Photosynthetic Characteristics and Growth of Rice Plants under Red Light with or without Supplemental Blue Light

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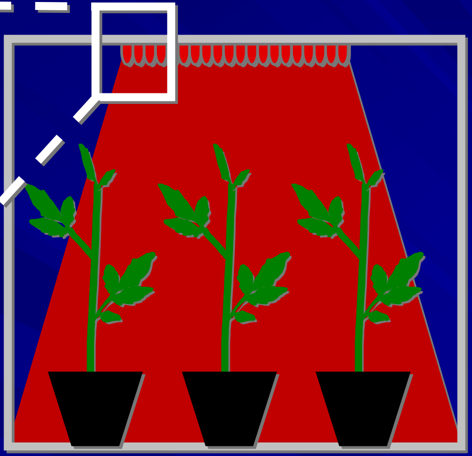
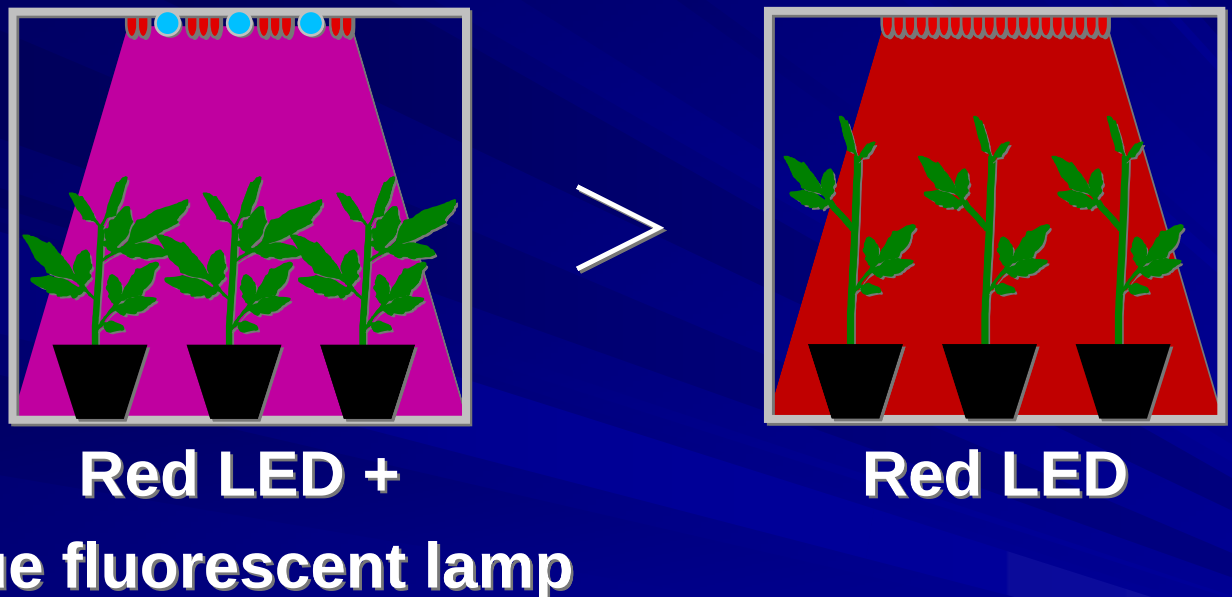
Some species can be grown by using red light-emitting diodes (LEDs) alone


Red LED



- Lettuce (Bula et al. 1991)
- Pepper and cucumber (Schuerger & Brown 1994)

Dry weight becomes 1.4-2.7 times larger by an addition of 1-10% blue light!



- Pepper (Brown et al. 1995)
- Wheat (Goins et al. 1997)
- Spinach, radish and lettuce (Yorio et al. 2001)

Objectives

To investigate the factors related to the enhancement of dry matter production by supplemental blue light to red light using rice plants with regard to

1) **photosynthetic characteristics at the single-leaf level and**
2) **growth and development at the whole-plant level**

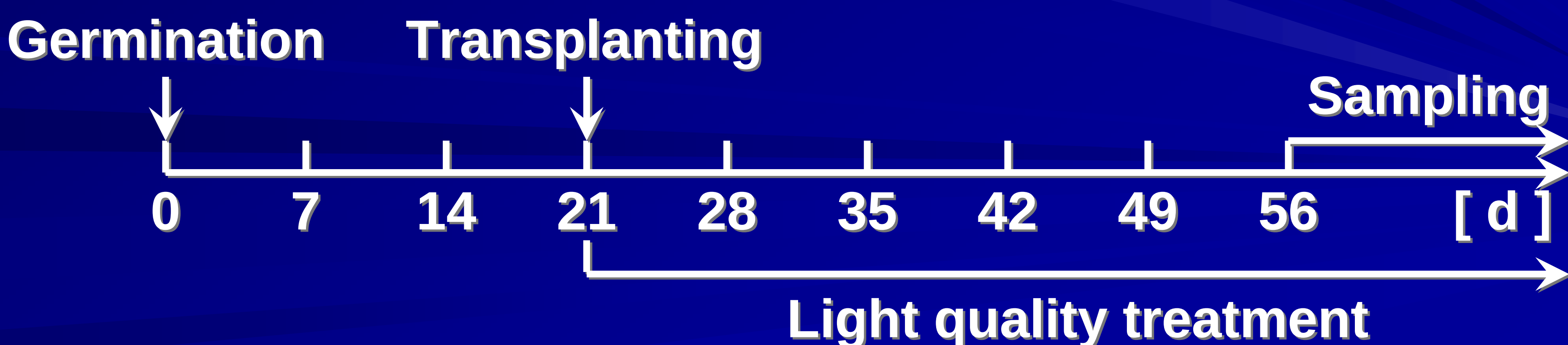
(1)
Photosynthetic Characteristics of Rice Leaves Grown under Red Light with or without Supplemental Blue Light

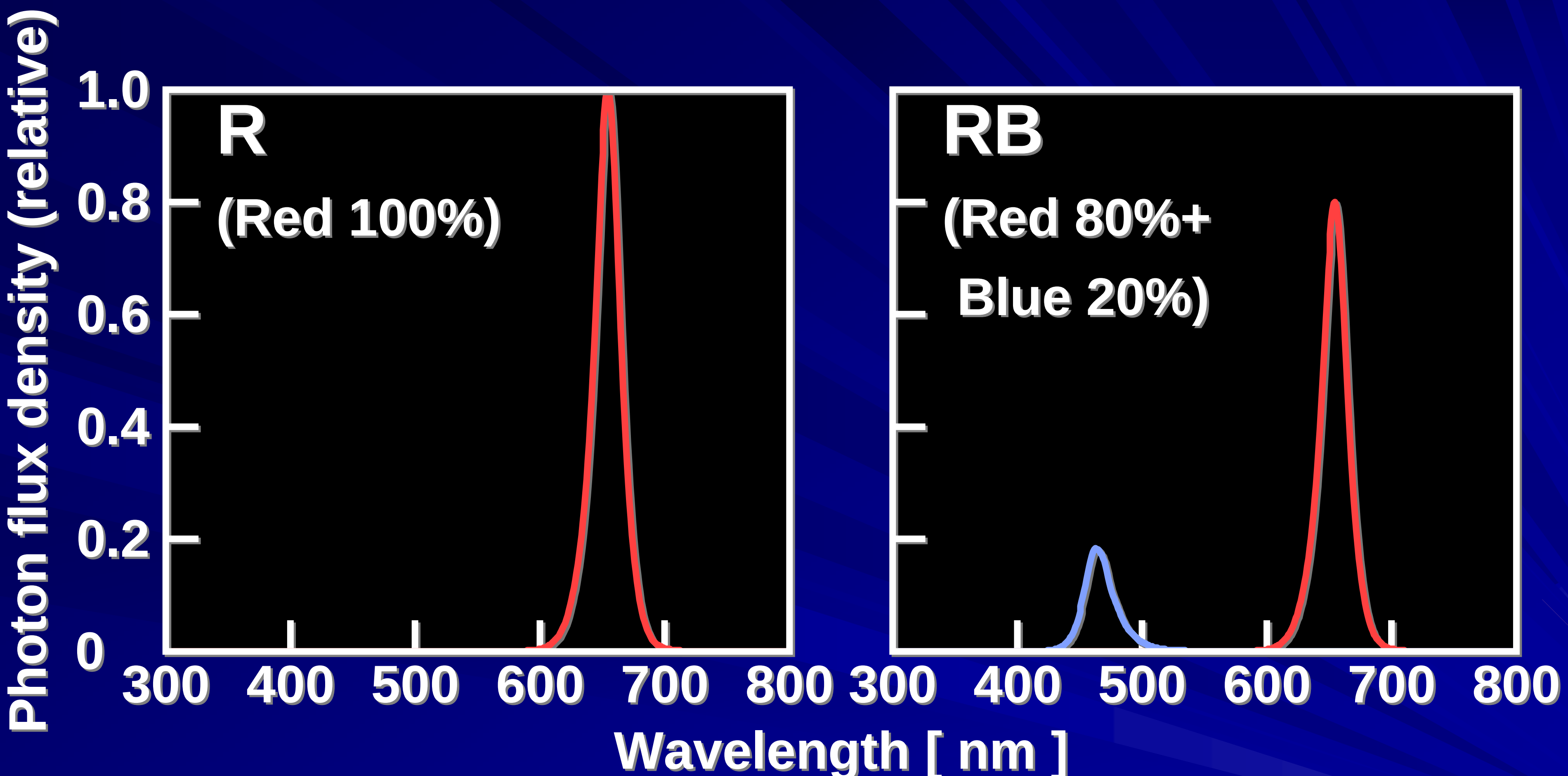
Matsuda, R., K. Ohashi-Kaneko, K. Fujiwara, E. Goto & K. Kurata (2004)

