Variations of Heterosis in Leaf Photosynthetic Activity of Maize (*Zea mays* L.) with Growth Stages*

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On heterosis in photosynthetic activity of maize leaf, conflicting results have been reported^{2,4,5}. The cause for such differences of heterosis in photosynthetic activity has not been elucidated yet.

This experiment was conducted to identify the causes of such differences of heterosis in photosynthetic activity of maize leaf.

Materials and Methods

Four inbreds, two Carribean flint originated from land races in Japan, Okuzuruwase 633 and Koshu 564, and two American dent, Oh 51A and Wisconsin 531—472, of *Zea mays* L. and their four F₁ hybrids listed in Table 1 were used. They were grown in 1/5,000 a pot with sufficient amount of fertilizer. Apparent photosynthesis and transpiration were measured five times at different growth stages after planting. Silking in most materials was at the end of July. Measurements were performed in most active intact leaves by enclosing them in an assimilation chamber under 30°C of leaf temperature in 0.45 cal/cm²/min. of photosynthetically active radiation (PAR). Atmospheric air from which moisture was removed was passed through the chamber. Carbon dioxide concentration in inlet and outlet air was determined with an infra-red gas analyzer (Beckman Model 315) and humidity in outlet air was detected with an electric hygrometer (Yamato kagaku Model Ace-AY). Rates of photosynthesis and transpiration were expressed as the average value

of 3 to 8 replications for each material. Specific leaf weight (SLW) of each measured leaf was obtained after the measurement of photosynthetic rate. Nitrogen content in leaf was determined by micro-Kjeldahl method.

Results and Discussions

Photosynthetic activity of all F₁ hybrids in the measurements of June 24 and 27 showed vigor over that of better parents. Photosynthetic activity in F₁ hybrids between Wisconsin 531—472 and Okuzuruwase 633 including their reciprocals did not show vigor at the measurement of July 1 but it again showed vigor on July 27. Although the reason for the disappearance of vigor in photosynthetic activity on July 1 cannot be known. On the other hand, vigor in photosynthetic activity in F₁ hybrids between Oh 51A and Wisconsin 531—472 and those between Okuzuruwase 633 and Koshu 564 disappeared almost on July 1 and 27. These results suggest that the manifestation of heterosis in photosynthetic activity varied with the growth stage and genetic divergence of two parental cultivar.

It has been known that vigor in photosynthetic activity of maize leaf varied with the differences in cross combinations⁴. The higher degree of heterosis in photosynthetic activity of F₁ hybrids of Japanese flint and American dent might be due to bigger genetic divergence as reported previously^{4,5}. This experiment also suggested that another possible cause for such conflicting results in the degree of heterosis in photosynthetic activity of maize leaf reported previously^{2,4} can be due to the differences in the growth stages of measurements as speculated by SINHA and KHANNA³.

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Table 1. Apparent photosynthetic rate of inbreds and their hybrids in maize.

Date	App. Photosynthetic rate, $\text{mgCO}_2/\text{dm}^2/\text{hr}$.							
	Materials							
	Oh	W×Oh	W	W×Ok	Ok×W	Ok	Ok×K	K
June 24	38.4	46.1 (120)	38.4	46.6 (121)	42.8 (111)	34.7	43.3 (125)	22.7
June 27	38.2	40.3 (105)	30.4	45.5 (128)	51.4 (144)	35.6	39.8 (112)	29.4
July 1	40.3	41.7 (103)	31.7	39.0 (84)	32.8 (71)	46.2	42.3 (92)	33.4
July 27	43.9	39.6 (90)	38.7	45.3 (104)	50.6 (116)	43.5	42.4 (87)	48.8
Aug. 30	59.0	55.9	—	56.8	62.2	46.0	56.4	—

Name of inbred lines : Oh-Oh 51A, W-Wis. 531-472, Ok-Okuzuruwase 633, K-Koshu 564.

Figures in parentheses show the relative rate to that of the better parent.

Table 2. Transpiration rate of inbreds and their hybrids in maize.

