Advances in Engineering Research, volume 151
International Conference on Smart Solutions for Agriculture (Agro-SMART 2018)

Comparison of Potato Chlorophyll Fluorescences Variables and Analysis of Clusterization

Lee Yi
PhD-student of Department of Agriculture and Plant Cultivation, Agronomical Faculty
Irkutsk State Agrarian University
named after A.A. Ezhevsky
Molodezhny, Irkutsk region, Russia
e-mail: li05161020 @163.com

Ya. M. Ivanyo
Professor of the Department of Informatics and Mathematical Modeling, vice-rector for research
Irkutsk State Agrarian University
named after A.A. Ezhevsky
Molodezhny, Irkutsk region, Russia
iasa_econ@ rambler.ru

V.I. Solodun
Professor of the Department of Agriculture and Crop Production, Agronomy Faculty
Irkutsk State Agrarian University
named after A.A. Ezhevsky
Molodezhny, Irkutsk region, Russia
rector@igsha.ru

V.V. Verkhoturov
Head of the department of technology of food and chemistry
Irkutsk National Research Technical University
Irkutsk, Russia
biovervv@mail.ru

S.P. Burlov
Ass. Prof. of Department of Agriculture and Plant Cultivation, Agronomical Faculty
Irkutsk State Agrarian University
named after A.A. Ezhevsky
Molodezhny, Irkutsk region, Russia
e-mail: 89501298375@yandex.ru

***Abstract*— The article presents the results of comparative analysis of chlorophyll fluorescence parameters of four potato hybrids: "Sante×Granat", "27004", "28034-7", "9635-30" and "Sarma", a widespread variety in Irkutsk region. The values of chlorophyll fluorescence parameters have been received by the method of pulse - amplitude modulation. According to five parameters characterizing the potential of photosynthesis and the strong mechanism of photosystem protection against intensive lighting, the most preferable hybrid has been the hybrid "9635-30". It can be used for further potato selection. Based on clustering we have distinguished three groups from four tested hybrids and one variety. The first group includes "Sarma" and "28034-7", the second group includes "Sante×Granat" and "27004", and the third group includes "9635-30". According to the clusters properties and experimental data the second group was the least perspective, firstly for the resistance to heat. Therefore, we have offered to continue researching samples "9635-30" and "27004" for receiving new variety.**

Keywords*— *potatoes, photosynthesis, chlorophyll fluorescence, main component, clusterization

I. Introduction

Potatoes are characterized by the high yield potential (60-100 t/hectare), resistance to unfavorable conditions and high content of useful substances. Studying the photosynthesis represents a fundamental and practical basis for formation of potatoes yield. To obtain the parameters characterizing chlorophyll fluorescence the widespread method of pulse - amplitude modulation is applied..

A. The research objective

The research objective is to assess the potential of efficiency of potato varieties and selection lines photosynthesis cultivated in the conditions of Baikal region for definition of the most perspective samples.

- to study the photosynthesis of perspective selection lines;
- to compare the condition of photosynthesis of potatoes hybrids to the recognized variety Sarma;
- to group potatoes samples according to the general variables of potato chlorophyll fluorescence;

- to allocate the most perspective hybrids by the efficiency of photosynthesis processes.

II. Materials and methods

The scientific research was conducted on the production experimental trial of the Irkutsk State Agricultural University in the settlement "Molodezhnyi" in 2017.

The soil of the experimental trial was gray forest medium-argillaceous with fine structure, subacidic reaction of soil solution (pH – 4.9 - 5.6), low degree of humus (the humus content is 2.4%), phosphorus – 36-38 mg/100g of soil, potassium – 5.2 mg / 100 of soil. Total absorbed bases were 20 - 40 mg.eq./100 g of soil, hydrolytic acidity was 2-4 mg.eq./100 g of soil, and degree base saturation was 80 - 90% [3].