Plant and Cell Physiology 45: 1870-1874

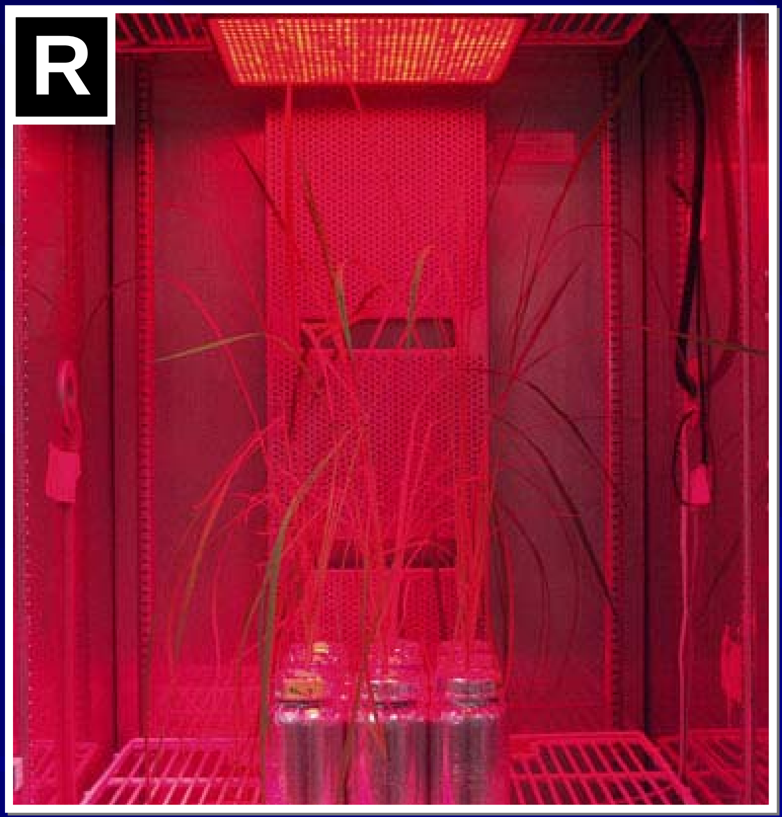
Materials and Methods

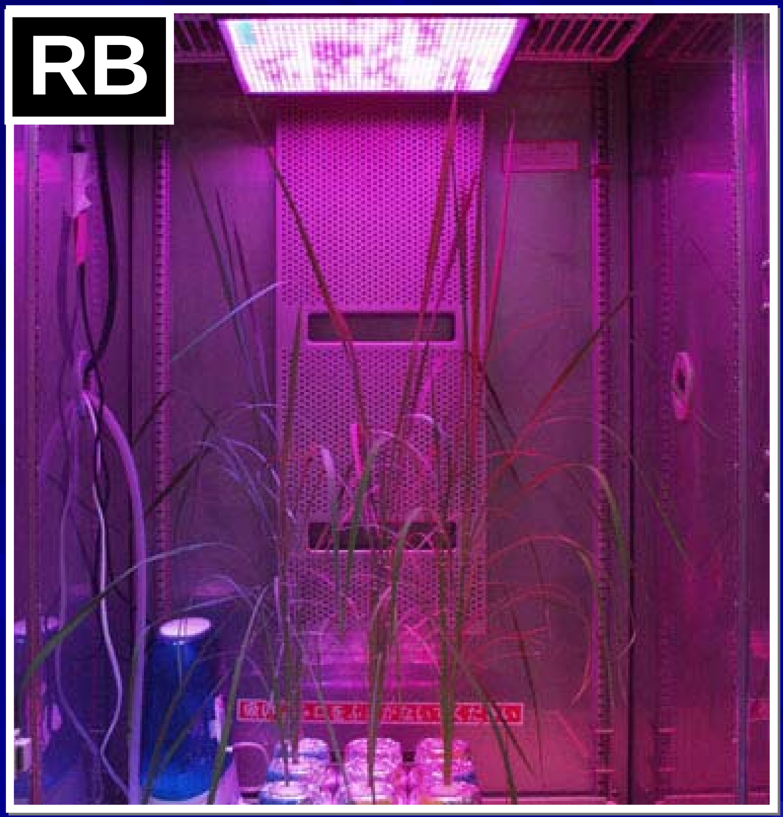
Plant material:	Rice (*Oryza sativa* L.)
Cultivar:	Sasanishiki
Cultivation method:	Hydroponics
PPFD:	240 μmol m^{-2} s^{-1}
Day/night cycle:	12 h/12 h
Temperature:	27°C/20°C (day/night)
Relative humidity:	75%



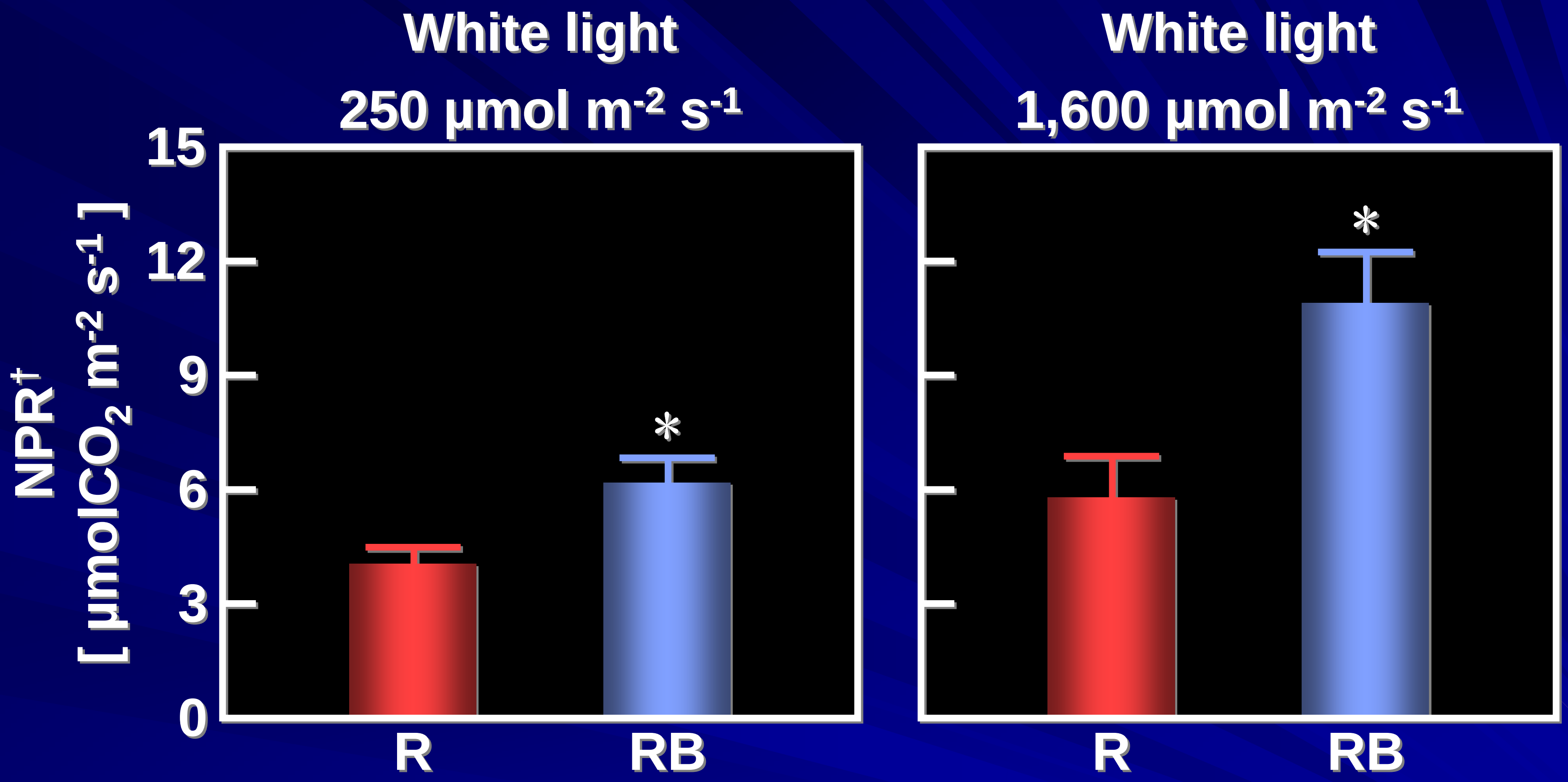


P_{fr}/P (phytochrome photoequilibrium) was nearly the same (0.88-0.89), indicating that the action of phytochrome was negligible.





