農学国際特論1
DGAS Special Lecture 1
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Plant growth #2.
Plant growth and crop harvest

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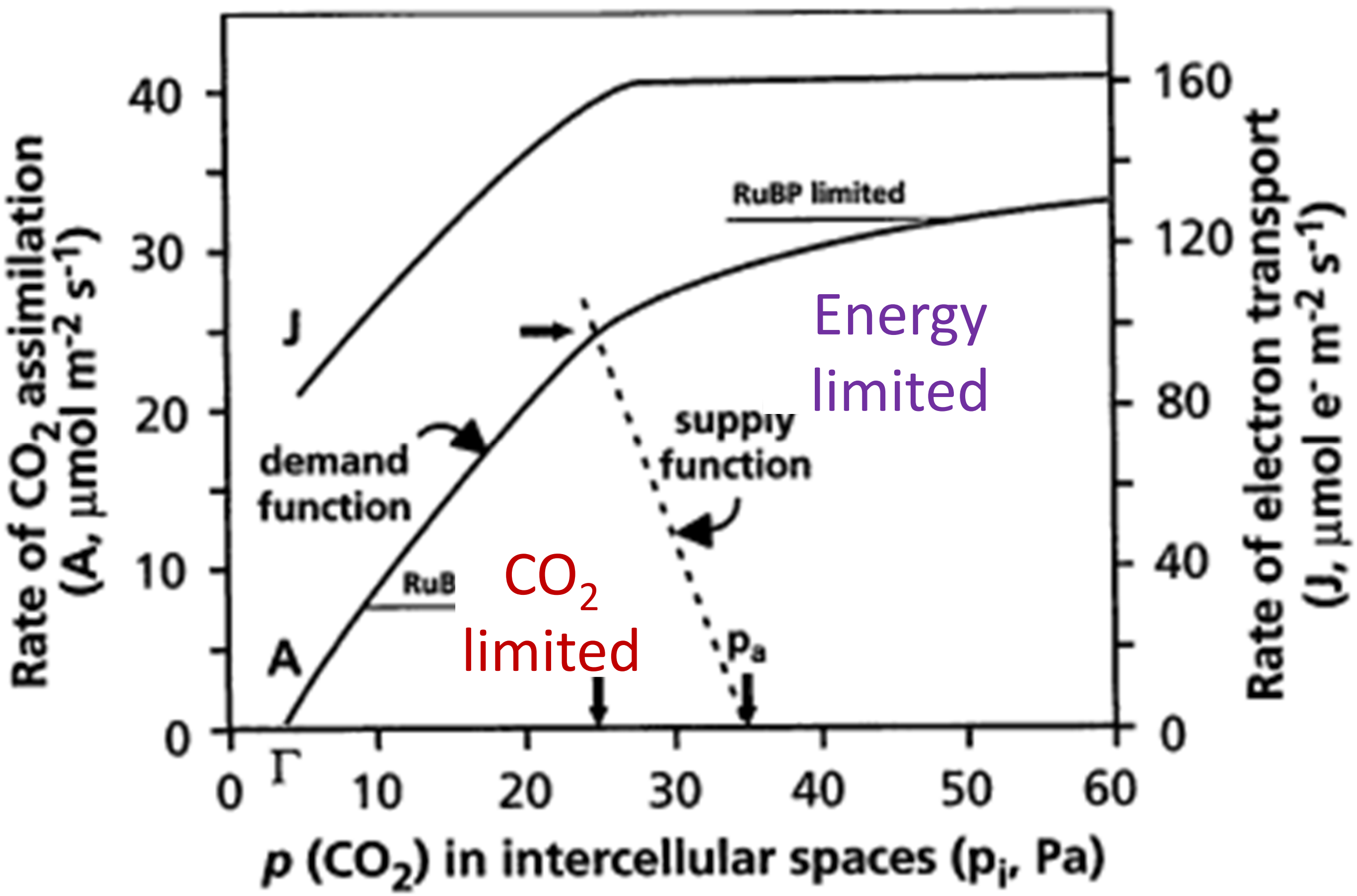
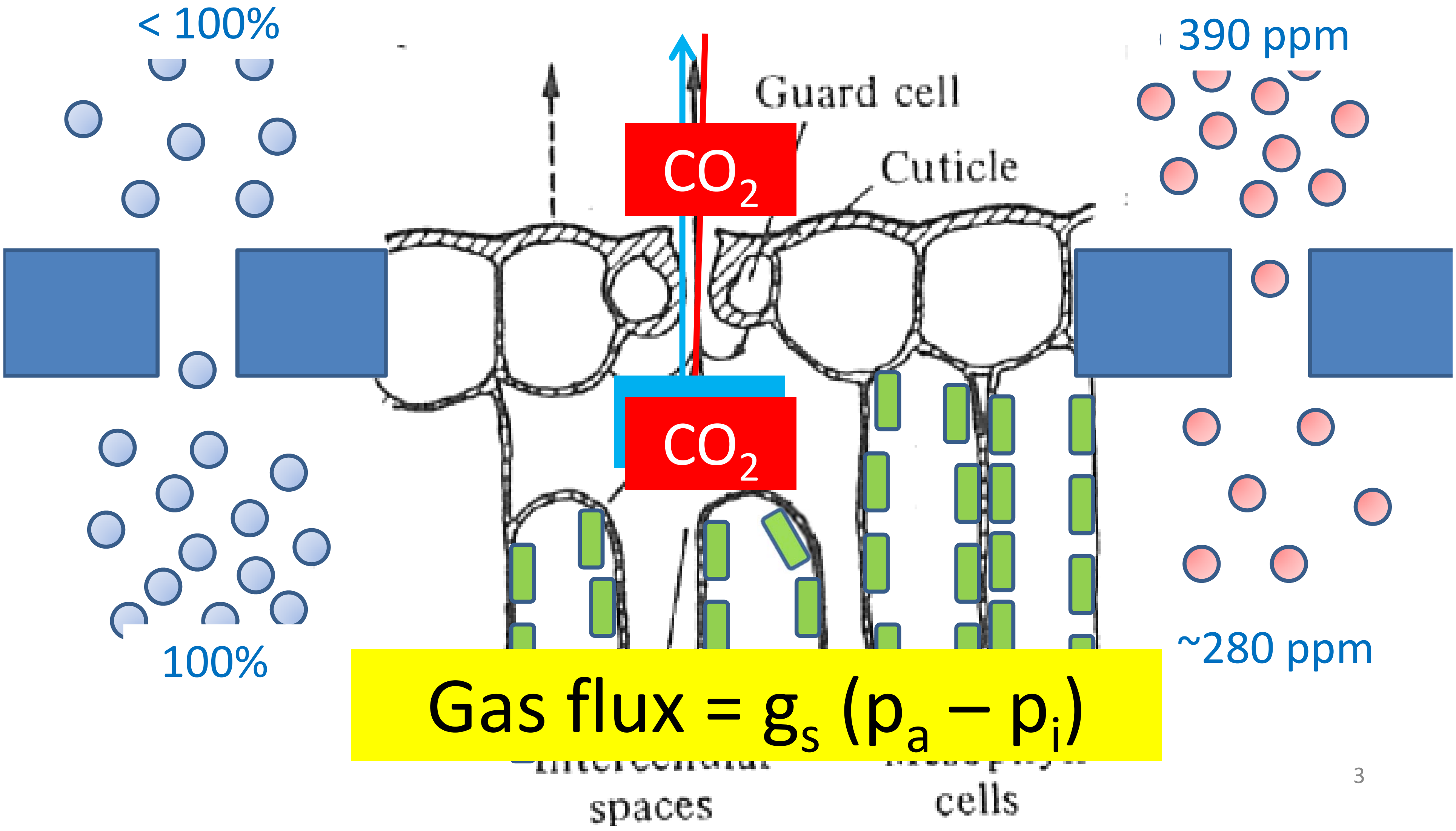
Supply of and demand for CO_2 in intercellular spaces