Potatoes were placed in a crop rotation: steam – potatoes – wheat. Ridges of 10-12 cm high were formed prior to planting by a cultivator “KOH-2.8”. Planting was carried out on May 18-25, the area of one bush was 70×35 cm. Care – mounding after sprouting were done by a cultivator-cum-ridger KOH - 2.8. As a control we chose the variety "Sarma" which was released in Irkutsk region [4].

Parameters of chlorophyll fluorescence of middle conopy branches apical leaves of potato hybrids (not lesser than 8 leaves) were measured, but they were previously adapted to darkness within 30 min. by means of a fluorometer of GFS-3000 (Pulse Amplitude Modulation).

During the experiments the parameters of chlorophyll fluorescence were registered (initial fluorescence F0 – ML: light intensity 0,1 µmol/m2·s, length 3µs, wavelength λ=655 nanometer; the maximum fluorescence of Fm – SP: light intensity till 1600 µmol/m2·s, lasting 0,8 with, wavelength λ = 665 nm); static fluorescence Ft – AL: light intensity from 200 to 6000 µmol/m2·s, wavelength λ = 665 nm; equal values of light intensity were used for the actual maximum fluorescence), minimal chlorophyll fluorescence F0' - where all corresponding settings were automatically set in memory of the GFS-3000 device. Other studied parameters of chlorophyll fluorescence are specified in the table 1.

TABLE I. Parameters of chlorophyll fluorescence

Formula	Name
$\Phi_{PSII}=\Delta F/F_m'$	quantum yield
$Q_P=(F_m'-Fs)/(F_m'-F_0')$	Photochemical suppression
$ETR=Yield\times0.84\times0.50\times\Phi_{PSII}$	Velocity of photosynthetic electronic transport
$qN=(F_m-F'_m)/(F_m-F_0)$	Nonphotochemical suppression
$NPQ=(F_m-F_m')/F_m'$	Nonphotochemical suppression

Field research was carried out by B.A. Dospekhov's method [1]. The cluster analysis [5] of the results, was made by the software of Microsoft Office of Excel and Statistica 7.0.

III. Results and their discussions

Carrying out the comparison of chlorophyll fluorescence of potato hybrids of the variety "Sarma", we have revealed that according to the value F_0, F_m, F_t, F_m', F_0', qN, NPQ there are significant differences between hybrids and the variety "Sarma" (таб. 1). The hybrid "9635-30" has low value of initial fluorescence F_0. The value amount of this indicator depends on the chlorophyll content in the studied tissues as well. High values of F_0 indicate less effective transmission of excitation energy between pigmentary molecules in the light-harvesting antenna PhS II (Photo System II). For example, at a thermal stress when thylakoids are damaged and there is an inactivation of PhS II [10] the hybrids "27004" and "Sante × Granat" have low value of maximum fluorescence F_m. Often to estimate the potential of photosystem efficiency the ratio F_m/F_0 is used – the retio of the Fl maximum level (F_m) to initial (F_0). Here we have not noticed any considerable differences in correlation of F_m/F_0 and F_v/F_o , that proves the efficiency of using the excitation energy in PhS II. The first ratio is equal to a constant of primary photochemical reaction speeds (k_p), and the second equals the general speed of nonphotochemical losses (k_n) [14].

We have not noticed any essential difference between hybrids and the variety "Sarma" on correlation F_v/F_o и F_v/F_m. The value F_V decreases under the influence of stressful factors of the environment (low or high temperatures, freezing, etc.), which cause damage of thylakoid [12]. Changes of values in the ratio F_V/F_m is considered the most sensitive indicator characterizing the influence of photoinhibition (the phenomenon of photosynthesis suppression and the damage of the photosynthetic device at a high light intensity) [8].

There are significant differences on parameters values F_t, F_m', F_0' between the hybrid "9635-30" and the variety "Sarma". Stationary fluorescence of Ft represents chlorophyll fluorescence strength which is radiated by photosynthesizing objects in the conditions of stationary illumination. At the same time, there comes the balance between production of assimilatory power in photochemical reactions (molecules ATP and NADPH) and the enzymatic reactions using these molecules in a dark phase [2].

