大豆葉同化速度の品種間差異の生ずる機作 第3報

誌名	日本作物學會紀事
ISSN	00111848
著者	渡辺, 巌 田淵, 公清
巻/号	42巻4号
掲載ページ	p. 437-441
発行年月	1973年12月

Proc. Crop Sci. Soc. Japan 42(4) : 437-441 (1973)

Mechanism of Varietal Differences in Photosynthetic Rate of Soybean Leaves*

III. Relationship between photosynthetic rate and some leaf-characters such as fresh weight, dry weight or mesophyll volume per unit leaf area

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INTRODUCTION

We have already some reports on the relationship between photosynthetic rate and some leaf-characters such as fresh weight, dry weight or leaf thickness[2,3,5,6,8,9,10,11,13]. Some of these works intended to clarify the physiological mechanism of varietal difference in photosynthetic rate[2,13] and some to find out leaf-characters which are correlative with photosynthetic rate[3,5,6,8,9,10,11]. They reported positive correlationships between photosynthetic rate and some of these characters and alluded that correlative characters might be acceptable as selection indices for leaf photosynthetic rate. But correlative coefficients were not always enough high or enough universal for these characters to be used alone as selection indices. In some reports, the relationships were dependent on the leaf position on the stem[8] or on growth stage[6]. The leaves used in the experiments did not seem to be always uniform as to the environmental conditions under which they grew, leaf position on the stem or as to the age of plant and leaf, in spite of the informations that leaf-characters were affected by these conditions[1,4].

In the previous study[12] we found equality of volume of chloroplasts existing in unit leaf area among primary leaves of soybean varieties. Hence we suggested that chloroplast quality would be more important factor than chloroplast quantity in view of varietal difference in photosynthetic rate of soybean leaves. This information made us suppose that these leaf-characters of primary leaves would not be highly correlative with photosynthetic rate.

The relationship between photosynthetic rate and these leaf-characters were examined using primary leaves of soybean varieties. We took extreme care of the uniformity of environmental conditions within each experiment and of leaf age, which was rather easy with primary leaves.

MATERIALS AND METHODS

Fifteen soybean varieties [*Glycine max* (L.) Merrill] were used; Amsoy, Acme, Harosoy, Wasekogane, Mandarin, Adams, Shiromenagaha, Norin NO. 2, Monroe, Shinanomejiro, Waseshirome, Oyachi NO. 2, Shiromeyutaka, Manshū, and Norin NO. 1. Experiment was repeated two times, expt. 1 and 2. Seeds were sown on July 19 (expt. 1) and on Aug. 12 (expt. 2) both in soil-packed Wagner pots (1/5000 a) for the material to be used for photosynthesis measurement and in soil-packed wooden boxes (65 cm × 50 cm, 10 cm deep) for the material to be used for leaf-character measurement. Primary leaves were used exclusively in the experiments, so that no fertilizer was added to the soil.

Photosynthetic rate of intact primary leaf was measured under saturating light (50 klx) with a Hitachi-Horiba absolute type infrared CO_2 analyzer. In both experiments, leaves were used just after the completion of leaf development, when soybean leaf was reported to be most active in photosynthesis[7]. Photosynthesis measurement was repeated five to six times for a variety using different leaves of different plants and the photosynthetic rates were averaged for each variety.

* Received for publication on April 6, 1973.

For the measurement of mesophyll volume per unit leaf area, 100 primary leaves were sampled for each variety on the same day as photosynthesis measurement. The leaves were piled up correctly and 100 leaf discs were cut off the pile at the middle part of each leaf with a cork-borer (inside area 6.674 cm^2). The volume of the pile was measured using a Toshiba-Beckman Air Comparison Pycnometer Model 930. Measurement was repeated 10 times for the same pile and mean value was calculated. To prevent transpiration from leaf discs, the pile was wrapped softly with a thin vinyl film. Mesophyll volume per unit leaf area was calculated deviding the volume of the pile by the total area of the discs.

Fresh weight per unit leaf area (density thickness based on fresh weight, DTFW) was measured using the pile of leaf discs above mentioned. Then the pile was dried in a forced-draft oven at 80°C for a day. Dry weight of the pile was measured and dry weight per unit leaf area (density thickness based on