(On day 56 after germination)



Measurement conditions

Atmospheric CO_2 partial pressure: 36 Pa

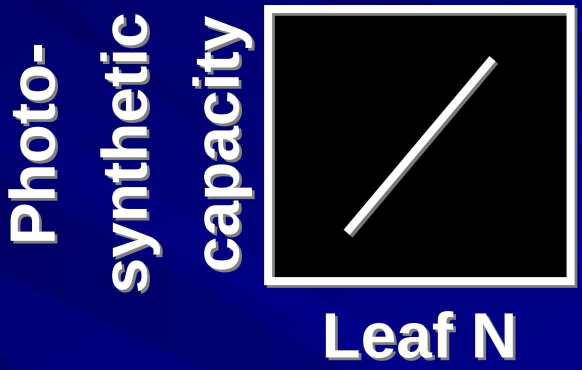
Leaf temperature: 27°C

Leaf-to-air vapor pressure deficit: 1.1 kPa

†Net photosynthetic rate

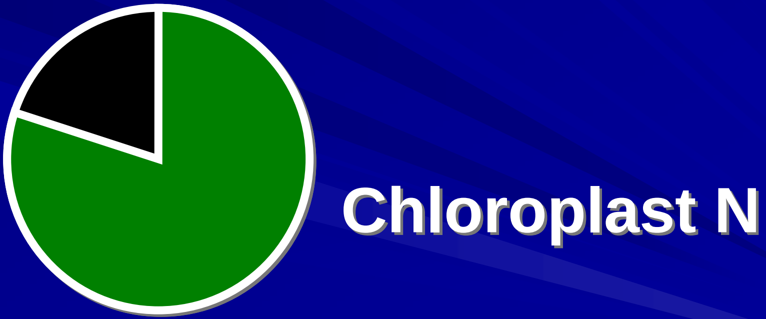
- **Photosynthetic capacity† in C_3 plants is highly correlated with leaf N content.**

  (Evans 1989)

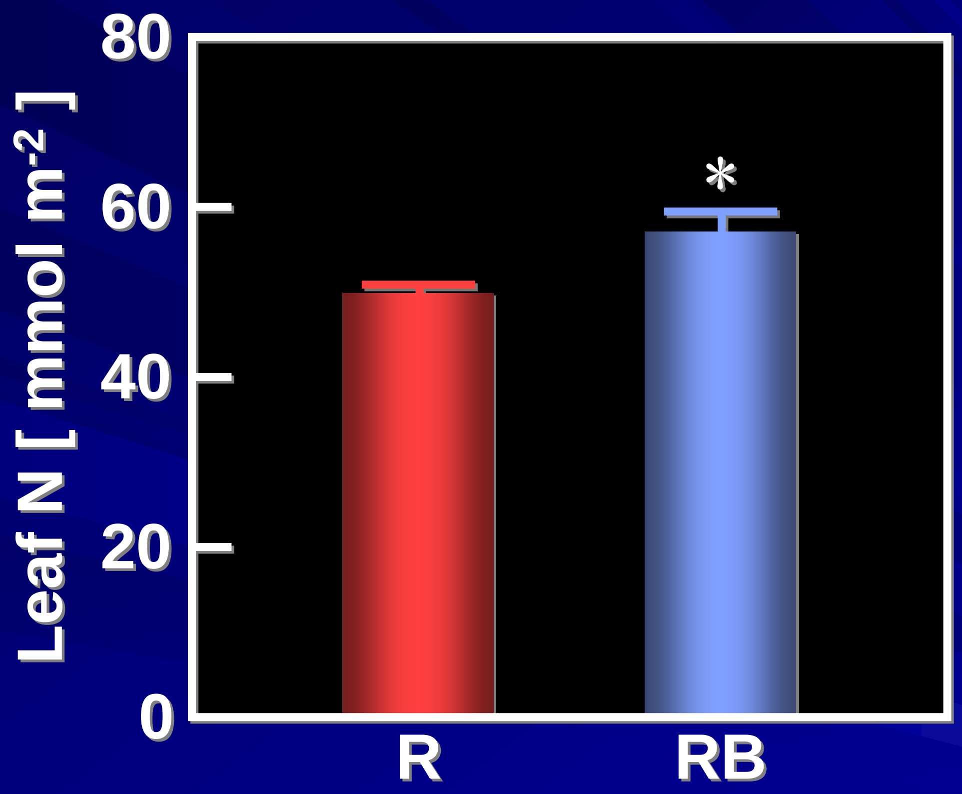


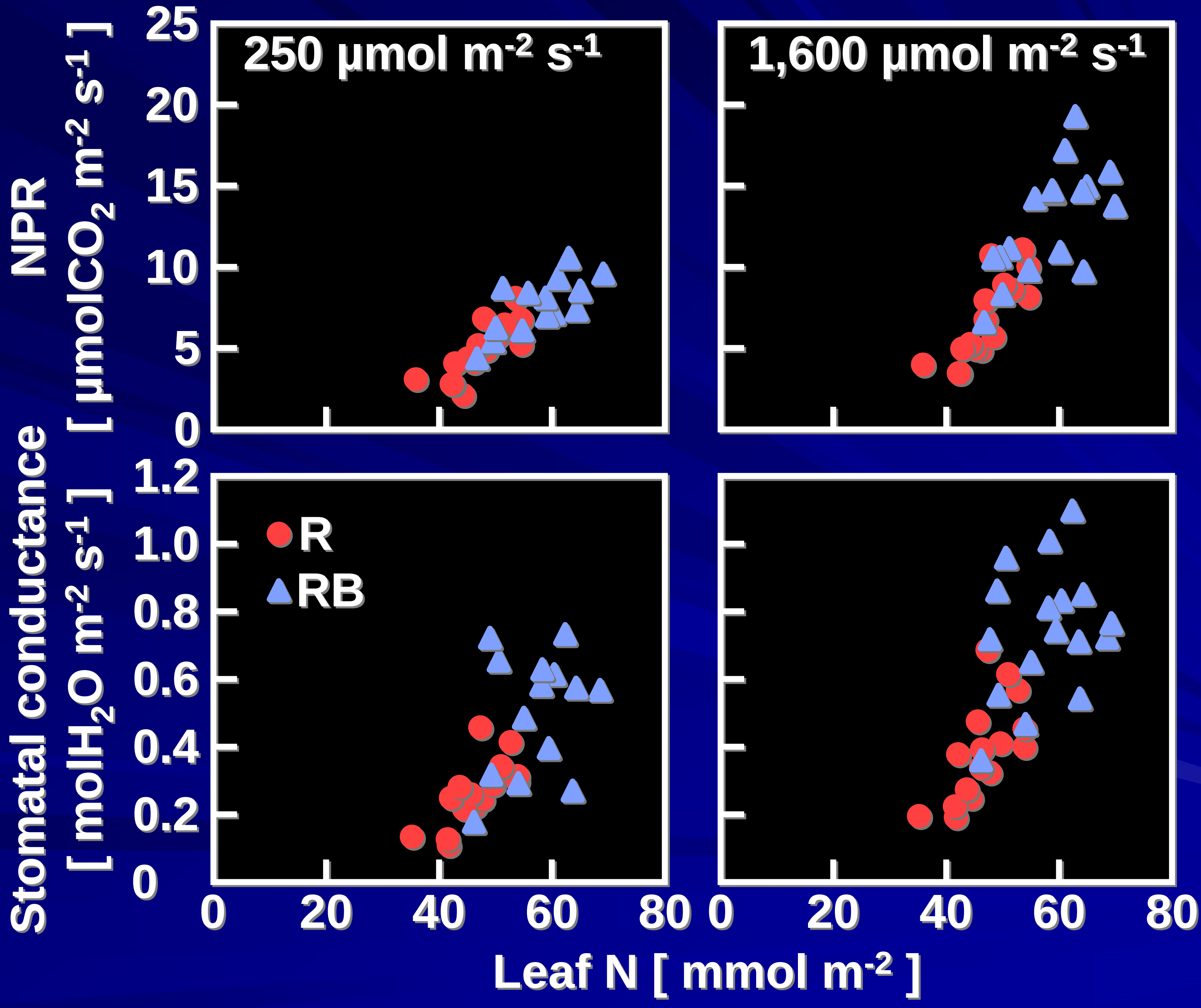
- **Approx. 80% of leaf N localize in chloroplasts.**

  (Makino & Osmond 1991)



† Net photosynthetic rate measured at a saturating PPFD, an optimal temperature and a normal atmospheric CO_2 partial pressure