There are no significant differences between hybrids and the variety "Sarma" on parameters values Yield, ETR, qP (tab. 2). The parameter Yield allows to estimate a quantum yield of photochemical reaction in PhS II. It is the most popular and important parameter which represents the ratio of quanta number used in photochemical transformations to the total number of the absorbed quanta of PAR [6]. The electrons flow through the ETR photosystems has positive correlation relationship with the carbon reduction speed under optimum conditions of potato growing, and on change of any factor this relation will be destroying. The qP parameter represents a share of the photo energy consumed by the open centers in photosynthesis reactions in total of the PhS II absorbed energy [2].

Non-photochemical suppression (qN, NPQ) is connected with the processes responsible for conversion of the part of energy to heat, absorbed in a light-dependent reaction. The analysis of parameters values of qN and NPQ for "9635-30" testifies that they are much higher, than at the variety "Sarma" (tab. 2).

By means of the correlation analysis we can reveal relations between different indicators of chlorophyll fluorescence of potato hybrids. Our studies has confirmed that there is a close positive relation between F_0 and F_0', F_t and F_0', Yield and ETR, qN and NPQ with the correlation coefficients exceeding 0,90. There is a slightly lower narrowness of communication between F0 and Fm, Ft, Fm and F0', Yield and qP, ETR and qP (coefficient of correlation 0,8-0,9). We have revealed close negative relations of the correlation coefficient values of 0,80 more between parameter Yield and qN, NPQ, ETR and qN, NPQ.

TABLE II. COMPARISON OF VARIABLES OF CHLOROPHYLL FLUORESCENCE OF POTATO HYBRIDS WITH A VARIETY SARMA

	F0, mV	Fm, mV	Fv/Fm	Fv/Fo	Ft, mV	Fm', mV	F0', mV	Yield	ETR	qP	qN	NPQ
Sarma	67.7	315.0	0.79	0.79	82.9	169.7	57.7	0.48	34.4	0.74	0.54	1.03
9635-30	59.0*	296.7	0.80	0.80	71.8*	133.5**	47.3**	0.45	30.4	0.72	0.64*	1.36**
27004	65.0	281.7**	0.77	0.77	81.4	155.1	55.2	0.47	31.5	0.74	0.54	0.86
28034-7	68.8	321.5	0.78	0.78	86.4	163.0	57.8	0.47	31.4	0.73	0.58	0.99
Sante x Granat	63.7	286.8*	0.78	0.78	77.2	152.0	53.2	0.49	33.1	0.76	0.55	0.89

Based on the Principal Component Analysis we have received the contributions of each parameter to the photosynthetic efficiency. It follows from the table 3 that the contribution accumulation of the first five principal components reaches 99,1% that is enough for the analysis of potato chlorophyll fluorescence. The first principal component (F1), equaled 44,7% from total variation, depends on the parameters Yield and ETR. The second component (F2), making 38,6% of the total variation, includes the parameters F_t, F_m' and F_0'; the third component equals 10,7% and contains the ratio F_v/F_m; the fourth one equals 4,7% and is connected with the parameter qP; the fifth component equals 1,0% and includes parameters qP and qN.

