *plant leaf, emmited infomation*

1. Introduction

In the plant world, the changes of morphology and physiological conditions of a leaf are always followed by the change of the leaf color (the emitted light). Several examples will be presented. The change of the leaf color can be direct consequence of destruction of the photosynthesis apparatus caused by the effect of high [1,2] or low [3] temperature. The insufficiency of minerals will always cause change of the leaf color [4]. The changes in the genetic structure of a plant will result in the changes of the emission spectrum of the plant leaves [5]. On the other hand, it is well known that the chlorophyll fluorescence in vivo is connected with the mechanism of photosynthesis [6]. Therefore, it is obvious that every change in the photosynthesis process will result in the change of fluorescence [7]. In accordance to all previously said, it can be assumed that the change of the color of a plant leaf (the position of the emission maximum and the shape of the spectrum) can give the information about the physiological condition of a plant as well as about the resulting changes in a leaf.

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2. Theory

Helmholtz free energy F is equal to the difference between internal energy U and product of entropy E and temperature T [8]:

$$F = U - TS \quad \text{Eq.}(1)$$

Decrease of working ability, i.e. live system's free energy F decreasing, means that ability for performing assimilation and dissimulation has decreased [9]. According to theory, one can write that information I which was emitted by biological system is directly proportional to the entropy S of the system [8]:

$$I = \frac{0.693}{k} S \qquad \text{Eq.}(2)$$

, k is Bolcman's constant. From Eq.(1) one can express entropy as S= (U-F)/T and placing in Eq.(2) we have:

$$I = \frac{0.693}{k} \frac{U - F}{T} \qquad \text{Eq.}(3)$$

Considering plant leaf, which presents biological system, it could be assumed that the efficiency of photosynthesis apparatus in performing photosynthesis is equal to the ability to perform assimilation and dissimilation. Determining photosynthesis apparatus' efficiency is based on Kautsky's effect and gained R_{fd}, factor of inducted kinetics that presents measure of photosynthesis apparatus' efficiency [10]. It can be concluded that $F = R_{fd}$, so relation Eq.(3) is transformed into :

$$I = \frac{0.693}{k} \frac{U - R_{fd}}{T} \qquad \text{Eq.}(4)$$

On the other hand a plant reminds visible over extended periods of time and has to gain as much energy as it loses during energy exchange with environment by radiation. Plant leaf surface are nearly black and have emissivity ε between 0.95 and 0.98 [11]. Therefore, we considered flat plant leaf fluorescence emission from point of view of black body radiation. We assumed, in agreement with Stefan-Boltzmann low, that area under the flat plant leaf fluorescence curve is equal or close to the total energy a plant leaf can emit in environment. According to the facts mentioned above the total energy budget of a flat plant leaf can be expressed by area under the fluorescence curve of a flat plant leaf: U = A_{FPL}. Now placing $Q_{\Sigma epl}$ Eq.(4) one obtained:

$$I = \frac{0.693}{k}\frac{0.965A_{PLF} - R_{fd}}{T} \qquad Eq.(5)$$

From Eq.(5) it is clear that in order to obtain information I which plant leaf emitted in environment, sufficient way is to use plant leaf optical measuring dates (chlorophyll fluorescence and induction kinetics/Kautsky effect).

2. RESULTS AND DISCUSSION

It is well known that any environmental unfavorable conditions can cause change in plant structure [12] and morphology [13]. At the same time, it can influence on fluorescence spectra and induction kinetics [14]. Therefore, one can conclude that any change in fluorescence spectra and induction kinetics is direct consequence of change in plant structure and photosynthetic activity. In agreement with facts mentioned above and Eq.(5) it is expected that information I which plant can emit in environment can be changed. In the other words, any changes in plant structure and photosynthetic activity can cause change of information which plant can emit in environment. Later in the paper, we present several examples, which clearly show connection between changes in plant morphology, photosynthesis activity and emitted information I.