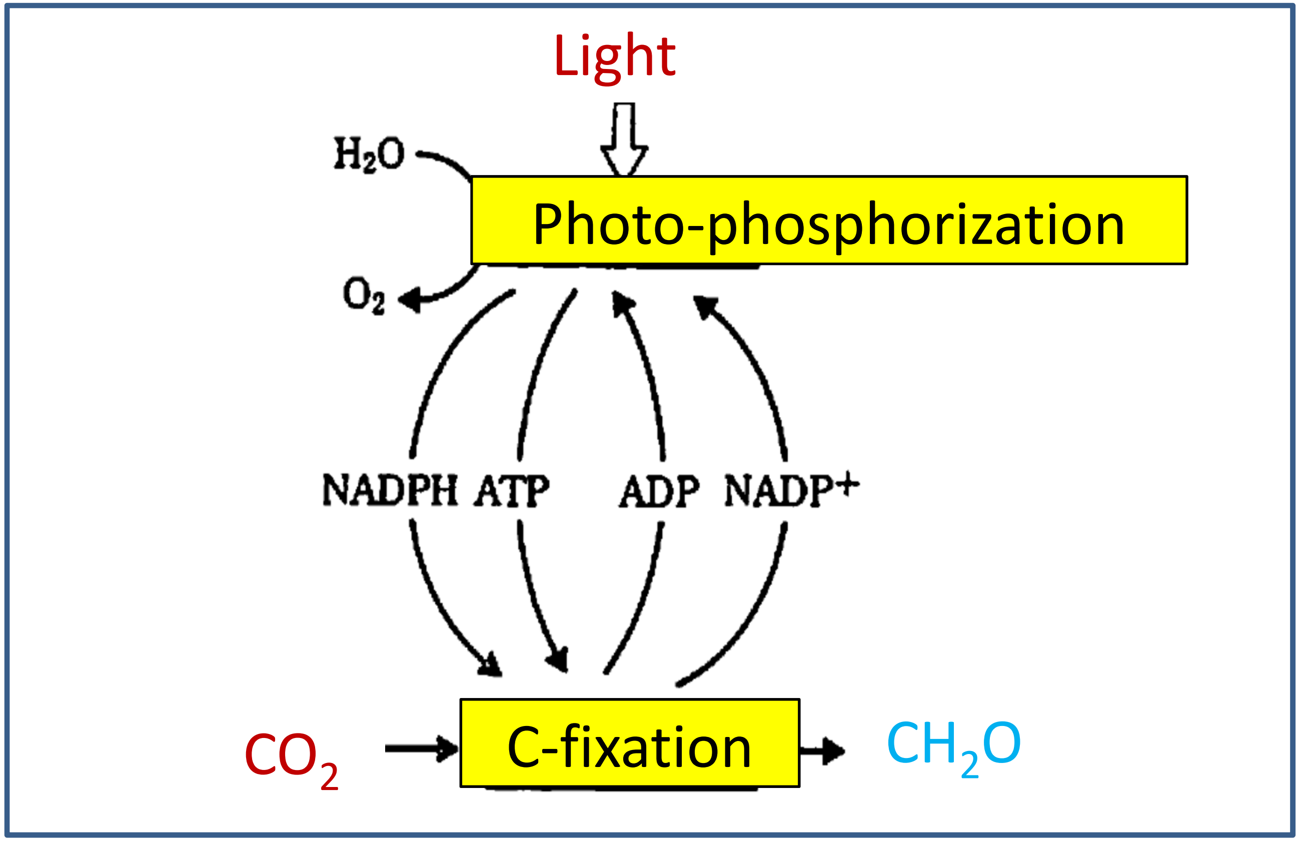


Supply: CO_2 diffuses in while water vapor diffuses out via stomatal pores



Gas flux = $g_s (p_a - p_i)$

Demand for CO_2: Photosynthetic processes in chloroplasts (Fig. 3)



Oxidation ⟷ Reduction (-O⁻, +2H⁺)

Supply = demand at the intersection

Why the demand increases at the 'Energy limited' region?