TABLE III. THE VECTORS OF A CORRELATION MATRIX CHARACTERIZING VALUES AND A CONTRIBUTION TO THE PHOTOSYNTHESIS EFFICIENCY

Components / Parameters	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Fo	-0.2910	0.3526	-0.0841	0.2706	-0.1684	-0.3303	-0.2108	0.2368	0.0188	-0.3981	0.5602
F_m	-0.3054	0.2948	0.3518	0.1838	-0.0627	-0.4768	0.2225	-0.3745	-0.2905	0.3545	-0.1765
F_v/F_m	0.0146	-0.2018	0.8526	-0.1514	0.1829	0.1201	-0.1556	-0.0745	0.0676	-0.1605	0.3182
F_t	-0.2195	0.4070	0.0813	-0.2748	0.2872	0.0278	0.2171	0.4201	0.5147	0.3629	0.0223
F_m'	0.0963	0.4567	0.2096	-0.0793	-0.1761	0.4166	0.1565	0.3674	-0.5474	-0.1850	-0.1845
F_0'	-0.1843	0.4330	-0.0312	0.1878	0.1642	0.4177	-0.2983	-0.5102	0.2854	-0.2309	-0.2383
Yield	0.4278	0.1123	0.1604	0.0796	0.1177	-0.4509	0.1751	0.1090	0.2757	-0.4967	-0.4358
ETR	0.4051	0.1589	0.1793	0.1893	-0.4734	-0.0310	-0.5254	0.1389	0.2028	0.4178	-0.0810
qP	0.3849	0.0670	-0.0071	0.6627	0.4287	0.1674	0.2538	0.0245	-0.0638	0.2013	0.2945
qN	-0.3648	-0.2527	0.0583	0.3090	0.3768	-0.0591	-0.4296	0.4234	-0.1787	0.0352	-0.4022
NPQ	-0.3195	-0.2830	0.1716	0.4197	-0.4797	0.2539	0.4069	0.1236	0.3340	-0.0884	-0.1325
Characteristic values A	4.92	4.24	1.11	0.52	0.11	0.06	0.02	0.01	0.01	0.00	0.00
Contribution %	44.7	38.6	10.1	4.7	1.0	0.6	0.2	0.1	0.1	0.0	0.0
Accumulation contribution %	44.7	83.3	93.4	98.1	99.1	99.7	99.9	100.0	100.0	100.0	100.0

By values of the photosynthetic efficiency competitiveness coefficient the potato variety "Sarma" is the best, and the hybrid "9635-30" is the worst.

On the basis of clusterization we have distinguished three groups from four tested hybrids. The first group includes "Sarma" and "28034-7", the second one includes "Sante×Granat" and "27004", and the third group includes "9635-30".

The first group "Sarma" and "28034-7" is characterized by the average parameters values of F_m, Yield, NPQ as well as the high levels of F_0 and F_t; qP.

Lower parameters values of F_m и NPQ as well as the average parameters of Yield, ETR and qP are characterized the second group (hybrids "27004" and "Sante×Granat").

The third group, which includes the hybrid "9635-30" is characterized by higher parameter values of F_m and NPQ, as well as low values of F_0, F_t, Yield, ETR and qP.

According to the properties of clusters and experimental data the second group was the least perspective, initially, on thermal resistance. In this regard the hybrid "9635-30" was the most perspective.

IV. Conclusions

The results of research demonstrate that from many parameters, the characterizing chlorophyll fluorescence, Fo, Fm, Fv/Fm, Ft, Fm', Fo', qN, NPQ have a great impact on differences between hybrids and control that substantially depends on a genotype [15].

Parameters of chlorophyll fluorescence Fv/Fm, Fv/Fo, Yield and ETR are important indicators of the photosynthesis effect. The proportion Fv/Fm presents the potential of the photoenergy conversion efficiency of the primary photochemical reaction [11]. Along with the Fv/F0 parameter they reflect efficiency potential of PhS II. According to the research we have revealed that, in magnitude Fv/Fm and Fv/Fo, the hybrid "9635-30" has the best efficiency potential of PhS II. The Yield parameter defines a quantum yield of the photochemical reaction in PhS II. The parameter ETR is closely connected with the active chemical energy efficiency of ATP and NADPH[13]. The analysis of these parameters has sown that "Sante × Granat" and "Sarma" have high actual ability of photosynthesis in Baikal region. The environmental factor strongly influences the photosynthesis effect. In particular, the hybrid "9635-30" has the largest potential of photosynthesis. However, the efficiency of photosynthesis was the lowest in comparison with other samples.

The identical tendency has been determined by the actual ability of photosynthesis according to the Yield, ETR and qP parameters for the tested samples.

The parameter of the non-photochemical suppression NPQ is connected with thermal losses and ability of dissipation of the private absorbed light energy that is the mechanism of photosystem protection [9]. Based on the analysis of this parameter we have revealed that the hybrid "9635-30" has rather strong mechanism of protection against intensive lighting.