From the other point of view the same problem can be considered inversely. So, one can say that any change in information I which plant emit in environment can be indicator that something happened in plant (destroyed or decrease of photosynthesis, changes in structure etc.) as direct consequence of change living environmental conditions.

Furthermore, we can show how information I, which plant can emit in environment is connected with plant state and its response on changes of environmental living conditions.

As we previously sad any change in environmental conditions can cause changes in structure and photosynthetic activity in plant and at this way can cause changing in system (plant) order - entropy S. This leads toward conclusion that information I which plant can emit in environment can be change. One illustrative example is cadmium-induced alteration in photosynthetic activities of Zea mays L.[15]. The data are presented in Table 1.

Taking great changes in plant photosynthetic activities, which is one the most important process in plant, into account, can cause great changes in plant order in the manner: greater changes in photosynthetic activities, greater changes in system order at thus way in system entropy S. Increase of Cd concentration causes damage of the photosynthetic apparatus [16]. Greater change in S can cause greater change in information I that plant sent to environment. Data from Table 1 suggest on conclusion that increasing Cd concentration can induce decrease of information I that mean great change in system (plant) order.

Table 1. Cadmium-induced change in information I for Zea mays L [15].

Treated with Cd (mM)	R_{fd}	A_{PLF}	I [bit/s] x 10^{18}
0.00	1.32	208726	3.45
0.01	1.27	194314	3.21
0.1	1.43	167450	2.77
1.00	1.48	108877	1.81

In this example we can consider connection between information I and structural changes in plant leaf. We can consider change of information I due to change of concentration of photosynthesis pigments. It is clear if the concentration of the most important constituent

[Ch(a), Chll(b), caroten] for photosynthesis decreases itself, the ability for photosynthesis in plant leaf can also decrease. In final state if the molecules of mentioned important pigment disappear or are completely destroyed, photosynthesis stop and plant is dead with the greatest change order at this way in the greatest change in entropy S. According to Eq.(2) it means the greatest change in information I. Information I calculated using literature data for Chery-laurel (Prunus laueocerasus) [17]. In the Table 2 obtained data are presented for chery-laurel (Prunus laueocerasus) [17]. One can see that information I, which plant, can emit in environment increase with decreasing pigment concentrations. It is expected, because smaller pigment concentration is connected with greater system disorder /greater entropy S. Also, data in Table 2 suggest conclusion that decreasing of photosynthesis pigment concentration is followed with adequate information I increasing.

Table 2. Effect of pigment content of Chery-laurel (Prunus laueocerasus) information I [17].

Σ[Chl(a)+Chl(b)+carot.] [μgr/cm^2]	R_{fd}	A_{PLF}	I [bit/s] x 10^{14}
66	2.90	110	17.68
40	2.30	165	26.88
6.5	2.00	275	45.11

In this case, the effect those completely different sources have on information I which plant can emit in environment is described. Namely, influence of unfavorable living environmental condition on information should be considered. Global worming and the increase of UV radiation, due to damaging the ozone layer, are obstacles for the normal photosynthetic activity and present a treat to the survival of the plant life itself.

Numerous researches point out that UV radiation doubtlessly induces multiple and various changes on plants. Gradually, it becomes one of the major ecological problems. But beside numerous experimental data there are contradictory results regarding the effect of UV radiation to the plants. So, exposure to increased UV-B radiation has been shown to reduce photosynthesis in many plant species [18].

A few studies show that UV-B radiation did not have significant effect on chlorophyll concentration at rice and pea plants [19]. In the Table 3 data about effect of the UV-B and UV-B/A radiation on soyaben (Glycine max) plant information I are presented. We used data of the effect UV radiation on soyaben (Glycine max) for calculating information I [20]. It is clear that information from the sample is smaller for plant exposed to UV-B and UV-B/A radiation comparing to the control plant. In agreement with conclusion about effect of UV radiation on plant we are not able to conclude if it has positive or negative effect on plant but it is sure that effect is not neglected.