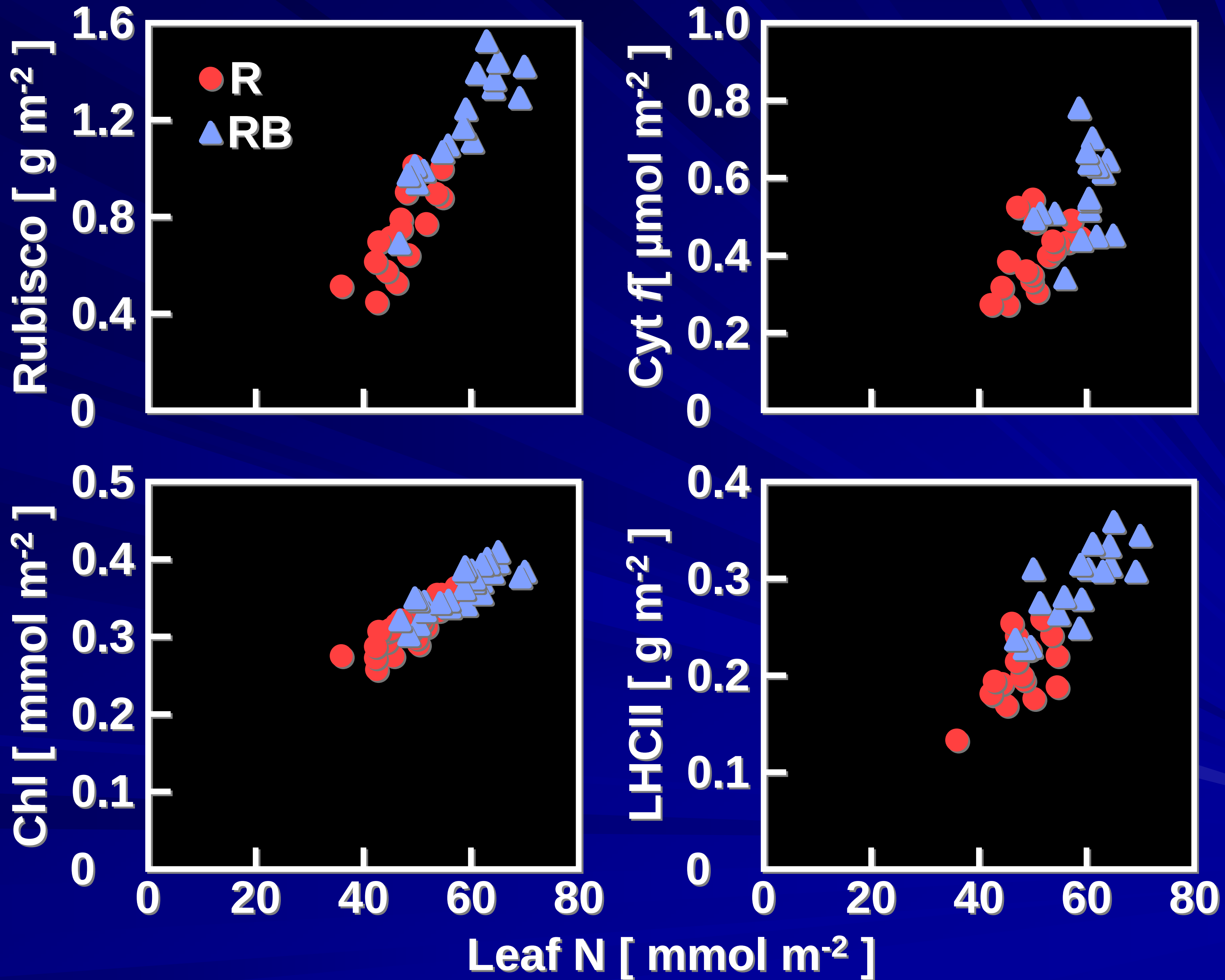

Leaf N [mmol m-2]
80
60
40
20
0
*
R
RB



250 μmol m-2 s-1
1,600 μmol m-2 s-1
NPR
[μmolCO2 m-2 s-1]
Stomatal conductance
[molH2O m-2 s-1]
R
RB
Leaf N [mmol m-2]
0
5
10
15
20
25
0
0.2
0.4
0.6
0.8
1.0
1.2
0
20
40
60
80

Determination of photosynthetic component contents

- Rubisco ··· key enzyme of CO_2 fixation
- Cytochrome *f* (Cyt *f*)
  ··· one of rate-limiting factors for photosynthetic electron transport
- Chl and light-harvesting Chl-binding protein of photosystem II (LHCII)
  ··· light-harvesting pigment and protein



R
RB
Rubisco [g m-2]
1.6
1.2
0.8
0.4
0
Cyt f [µmol m-2]
1.0
0.8
0.6
0.4
0.2
0
Chl [mmol m-2]
0.5
0.4
0.3
0.2
0.1
0
LHCII [g m-2]
0.4
0.3
0.2
0.1
0
0
20
40
60
80
Leaf N [mmol m-2]

Summary

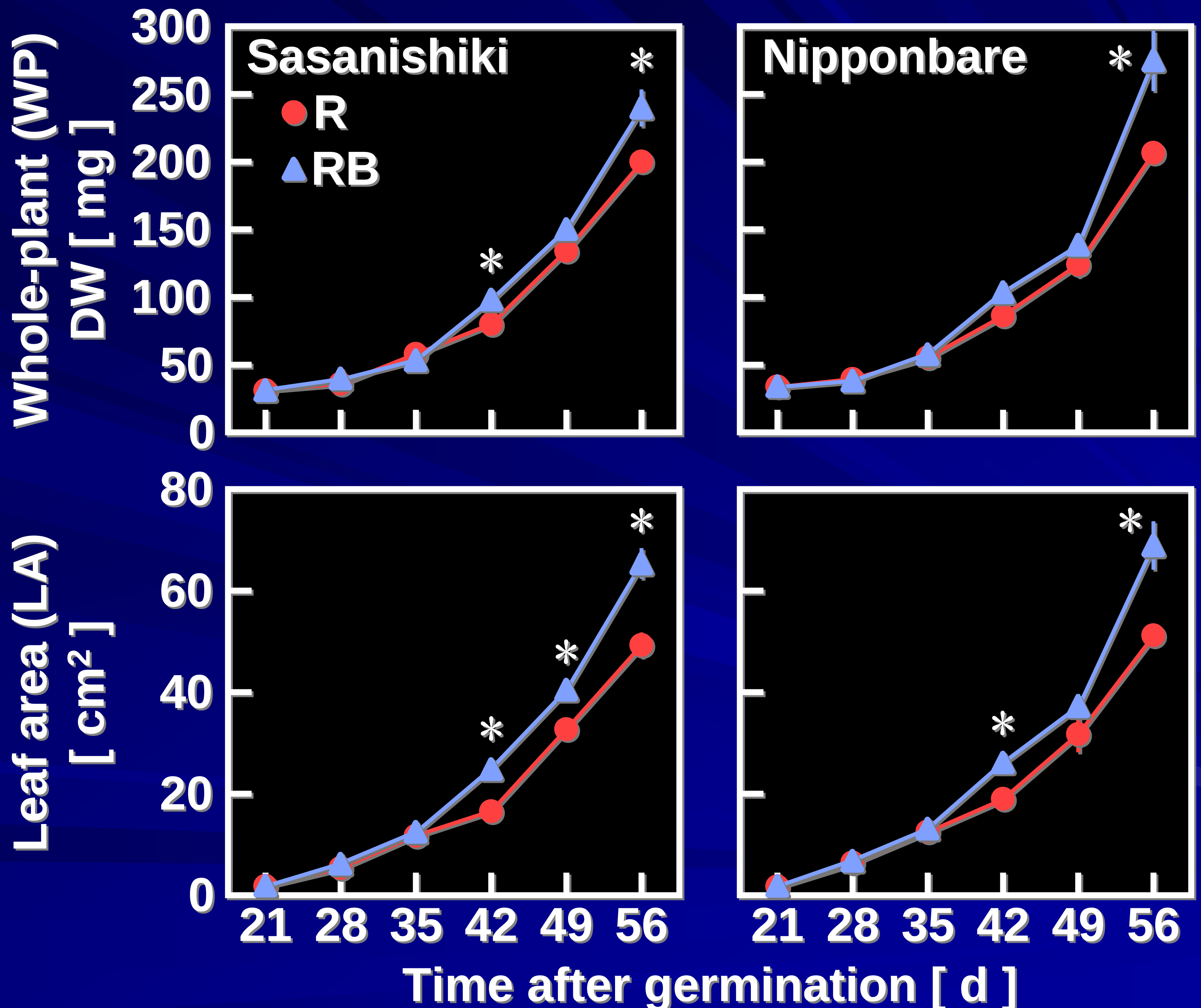
(1. leaf photosynthetic characteristics)

- RB leaves had higher photosynthetic rate than R leaves under both saturating light and limited light conditions.
- Higher photosynthetic rates in RB leaves were closely related to a greater leaf N content per unit leaf area.
- Photosynthetic rate under actual growth conditions should be higher in RB leaves.

