

**The Relationship Between Photosynthesis and
Hybrid Vigour in Arabidopsis**

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abbreviations

A	—	the CO ₂ assimilation rate
a/b ratio	—	the ratio of chlorophyll a to b
Ca	—	the ambient CO ₂ partial pressure
CCA1	—	circadian clock associated 1
Chl a	—	chlorophyll a
Chl b	—	chlorophyll b
C _i	—	the intercellular CO ₂ partial pressure
C _i /C _a	—	the ratio of intercellular to atmospheric CO ₂ partial pressure
CNR	—	cell number regulator
Col	—	Columbia-0
cyol	—	shi-yo-u 1; the Japanese word for “cotyledon”
Cyt <i>b₆f</i>	—	cytochrome <i>b₆f</i> complex
DAS	—	days after sowing
DIC	—	differential interference contrast
ED	—	end-of-the-day
EN	—	end-of-the-night
FNR	—	ferredoxin NADP oxidoreductase
F, F'	—	fluorescence emission from dark- or light-adapted leaf, respectively
Fd	—	ferredoxin
F _m '	—	maximal fluorescence from dark- and light-adapted leaf

F_o, F_o'	— minimal fluorescence from dark- and light-adapted leaf, respectively
F_q'	— difference in fluorescence between F_m' and F'
F_q' / F_m'	— PSII operating efficiency
FW	— fresh weight
g_s	— the stomatal conductance of water vapour
GUN	— genomes uncoupled
<i>Ler</i>	— Landsberg <i>erecta</i>
LHC	— light harvesting complexes
LHCI	— light harvesting complex I
LHCII	— light harvesting complex II
LHY	— late elongated hypocotyl
J	— chloroplast electron transport rate
J_{max}	— the estimated maximum electron transport rate
μE	— micro Einstein; $\mu mol \text{ photons m}^{-2} \text{ s}^{-1}$
MPV	— mid-parent value
MS	— Murashige and Skoog medium
mv	— midvein
PAM	— pulse amplitude modulated
PAR	— photosynthetically active radiation
PC	— plastocyanin
Φ_{PSII}	— operating quantum yield of PSII
PLB	— prolamellar bodies
PM	— palisade mesophyll

PQ	—	plastoquinone
PS	—	photosystems
PSI	—	photosystem I
PSII	—	photosystem II
Q _A	—	plastoquinone A
Q _B	—	plastoquinone B
R: FR ratio	—	the ratio of red light to far-red lights
Rubisco	—	ribulose-1,5-bisphosphate carboxylase/oxygenase
RuBP	—	ribulose-1,5-bisphosphate
sco1	—	snowy cotyledon 1
sco2	—	snowy cotyledon 2
SE	—	standard error
TOC1	—	timing of CAB expression 1
V _{cmax}	—	the maximum velocity of carboxylation in Rubisco
VDE	—	violaxanthin de-epoxylase
VPD	—	water vapour pressure deficit
W _s	—	Wassilewskija
ZE	—	zeaxanthin
ZT	—	Zeitgeber time

Abstract

Heterosis, or hybrid vigour, is the phenomenon where a F1 hybrid exceeds the parents in biomass and seed production. Hybrids are used in production in rice, maize and other crops. In *Arabidopsis*, biomass heterosis occurs in hybrids at an early developmental stage and throughout development. Previous findings suggest that heterosis is associated with altered gene expression, especially for the genes involved in the photosynthesis pathway, but the relationship between photosynthesis and the generation of biomass heterosis is not clear. The aims of this project were to analyse *Arabidopsis* hybrids for their photosynthetic parameters and growth patterns and compare them to the corresponding parents to elucidate the relationship between heterosis and photosynthesis.

To investigate whether photosynthetic properties in hybrids were different from the parents, the chlorophyll fluorescence and the CO₂ gas-exchange on a per leaf area basis were measured as indicators of the capacity of the light and dark reactions, respectively; the content of chlorophyll and the number of chloroplasts per mesophyll cell were analysed as indicators of the density of photosynthetic machinery in leaves; and leaf parameters that might affect gas-exchange in the leaf, including leaf thickness and the number of mesophyll cell layers, were examined. In all hybrids these photosynthetic parameters were at levels either between the two parents or similar to the better parent, showing that photosynthetic processes were highly conserved in hybrids and parents. Increasing photosynthesis via increasing the growth irradiance conditions did not enhance

the heterosis level of hybrids compared to the parents. These results indicate that the biomass heterosis was not due to changes in photosynthetic processes.

The growth patterns of the leaves of the heterotic C24/*Ler* hybrids, showed that biomass heterosis was due largely to the newly developed leaves in the hybrid being larger than those of the parents at any point in time during development. The heterosis in leaf growth was due to greater cell size and increased cell number. Although the unit leaf area photosynthetic rate in the hybrids was not greater than the parents, the hybrids had a greater total leaf area to intercept more light to sustain the increased demands of energy and building blocks for the fast-growing new leaves. The growth heterosis in early leaf development might be a prerequisite for biomass heterosis throughout development.

A critical role for photosynthesis in cotyledons in the generation of biomass heterosis was demonstrated by a mutant, *snowy cotyledon2*, which had impaired chloroplast biogenesis, specifically in the cotyledons. Whereas *Ws/Ler* hybrids had a considerable biomass heterosis compared to the parents, mutant *Ws/Ler* hybrids that were unable to carry out photosynthesis in cotyledons showed no heterosis relative to the homozygous mutant parents. This result indicates that the generation of biomass heterosis in early seedling development depends on photosynthesis in the cotyledons and that this is important for the biomass heterosis in subsequent stages.