Table 3. Effect of the UV-B and UV-B/A components of solar radiation on soyaben (Glycine max) information I. [20]

	R_{fd}	Area	I [bit./s] x 10^{15}
Control.	0.694	612	10.10
UV-B	0.699	553.96	9.14
UV-B/A	0.695	490.53	8.09

Finally we can consider morphology change in plant leaf and its effect on information I. As we mentioned above any change in plant morphology can cause change in efficiency of plant photosynthetic activity regardless the reason, which cause change. Sometimes unforgivable environmental conditions such γ-radiation can cause genetic change in plant and direct consequence can be mutant. Thus, in any mutant of one plant species genetic difference can cause difference in structure and morphology and in this way difference in photosynthetic activity. Direct consequence of changing plant photosynthetic activity can be change of the florescence spectra and induction kinetic. Changes in genetic mean changes in structure and in the same way changes in order – entropy S. According to Eq.(5) it is expected that information I which plant emit in environment can vary from species to species. In other words, change in information I unambiguously can show that change in morphology occurred. In Table 4 data for five mutants of the cowpea (Vigna unguiculata (L) Walp) varieties [21] are presented. One can see from Table 4 that for the same variety information I change with its age: information I increases with age. This change can be connected with change in structure and functionality of the photosynthesis apparatus efficiency due to getting old. Described change – increase of information I due to getting older is understandable. Namely, process of getting older is unavoidable for all biological objects. Destruction and retrogression of biological object's structure and decreasing of physiological processes follow it. Direct consequence of these changes is increase of system's disorder, measured by entropy. It means that entropy of the system will be increased too. By getting older, biological systems move from the state of higher order (higher entropy S) toward states of lower order (lower entropy S). In accordance to the information theory, it can be said that the information I, which is sent to the environment, is directly proportional to the system entropy S [8]. Therefore, in agreement with facts mentioned above, discursion and information theory obtained increasing information I with plants getting old are expecting. Also, one can see (Table 4) that information I is different for the same age of varieties. One of reasonable explanation can be that different mutant during the growing process change its order, entropy S, slower or faster and have different "grooving rate". At this way slower or faster change of entropy can cause slower or faster change in information I. This fact leads to conclusion that rate of change in information I can be measure of biological system vitality. In the simple words: slower change of information I mean greater biological vitality and contrary faster change of information I mean lower biological vitality.

Table 4. Information I in cowpea (Vigna unguiculata (L) Walp) varieties [21].

Cowpea (Vigna unguiculata (L) Walp) varieties				
		R_{fd}[22]	A_{PIF} [cm^2]	I [bit/s] x 10^{15}
V1	6 week	3.4	250.11	4.076
	7 week	3.4	340.30	5.567
	8 week	3.4	510.81	8.385
V2	6 week	3.4	684.25	11.25
	7 week	3.4	1032.65	17.01
	8 week	3.4	2593.84	42.81
V3	6 week	3.4	353.53	5.785
	7 week	3.4	584.81	9.608
	8 week	3.4	1890.82	31.19
V4	6 week	3.4	296.40	4.841
	7 week	3.4	628.81	10.34
	8 week	3.4	1713.06	28.26
V5	6 week	3.4	358.75	5.871
	7 week	3.4	1328.32	21.9
	8 week	3.4	2659.17	43.89

Taking facts mentioned above into account, if we define information rate Ir as change of information I in chosen time interval ΔI/Δt it can be possible to determine biological vitality. Time interval Δt may be defined as second, day, months or years depend of biological object, growing condition etc. So comparing Ir of several different biological objects in unforgivable environmental condition it can be determined which one have greater vitality, abilities to keep its properties better then the other ones.

3. Conclusion

Information that plans can emit in environment could be used as tool to give answer on questions:

- Did unfavorable environmental conditions cause damage in plant;
- What is plant ability to adapt to unforgivable environmental conditions
- Did unfavorable environmental conditions cause change in plant genetic.

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