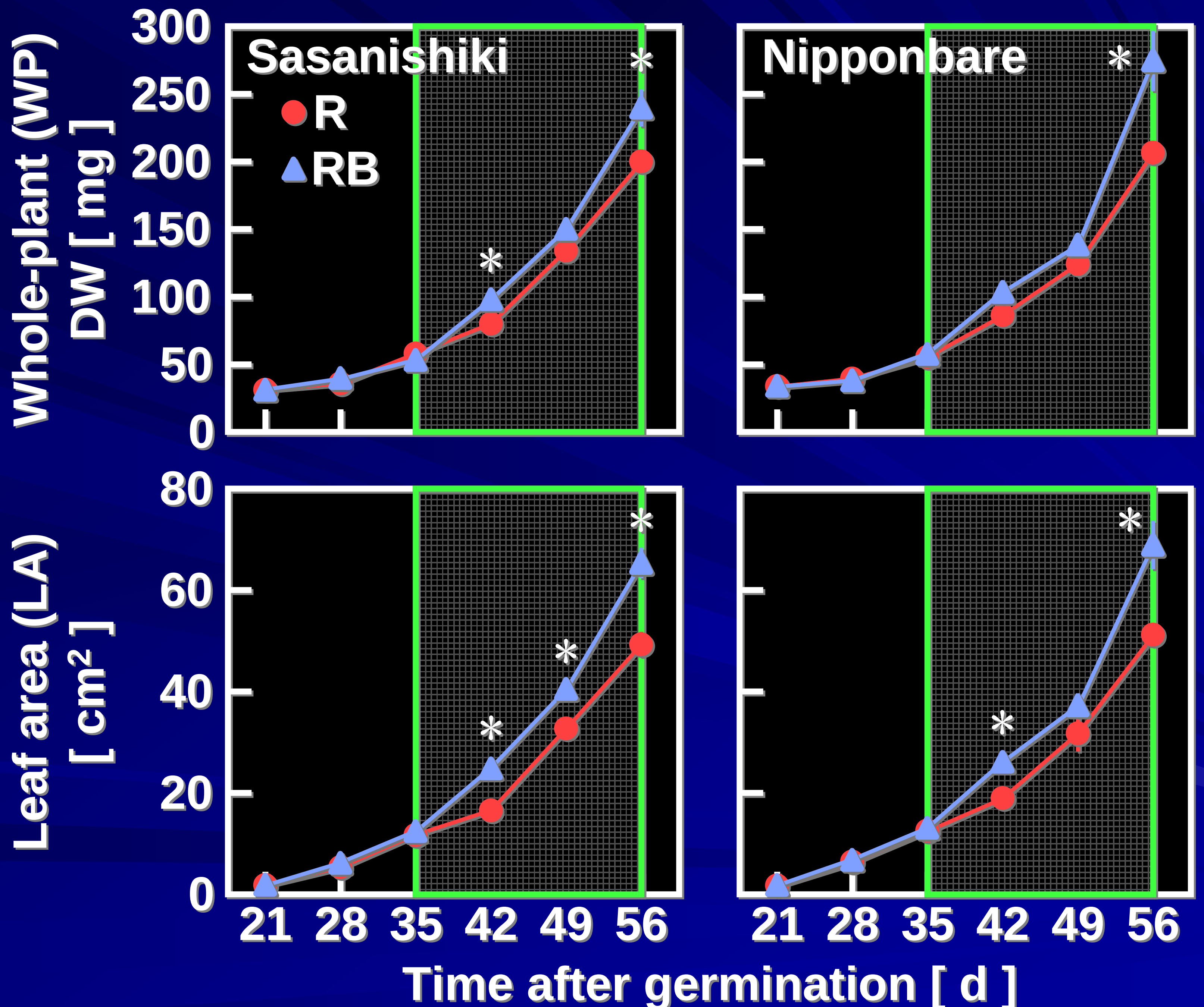
(2)
Growth of Rice Plants under Red Light with or without Supplemental Blue Light

Ohashi-Kaneko, K., R. Matsuda, E. Goto, K. Fujiwara & K. Kurata (2006)

Soil Science and Plant Nutrition 52: 444-452



Sasanishiki
Nipponbare
R
RB
Whole-plant (WP) DW [mg]
Leaf area (LA) [cm2]
300
250
200
150
100
50
0
80
60
40
20
0
21 28 35 42 49 56
21 28 35 42 49 56
*
Time after germination [d]



Sasanishiki
Nipponbare
R
RB
Whole-plant (WP) DW [mg]
Leaf area (LA) [cm^2]
300
250
200
150
100
50
0
80
60
40
20
0
*
21
28
35
42
49
56
Time after germination [d]

Growth Analysis

$$\boxed{RGR = NAR \times LAR}$$

RGR (Relative Growth Rate) $= \dfrac{dW}{dt} \cdot \dfrac{1}{W}$

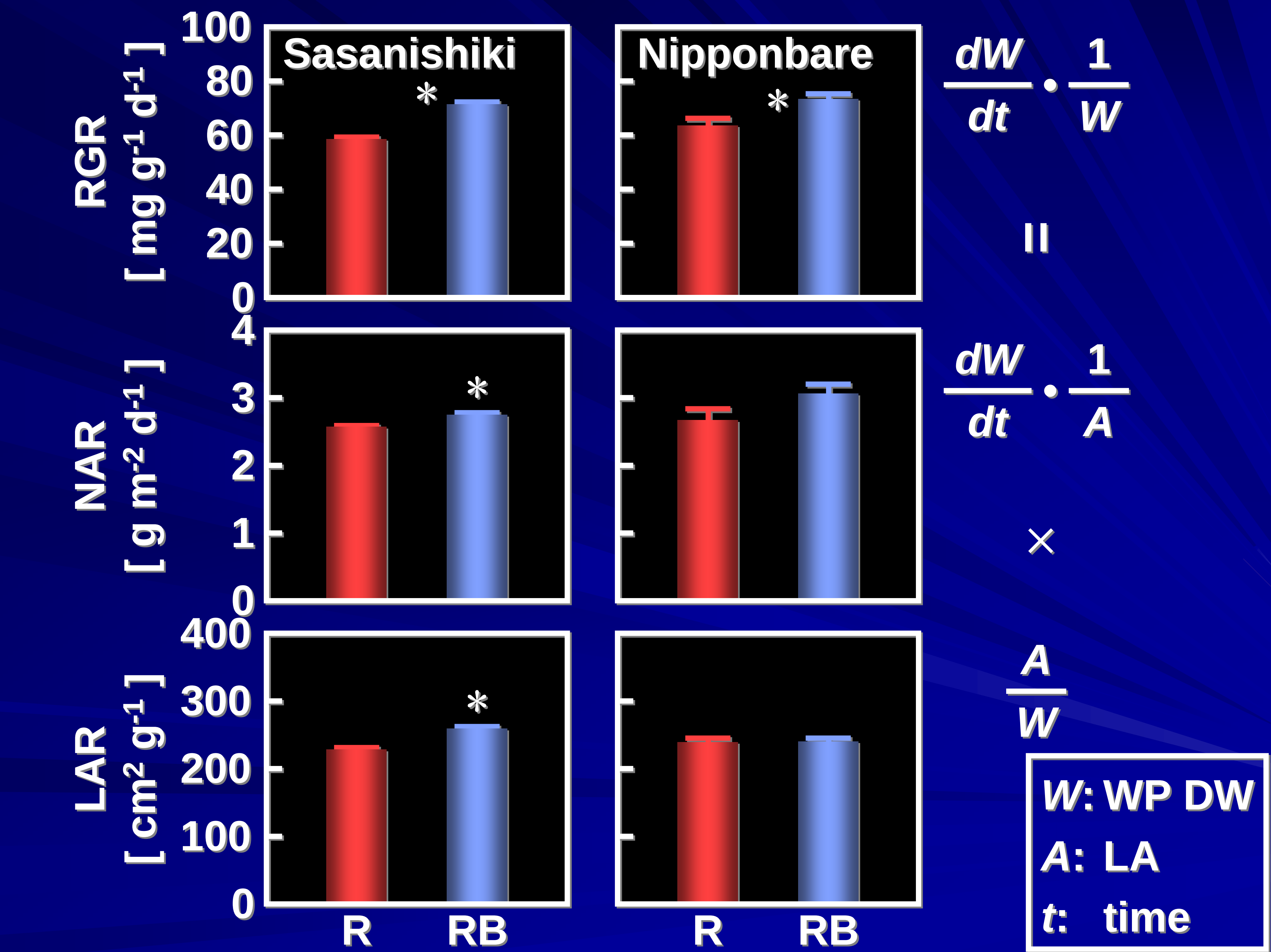
NAR (Net Assimilation Rate) $= \dfrac{dW}{dt} \cdot \dfrac{1}{A}$