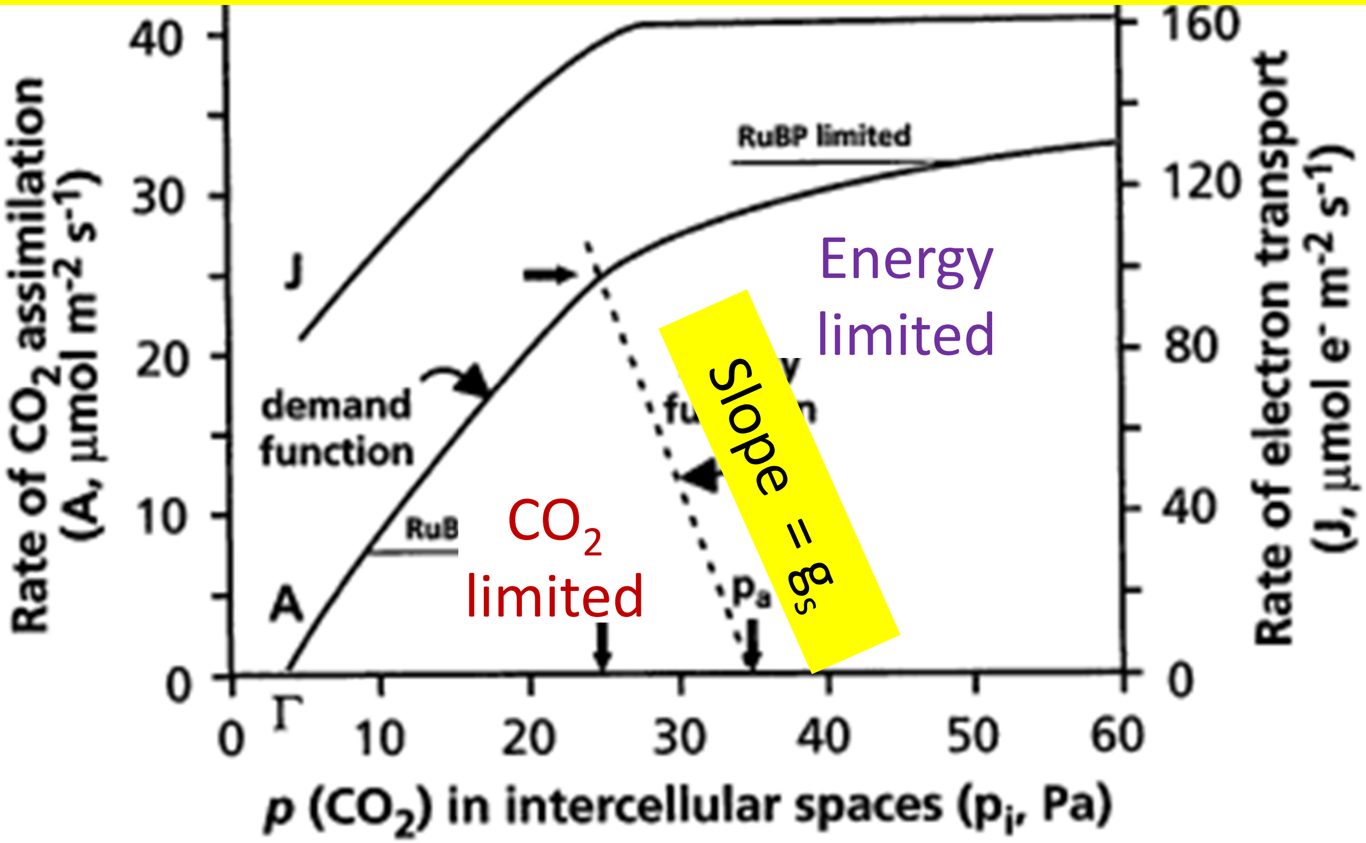
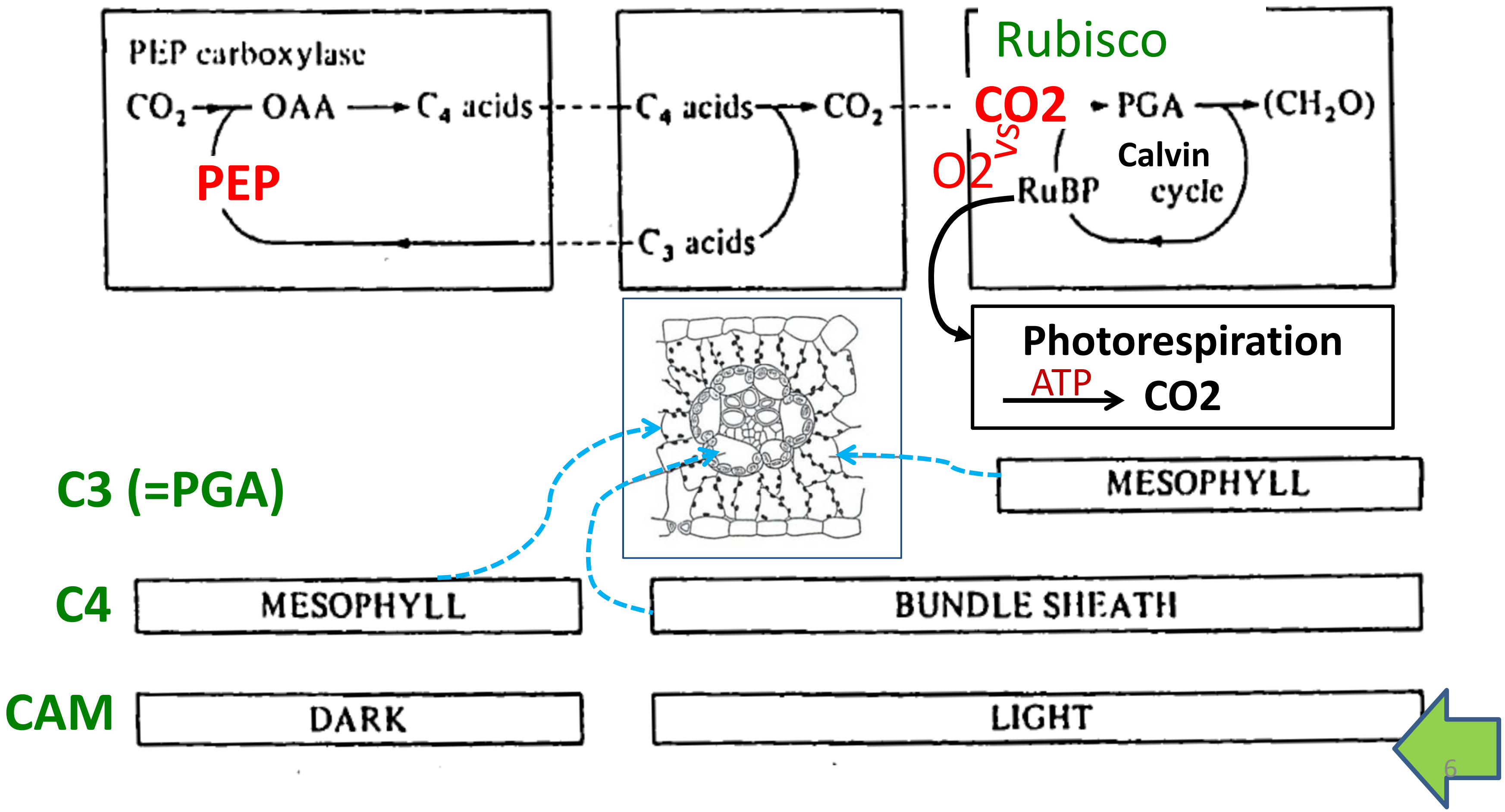