Usage of the method of pulse - to amplitude modulation illustrates that samples "Sante × Granat" and "Sarma" have high efficiency of photosynthesis in the conditions of Baikal region. This conclusion coincides with the result of the main components analysis. The hybrid "9635-30" has high potential of photosynthesis and the strong mechanism of photosystem protection against intensive lighting that can be used in potato selection. The efficiency of photosynthesis is not a unique factor of formlating productivity, it has been confirmed by the data on the yield of the studied samples ("Sante x Granat" - 34,3 t/ha, "Sarma" - 27,2 t/ha, "27004" - 39,0 t/ha, "28034-7" - 32,2 t/ha, "9635-30" - 35,7 t/ha).

References

[1] B.A. Dospekhov, “Fielplot technique”, Moscow: Agropromizdat, 1985, p. 351.

[2] V.N. Goltsev, H.M. Kaladzhy, M. Paunov, V. Baba, T. Khorachek, et.al, “Using variable chlorophyll fluorescence for assessment of the physiological state of photosynthetic applicator”, Plant physiology, 2016, Vol. 63 (6), pp. 881–907.

[3] Yi Lu, “Ecological plasticity and stability of potato hybrids in conditions of Baikal region”, Bulletin of BSACA, 2018, Vol. 51, pp.139-142.

[4] Yi Lu, S.P.Burlov, “Results of testing potato hybrids in Baikal region”, Bulletin of Irk SACAc, 2018, Vol. 85, pp. 38-45.

[5] S.A. Aivazyan, V.S. Mhitarian, “Applied statistics”, Moscow, 2001, p. 641.

[6] B. Genty, J.-M. Briantais, N.R. Baker, “The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence:, Biochim. Biophys. Acta, 1989, vol. 990, pp. 87-92.

[7] B. Genty, J.-M.Briantais, N.R. Baker, “The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence”, Biochim. Biophys. Acta, 1989, Vol. 990, pp. 87–92.

[8] J. He, C.W. Chee, C.J. Goh, ”Photoinhibition’ of Heliconia under natural tropical conditions: the importance of leaf orientation for light interception and leaf temperature”, Plant Cell Environ, 1996, vol. 19, P. 1238–1248.

[9] Zh.Ming, D. Zaisong, R. Ishhill, et al,. “The changes and components of non-photochemical quenching under drought and shade conditions in maise”, Acta Agron Sin, 2003, vol. 29, No.1, pp. 59-62.

[10] A. Murkowski, “Oddziaływanie czynników stresowych na luminescencję chlorofilu w aparacie fotosyntetycznym roślin uprawnych”, Monografia, vol. 61, Lublin: Instytut Agrofizyki im. Bohdana Dobrzańskiego PAN, 2002.

[11] Q. Zhang, G. Jiang, X. Zhu, et al., “Photosynthetic capability of 12 genotypes of Tritium aestivum”,. Acta Phytoecol Sin, 2001, vol. 25, No. 5, pp. 532 -536.

[12] R.M.J. Reigosa, O. Weiss, “Fluorescence techniques // Handbook of plant ecophysiology technique”, S. Reigosa R.M. Dordrecht, Eds. the Netherlands: Acad. Publ., 2001. pp. 155-171.

[13] K. Rohacek, “Chlorophyll flourescence parameters: the definitions, photosynthetic meaning and mutual relationships”, Photosyntetica, 2002, vol. 40, No. 1, pp. 13-29.

[14] R.J. Strasser, M. Tsimilli-Michael, S. Qiang, V. Goltsev, “Simultaneous in vivo recording of prompt and delayed fluorescence and 820-nm reflection changes during drying and after rehydration of the resurrection plant Haberlea rhodopensis”, Biochim. Biophys. Acta, 2010, vol. 1797, pp. 1313–1326.

[15] X. Zhao, M. Zhao, L. Jun, et al, “Research on photosynthetic characteristics attemperate of remote crossing progenies which present high photosynthesis at tropic zone”,. J China Agric Univ, 2002, vol. 7, No. 3, pp. 1-6.