LAR (Leaf Area Ratio) $= \dfrac{A}{W}$

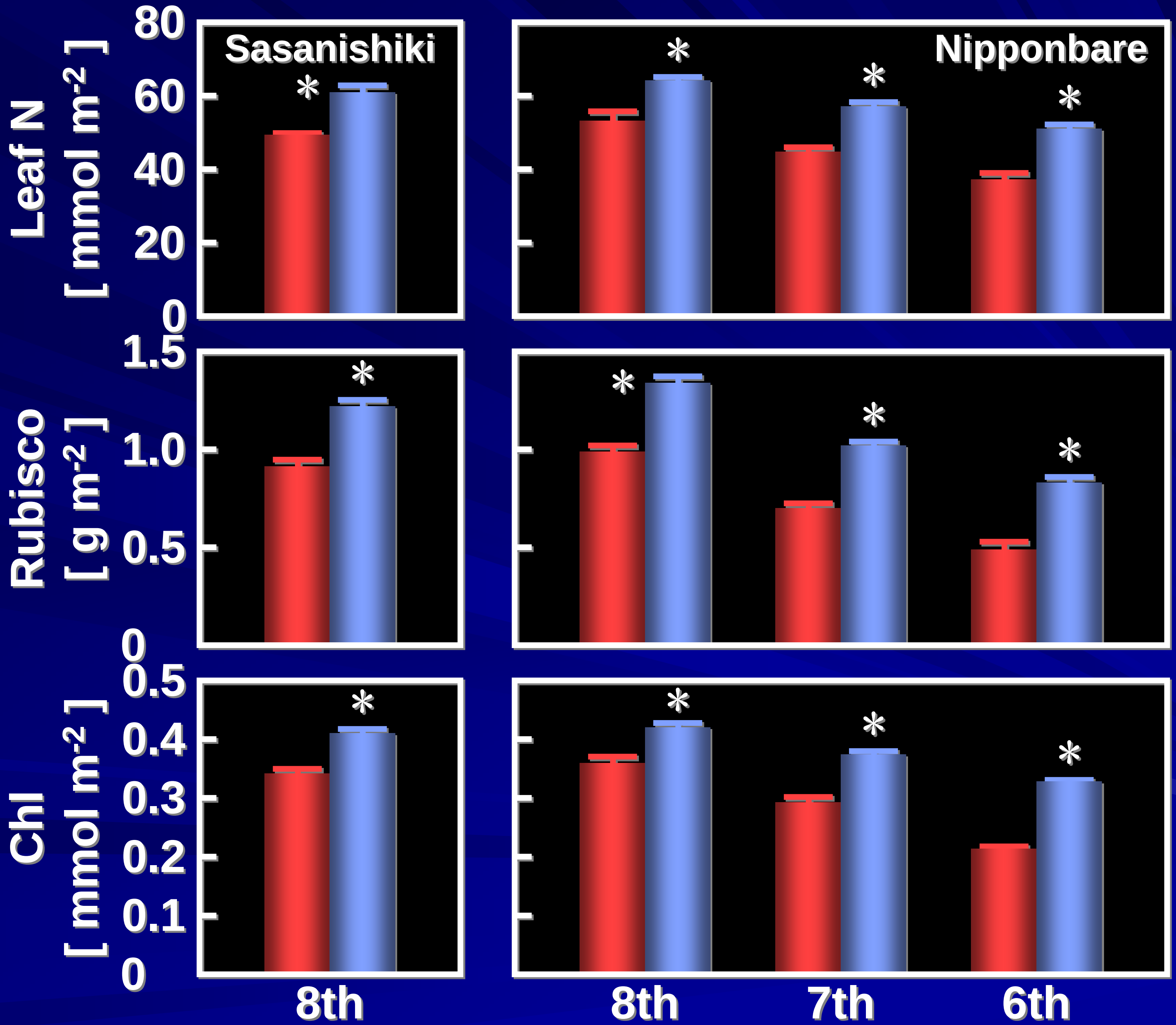
W: whole-plant dry weight

A: leaf area

t: time



Sasanishiki
Nipponbare
RGR [mg g-1 d-1]
NAR [g m-2 d-1]
LAR [cm2 g-1]
0
20
40
60
80
100
0
1
2
3
4
0
100
200
300
400
*
*
*
*
R
RB
R
RB
dW/dt · 1/W
=
dW/dt · 1/A
×
A/W
W: WP DW
A: LA
t: time


Sasanishiki
Nipponbare
Leaf N [mmol m-2]
Rubisco [g m-2]
Chl [mmol m-2]
80
60
40
20
0
1.5
1.0
0.5
0
0.5
0.4
0.3
0.2
0.1
0
*
8th
8th
7th
6th

Summary

(2. Whole-plant growth)

- NAR was higher in RB plants than in R plants, contributing to higher RGR.
- Increases in the amounts of photosynthetic components in RB plants occurred at the whole-plant level.
- In Sasanishiki, higher LAR also contributed to higher RGR, but not in Nipponbare.

By combining the results at the single-leaf level with those at the whole-plant level...

Supplementing red light with blue light

↓

Increase in leaf photosynthesis

↓

Increase in NAR

↓

Promotion of dry matter production

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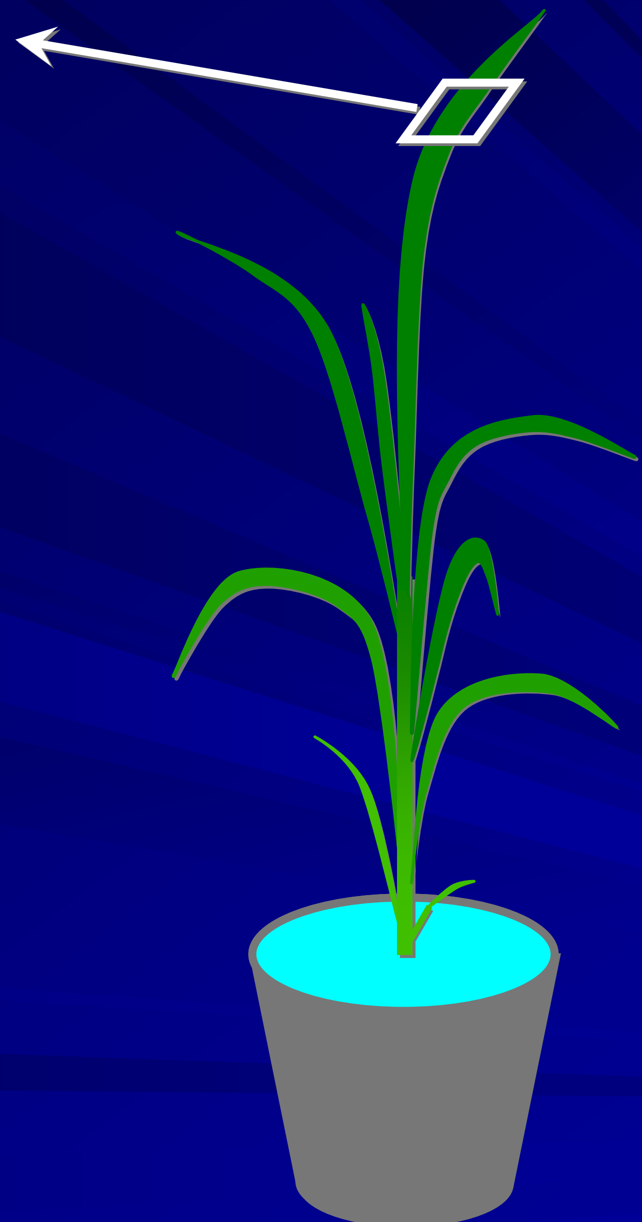
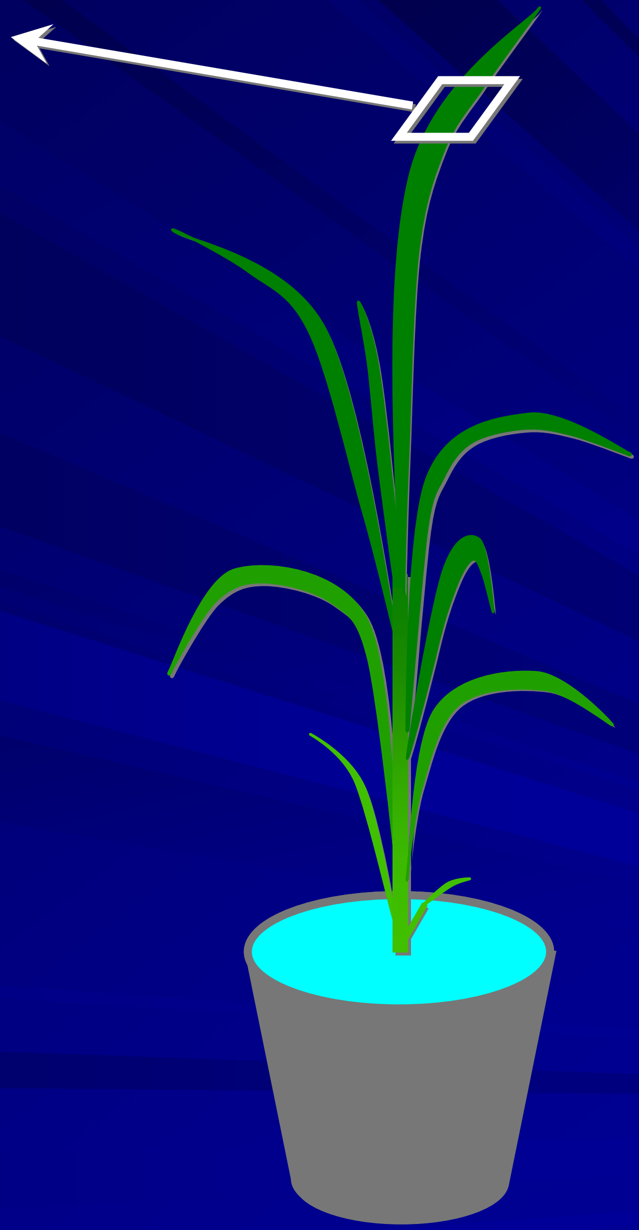
NPR per unit leaf area