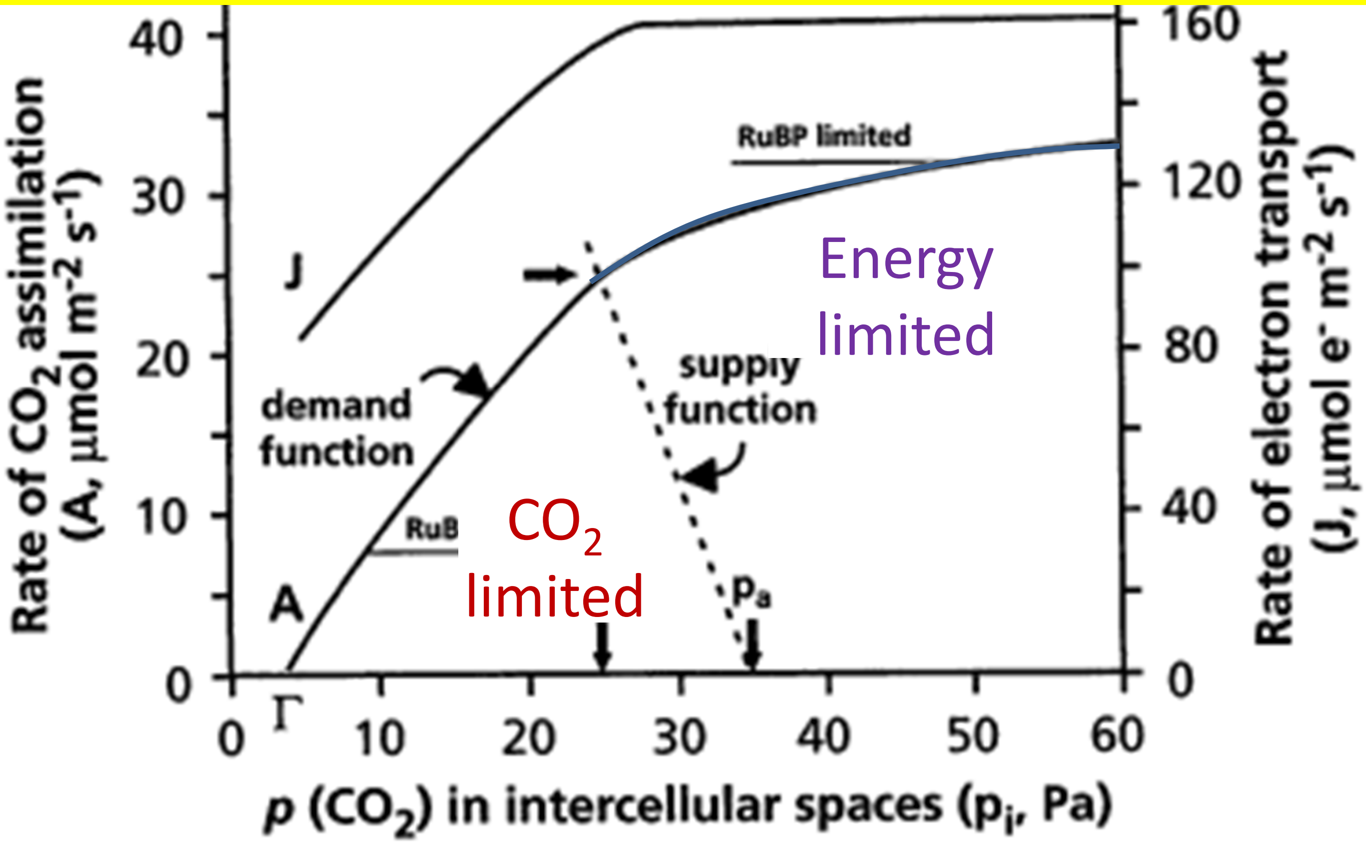