Table 1 Varietal leaf-characters

Order of photosynthetic rate	Variety	Photosynthetic rate $mgCO_2/dm^2 \cdot hr$	Mesophyll volume μ^3/μ^2	DTFW[a] g/dm^2	DTDW[b] mg/dm^2	Dry weight percentage
Expt. 1						
1	Amsoy	66.7	154	1.64	217	13.2
2	Harosoy	57.4	148	1.55	183	11.7
3	Shiromenagaha	56.0	160	1.72	223	13.0
4	Adams	54.1	140	1.50	191	12.7
5	Wasekogane	52.0	167	1.77	197	11.1
6	Mandarin	49.2	152	1.60	201	12.6
7	Monroe	45.2	141	1.50	211	14.0
8	Shiromeyutaka	43.9	151	1.59	195	12.3
9	Norin NO. 2	43.8	142	1.48	182	12.2
10	Acme	41.2	134	1.39	164	11.8
11	Norin NO. 1	41.1	139	1.48	242	16.4
12	Ōyachi NO. 2	40.7	138	1.44	204	14.1
13	Shinanomejiro	36.5	145	1.51	198	13.1
14	Waseshirome	35.7	139	1.50	216	14.4
15	Manshū	26.1	151	1.59	222	14.0
	Mean	46.0	147	1.55	203	13.1
Expt. 2						
1	Monroe	49.3	148	1.55	227	14.7
2	Amsoy	45.2	151	1.60	278	17.4
3	Shiromenagaha	44.7	155	1.62	267	16.5
4	Mandrain	42.4	156	1.64	262	15.9
5	Shiromeyutaka	40.6	158	1.66	191	11.5
6	Wasekogane	39.5	165	1.75	242	13.2
7	Harosoy	37.9	154	1.61	231	14.3
8	Adams	37.3	147	1.56	246	15.8
9	Ōyachi NO. 2	37.1	147	1.54	182	11.8
10	Acme	34.9	157	1.62	242	14.3
11	Manshū	31.9	145	1.51	201	13.3
12	Norin NO. 2	31.2	163	1.71	265	15.5
13	Norin NO. 1	28.6	141	1.49	204	13.7
14	Waseshirome	26.3	158	1.66	243	14.6
15	Shinanomejiro	23.8	148	1.55	201	12.9
	Mean	36.7	153	1.60	232	14.4

[a]: Density thickness based on fresh weight.
[b]: Density thickness based on dry weight.

dry weight, DTDW) was calculated.

RESULTS

Results of expt. 1 and 2 were listed in table 1. Varietal order of photosynthetic rate was not consistent between experiments. Only two varieties, Amsoy and Shiromenagaha, ranked within fifth in both experiments. On the contrary, four varieties,

Table 2 Correlations between leaf-characters

Expt. 1 / Expt. 2	Photosynthetic rate	Mesophyll volume per unit area	DTFW[a]	DTDW[b]	Dry weight percentage
Photosynthetic rate		0.419	0.449	−0.113	−0.395
Mesophyll volume per unit area	0.124		0.984**	0.189	−0.418
DTFW	0.126	0.986**		0.283	−0.336
DTDW	0.355	0.480	0.490		0.804**
Dry weight percentage	0.366	0.162	0.118	0.915**	

a: Density thickness based on fresh weight.
b: Density thickness based on dry weight.
c: Significant at 1% level.

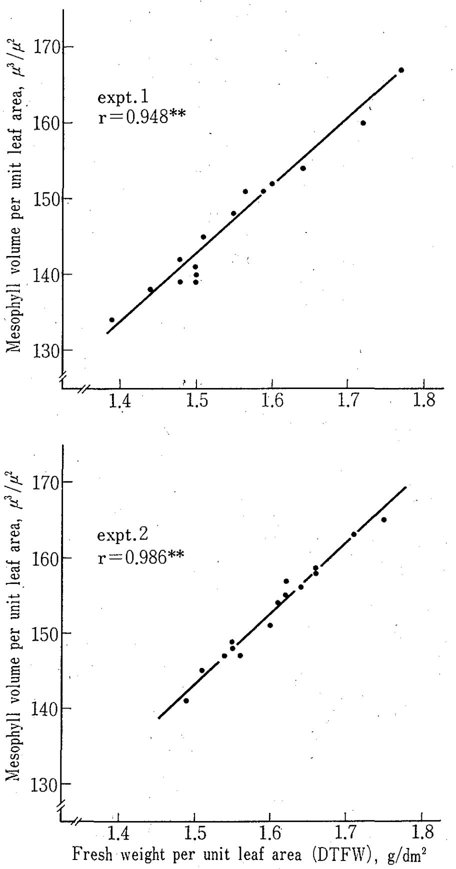

Fig. 1 Correlation between fresh weight per unit leaf area (DTFW) and mesophyll volume per unit leaf area. Each dot represents a variety