Date	Transpiration rate, $\text{gH}_2\text{O}/\text{dm}^2/\text{hr}$.							
	Materials							
	Oh	W×Oh	W	W×Ok	Ok×W	Ok	Ok×K	K
June 24	2.12	2.93 (117)	2.51	3.29 (131)	2.76 (110)	2.38	2.78 (117)	1.85
June 27	2.47	2.62 (106)	2.22	2.70 (109)	2.67 (108)	2.48	2.52 (102)	2.01
July 1	1.90	2.10 (100)	2.10	2.30 (110)	1.90 (90)	2.10	2.30 (110)	2.00
July 27	2.42	2.41 (100)	2.18	2.91 (120)	3.02 (125)	2.42	2.45 (91)	2.69
Aug. 30	2.39	2.42	—	2.93	3.26	1.96	2.62	—

Symbols are the same as those in Table 1.

Table 3. Nitrogen content of leaves of inbreds and their hybrids in maize.

Date	Nitrogen content, mgN/dm^2							
	Materials							
	Oh	W×Oh	W	W×Ok	Ok×W	Ok	Ok×K	K
June 24	8.95	8.48	8.65	9.24	8.68	9.45	10.81	8.17
June 27	10.29	8.63	8.28	8.88	9.70	10.66	8.83	7.26
July 1	—	8.12	7.91	—	—	10.48	—	8.82
July 27	11.44	10.66	9.61	10.39	10.72	11.10	10.78	11.67
Aug. 30	9.69	11.30	—	10.08	9.95	8.17	10.56	—

Symbols are the same as those in Table 1.

Vigor in transpiration rate showed a tendency similar to that in photosynthesis (Table 2). Little heterosis was however, observed in leaf nitrogen content and in specific weight except two measurements of F_1 hybrids

between Wisconsin 531-472, Okuzuruwase 633 and Okuzuruwase 633, Koshu 564 on June 24 (Tables 3 and 4). The correlation between photosynthetic rate and transpiration rate was high in each stage (Fig.1).

Table 4. Specific leaf weight of inbreds and their hybrids in maize.

Date	Specific leaf weight, g/dm ²							
	Materials							
	Oh	W×Oh	W	W×Ok	Ok×W	Ok	Ok×K	K
June 24	.200	.194	.198	.227	.201	.190	.234	.196
June 27	.231	.218	.205	.213	.204	.238	.203	.201
July 1	.232	.231	.199	.223	.236	.255	.231	.228
July 27	.276	.275	.233	.254	.282	.305	.321	.278
Aug. 30	.246	.296	—	.274	.271	.238	.284	—

Symbols are the same as those in Table 1.

Fig. 1. Photosynthetic rate in relation to transpiration rate in maize leaf.

Solid marks—parents.
Hollow marks—hybrids.

The higher correlation between photosynthetic rate and transpiration and poor correlation between photosynthetic rate and nitrogen content of leaf and leaf specific weight suggest that higher photosynthetic rate in F_1 hybrids in an earlier growth stage was chiefly due to morphological change of leaves which might have caused lower stomatal diffusion resistance in F_1 hybrids.

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〔和 文 摘 要〕

トウモロコシの光合成速度にみられる
雑種強勢の生育時期にともなう変動について

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トウモロコシ自殖4系統およびそれらの間の雑種第一代4組合せを材料とし、生育時期にともなって、単位葉面積あたりの光合成速度がどのように変動するかについて検討した。材料は1974年6月上旬ポットに播種し、葉色が退色しないよう適宜追肥を行ない野外にて生育させた。光合成速度、蒸散量の測定は生育時期を追って播種後ほぼ1ヶ月ごとに6月末、7月末(絹糸抽出直前)、8月末に着生したままの活動中心葉について同化箱法により行なった。測定は温度30℃、光強度0.45 cal/cm²/min (PAR)、大気中CO₂濃度下で行ない、光合成速度はCO₂濃度0.03%における値で示した。その結果、生育時期が早い時の測定においては、4組合せのF₁すべてにおいてその光合成速度は、better parentの値よりも明らかに高く、vigorの程度も大きかった。しかし、生育が進むにつれて近縁同志のF₁では光合成速度にvigorがあらわれない場合が多く、遠縁間のF₁には一時vigorが消失するがそれ以後再びvigorがみられた(第1表)。一方、蒸散量についても光合成速度の場合とほぼ同じ傾向が認められた(第2表)。しかし、窒素含量と光合成速度の間には1, 2, の特定の場合を除いて相関がみられなかった。また、光合成速度と蒸散量の間には各測定時期ごとに強い相関がみられた。これらの結果は、トウモロコシの光合成速度にみられるF₁ vigorは生育時期および組合せにより変動し、それらの変動をもたらす主要な要因は気孔の拡散低抗の変動にあると考えられた。