Fig. 9. Extra pathway for higher efficiency of carbon fixation by Rubisco



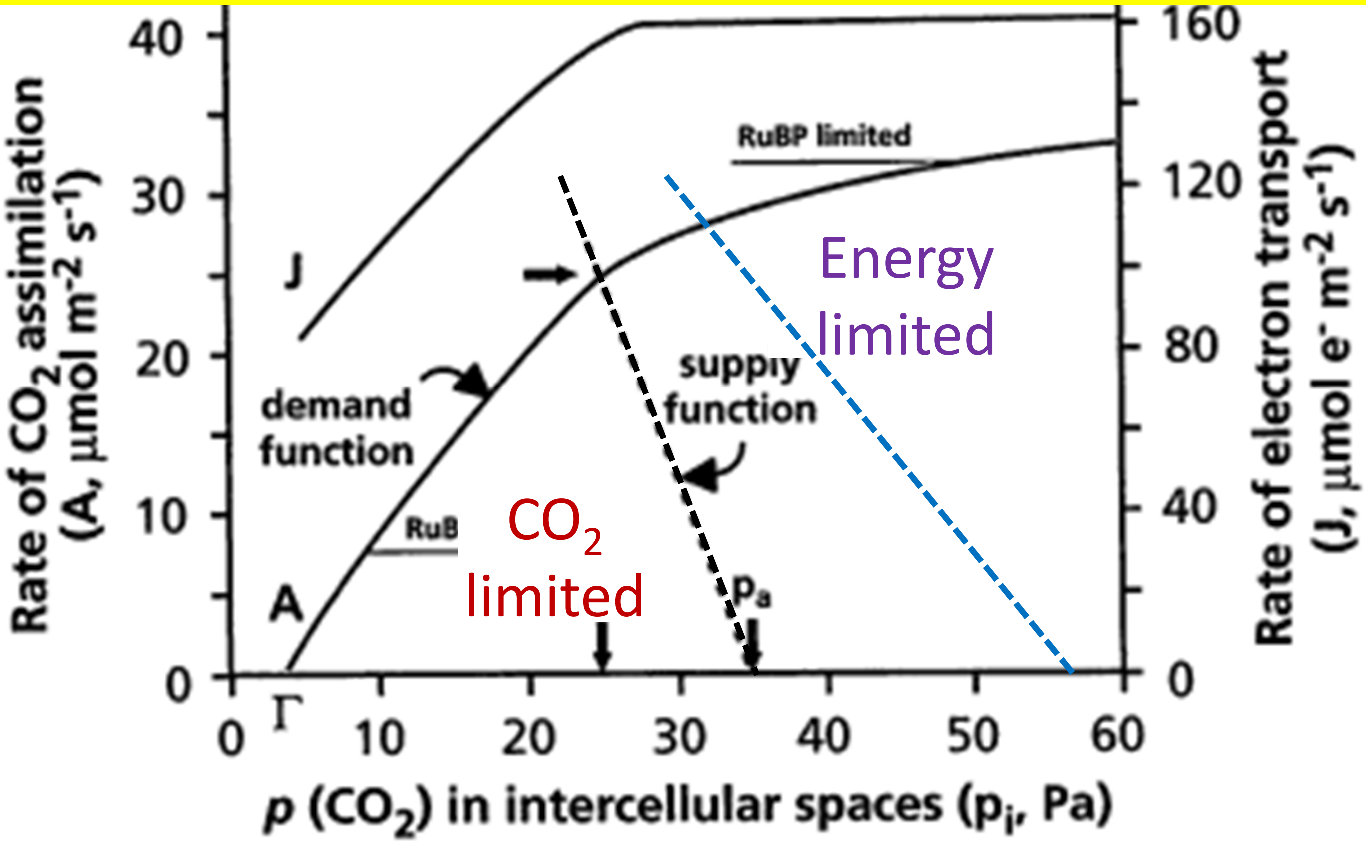
Supply = demand at the intersection

What happens if light intensity is changed?



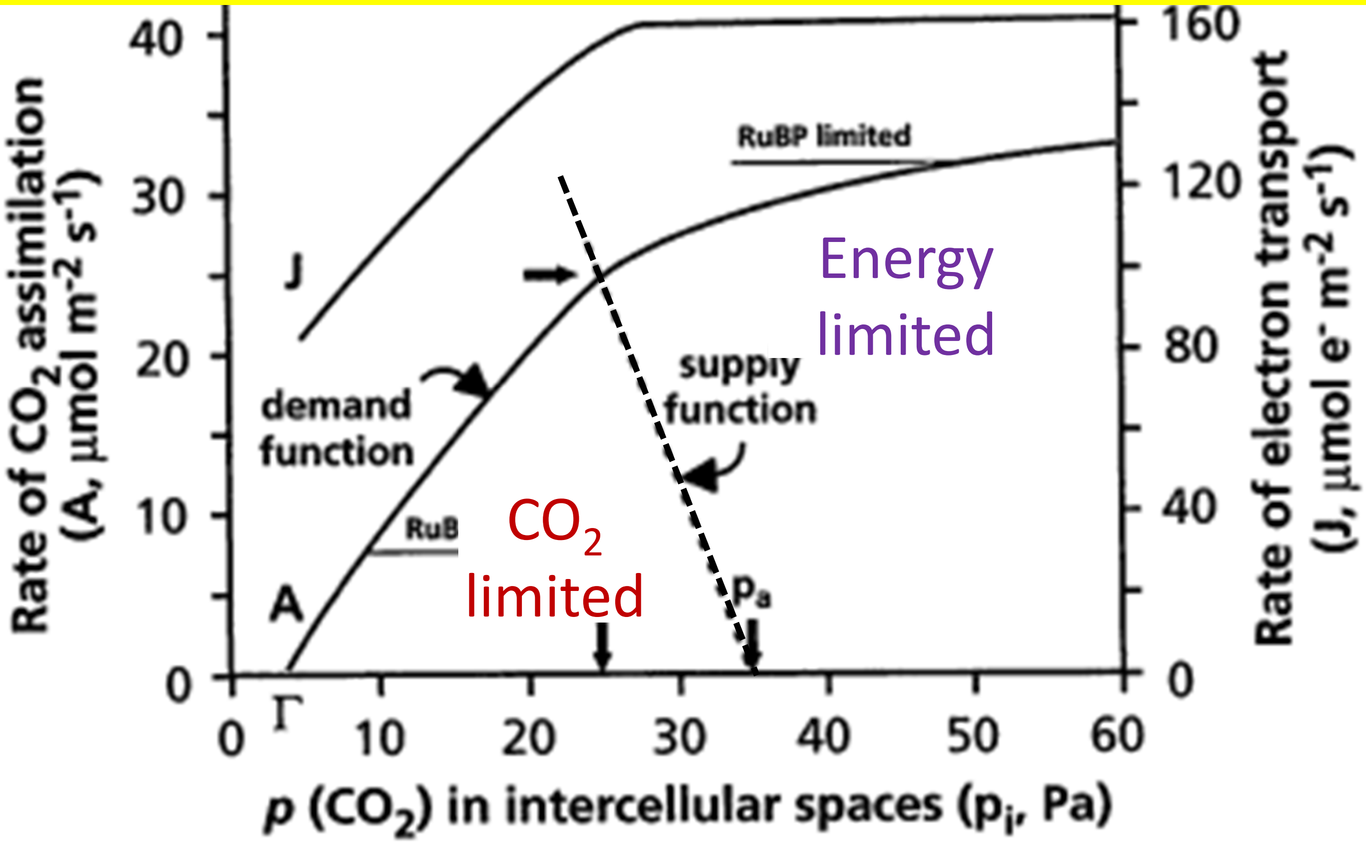
Supply = demand at the intersection

What happens if CO_2 concentration is increased?