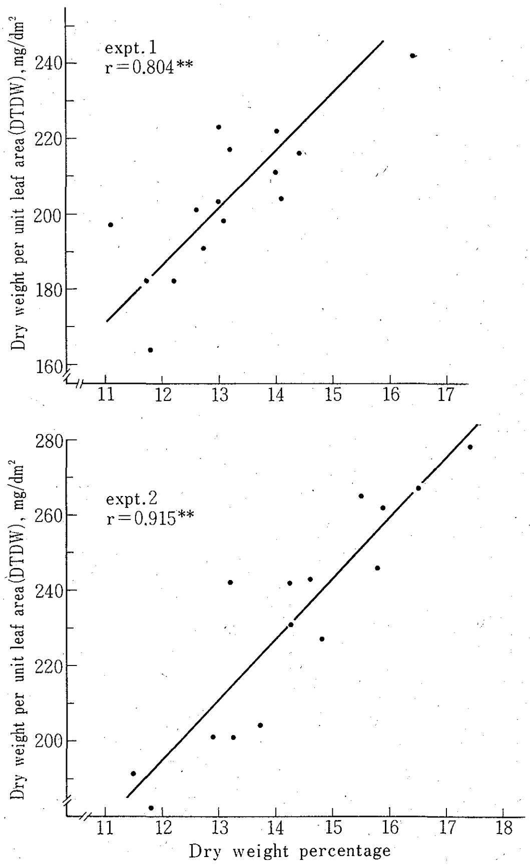

Fig. 2 Correlation between dry weight percentage of leaf and dry weight per unit leaf area (DTDW). Each dot represents a variety

Norin NO. 1, Shinanomejiro, Waseshirome and Manshū, ranked below 10th in both experiments. Wasekogane and Shiromenagaha had the largest mesophyll volume per unit leaf area. These varieties have long-shaped leaves and mesophyll volume seemed to be associated with varietal leaf shape. Norin NO. 1 and Ōyachi NO. 2 had the smallest mesophyll volume.

Correlative coefficients between characters were listed in table 2. None of the leaf characters examined was significantly correlative with photosynthetic rate in both experiments.

Mesophyll volume per unit leaf area was closely correlated with DTFW in both experiments as is shown in fig. 1. Between mesophyll volume Y (μ^3/μ^2 leaf area) and DTFW X(g/dm^2 leaf area), following regression formulas were obtained in expt. 1 and 2 respectively. $Y=89.55X+7.80$, $Y=92.17X+5.10$. DTDW was correlative neither with mesophyll volume per unit leaf area nor with DTFW It was correlative with dry weight percentage as is shown in fig. 2.

Discussion

Using 20 soybean varieties Dornhoff et al.[2] observed significant correlation between photosynthetic rate and DTFW (r=0.61**), DTDW (r=0.71**). The leaves tested were 'the most recently fully expanded' terminal ones. Leaf position on the stem was not mentioned. Ojima et al.[8] also observed significant correlation with soybean varieties between photosynthetic rate and DTDW, but only with lower leaves (1st or 4th trifoliate ones). With upper leaves (10th, 12th or terminal trifoliate ones), they did not find correlation between the two characters. They observed negative correlation between photosynthetic rate and dry weight percentage of leaves. DTFW or leaf thickness were also reported to be correlative with photosynthetic rate of soybean leaves[9].

The negative results reported herein may be due to the specificity of primary leaves or to the insufficiency of varietal number used or of experimental repetition. It is true that primary leaves are less important than trifoliate ones in acutual soybean production, but they have the advantage for experimental material that experimental conditions are easier to be uniform among varieties and that individual variations of leaf-characters are easier to be got rid of. Besides they are preferable to trifoliate leaves for the material to be studied about selection indices for leaf photosynthetic rate. Because they are the first leaves obtained after germination. A little more experiments with primary leaves are needed for us to be conclusive about these relationships.

Authors are grateful to Dr. Kimito Mikoshiba, Dr. Masataka Saito and their co-workers for kindly offering us soybean seeds. Stimulating discussions and encouragement by Dr. Shoshin Konno are also acknowledged.

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〔和 文 摘 要〕

大豆葉同化速度の品種間差異の生ずる機作

第3報　同化速度と面積生体重，同乾物重，単位面積当り葉肉容積との関係

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大豆 15 品種の初生葉を用いて，同化速度と面積生体重，同乾物重，単位面積当り葉肉容積等との関係を検討し次の結果を得た．

1．面積生体重，同乾物重，単位面積当り葉肉容積，乾物率等の形質と同化速度との間には相関関係が認められなかつた．

2．単位面積当り葉肉容積と面積生体重との間にはきわめて密接な正の相関関係が認められた．単位面積当り葉肉容積 Y (μ^3/μ^2) と面積生体重 X (g/dm^2) との間には，実験1では $Y=89.55X+7.80$，実験2では $Y=92.7X+5.01$ の回帰式が得られた．

3．面積乾物重は，単位面積当り葉肉容積および面積生体重との間には相関が認められず，乾物率との間に正の相関が認められた．