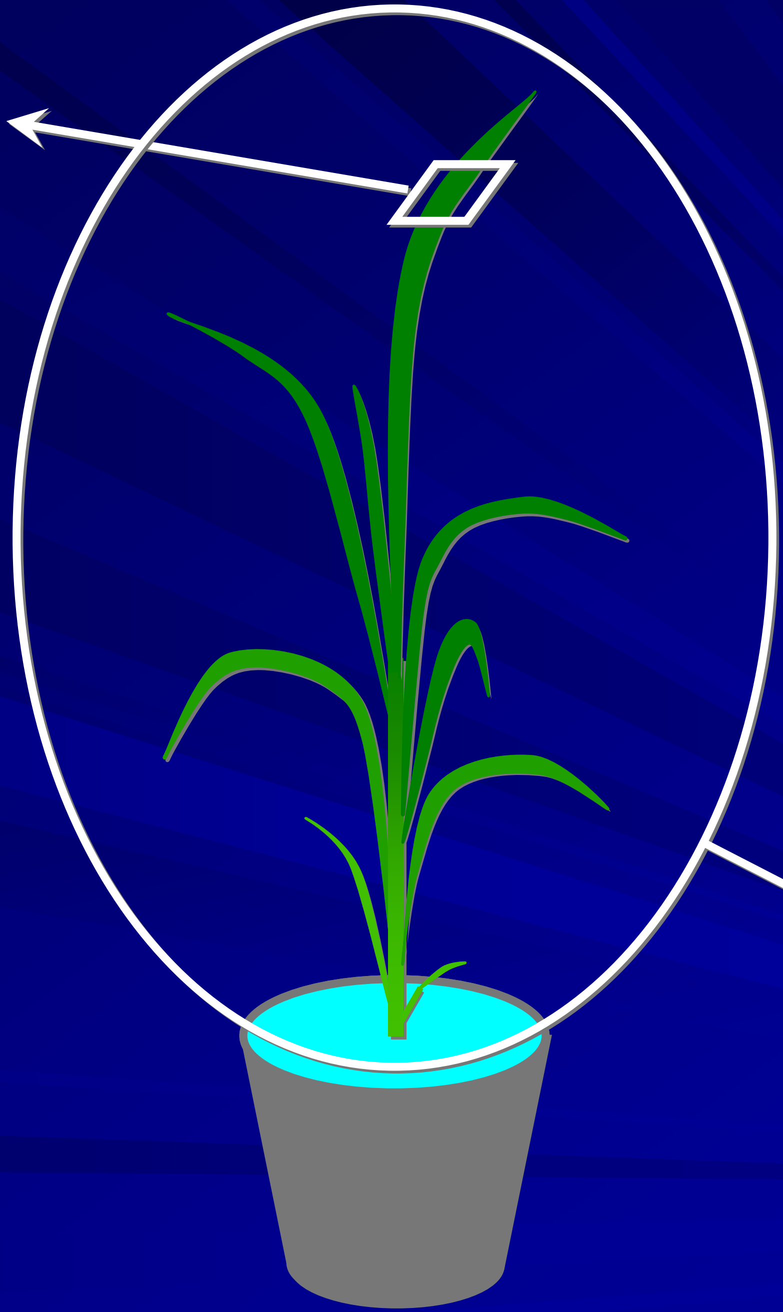
NPR per
unit leaf area



In response to
long-term
•low irradiance
•low temp.
•high CO_2

(e.g., Makino et al. 1997a, b, Ohashi et al. 2000)

NPR per unit leaf area



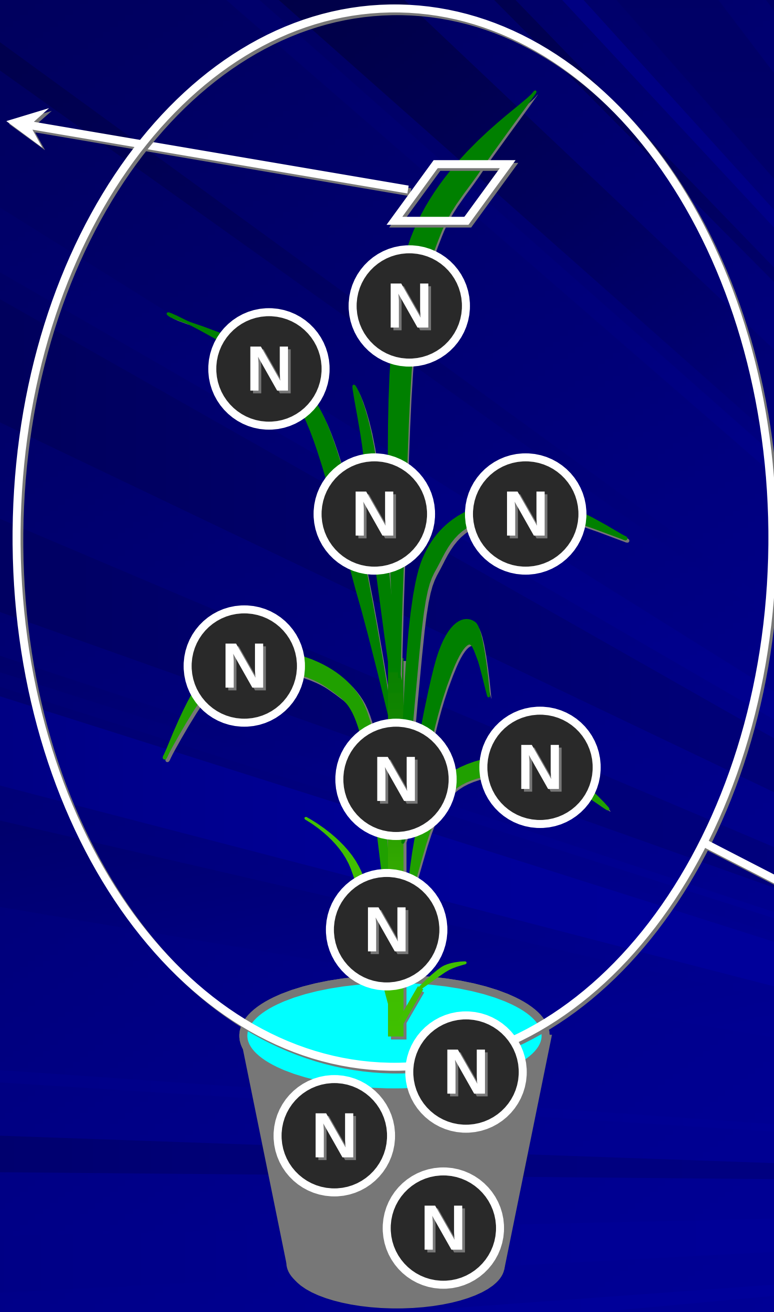
In response to long-term

- low irradiance
- low temp.
- high CO_2

Leaf area expansion

(e.g., Makino et al. 1997a, b, Ohashi et al. 2000)