Supply = demand at the intersection

What happens if leaf N content is increased?

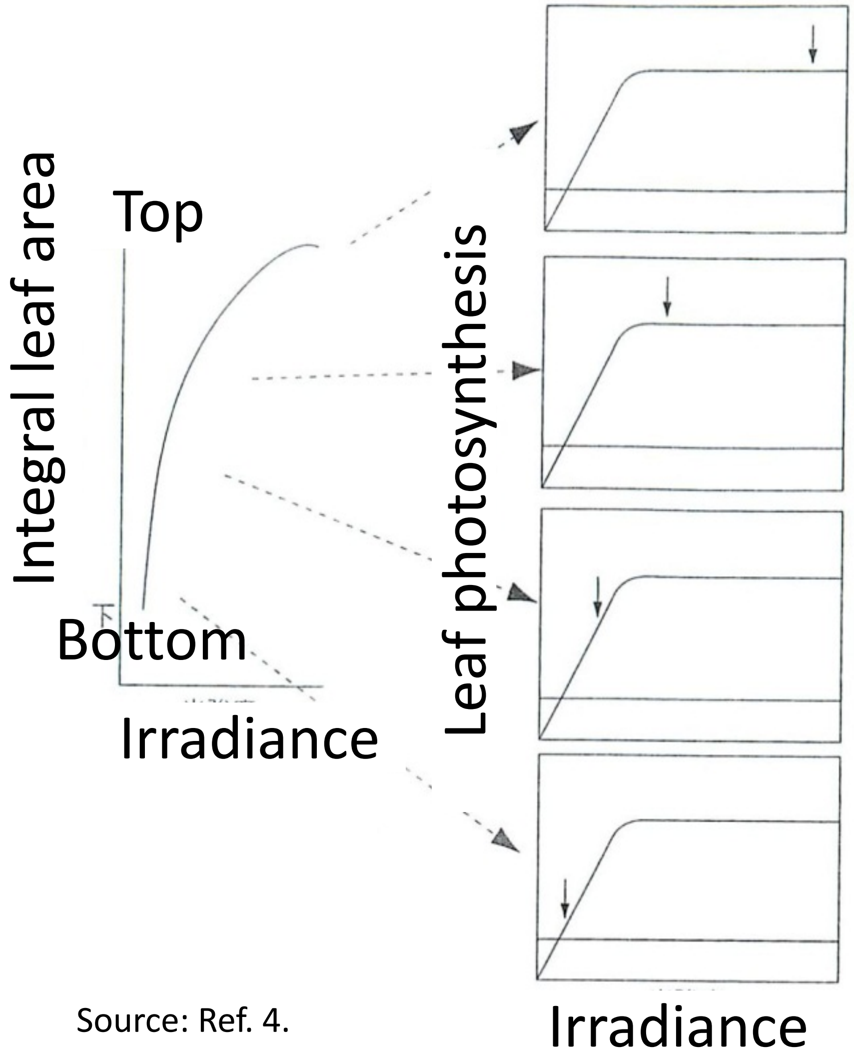


The demand-supply concept can thus explain the leaf gas exchange behavior under changing environment reasonably well.

- Leaf stomata behaves to attain a good balance between carbon gain and water loss.
- The stomatal behavior is based on genetic program which varies by species and varieties, and has been developed during the processes of evolution and breeding.

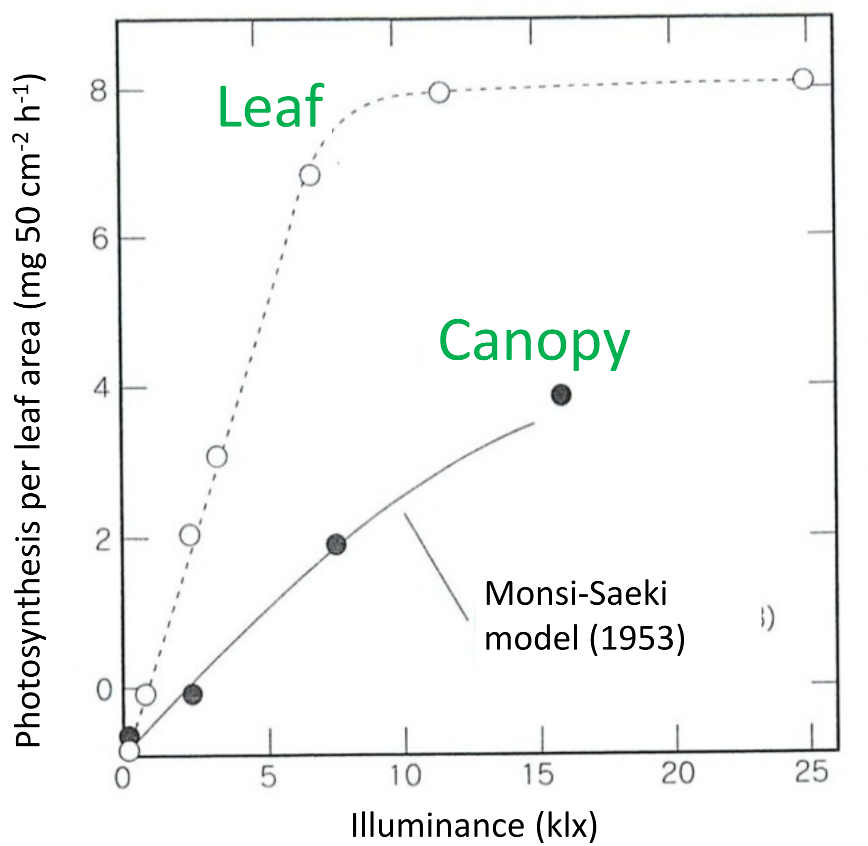
Scaling-up leaf photosynthesis to plant canopy photosynthesis