NPR per unit leaf area



In response to long-term

- low irradiance
- low temp.
- high CO_2

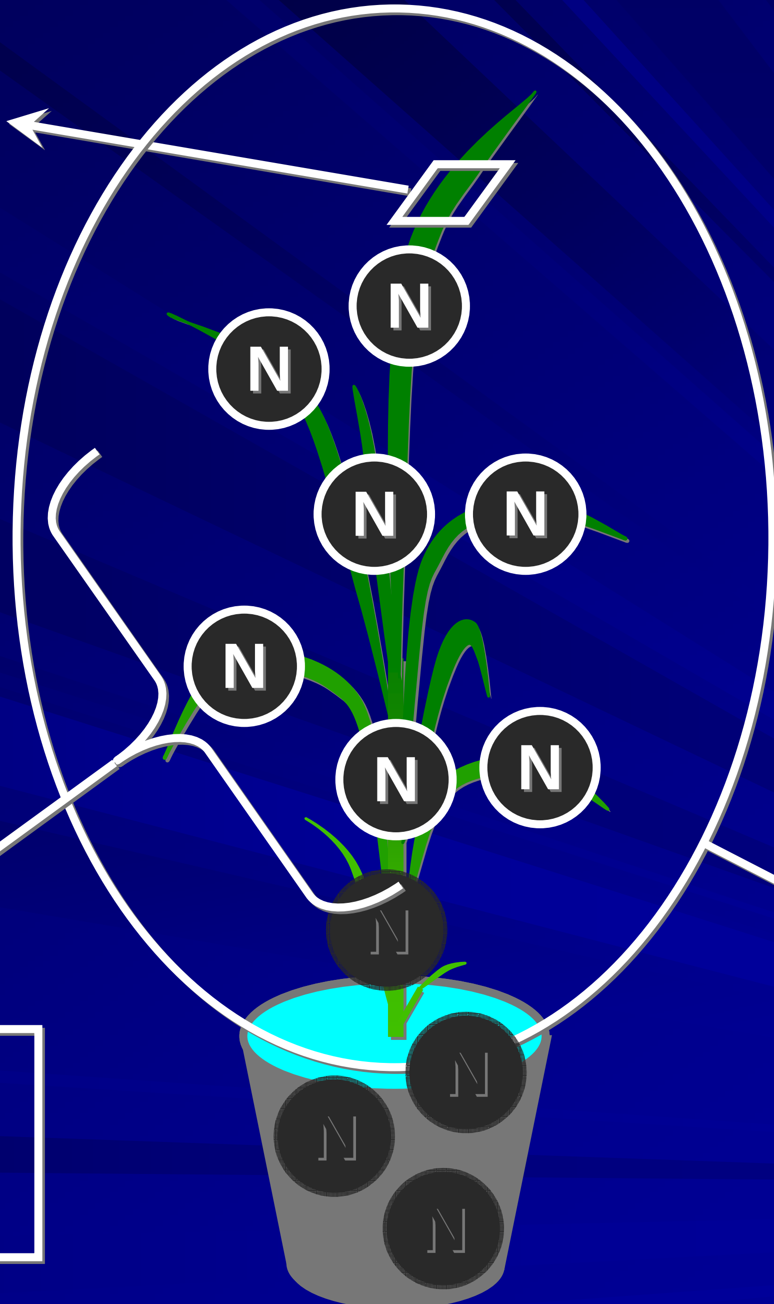
Leaf area expansion

(e.g., Makino et al. 1997a, b, Ohashi et al. 2000)

NPR per unit leaf area

In response to long-term

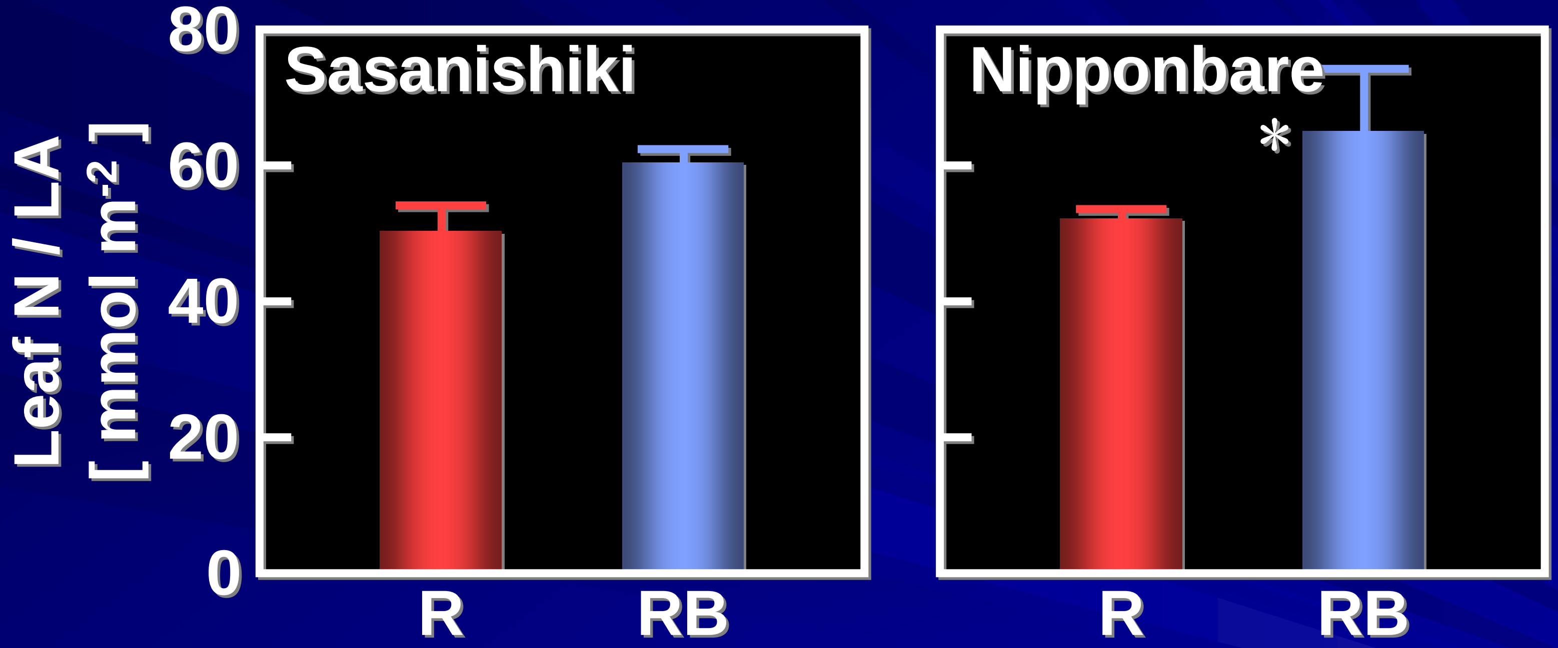
- low irradiance
- low temp.
- high CO_2



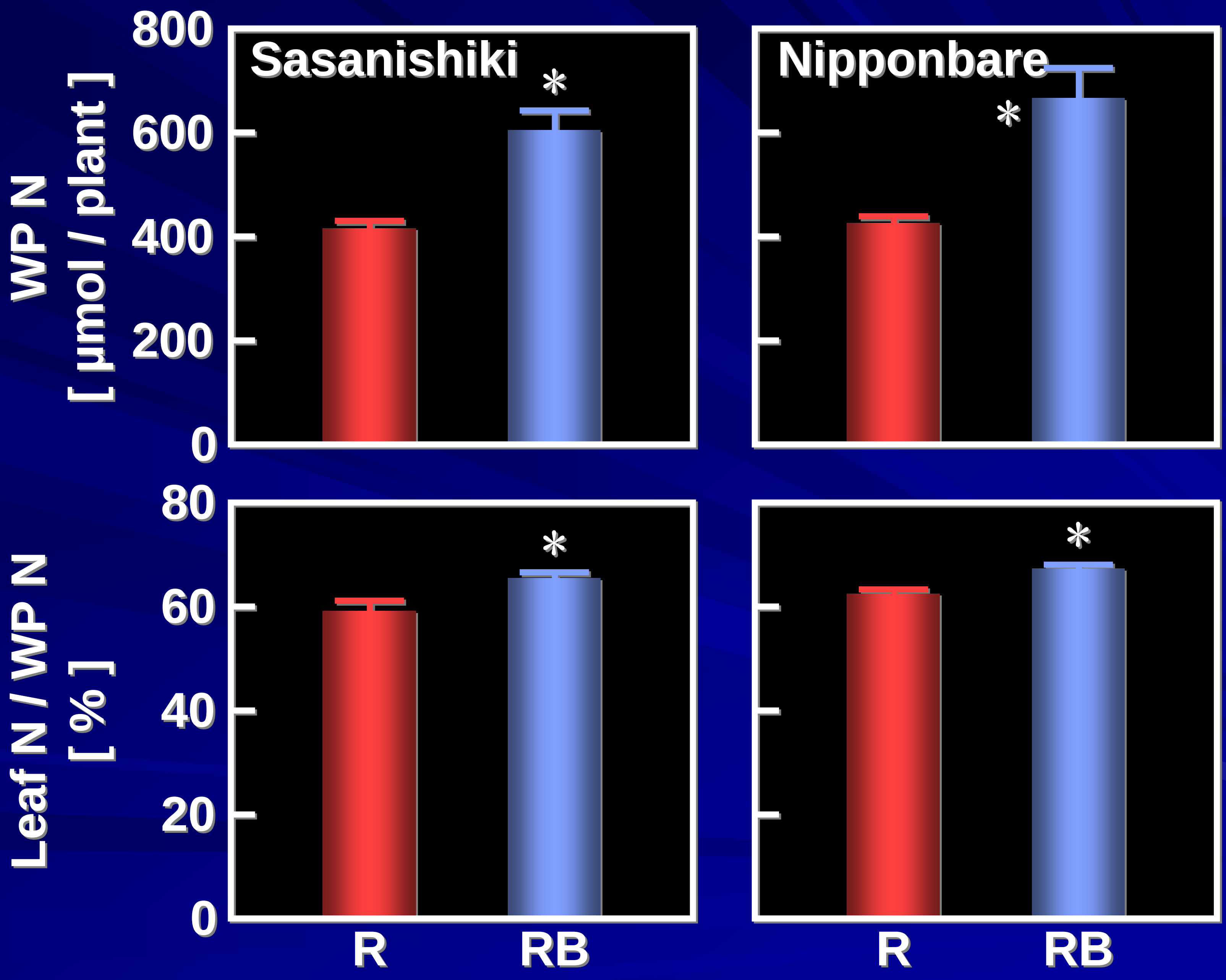
N investment in leaves

Leaf area expansion

(e.g., Makino et al. 1997a, b, Ohashi et al. 2000)



Leaf N / LA
[mmol m-2]
80
60
40
20
0
Sasanishiki
Nipponbare
*
R
RB
R
RB



WP N
[µmol / plant]
Leaf N / WP N
[%]
Sasanishiki
Nipponbare
800
600
400
200
0
80
60
40
20
0
*
*
*
*
R
RB
R
RB