Fig. 20. Monsi-Saeki Model of canopy photo-synthesis.



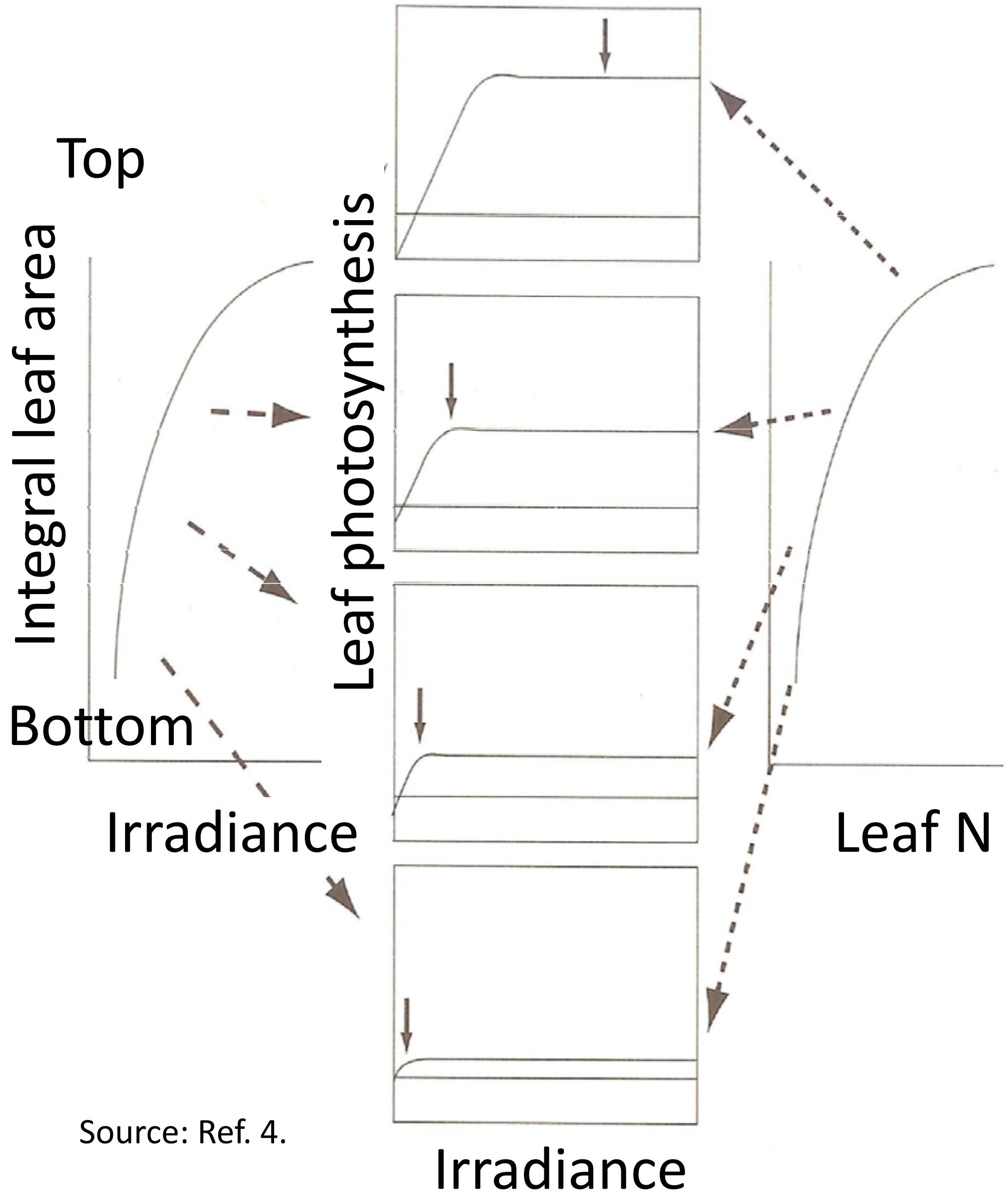
Source: Ref. 4.

Fig. 21. Monsi-Saeki Model as compared with observed canopy and leaf photosynthesis rates.



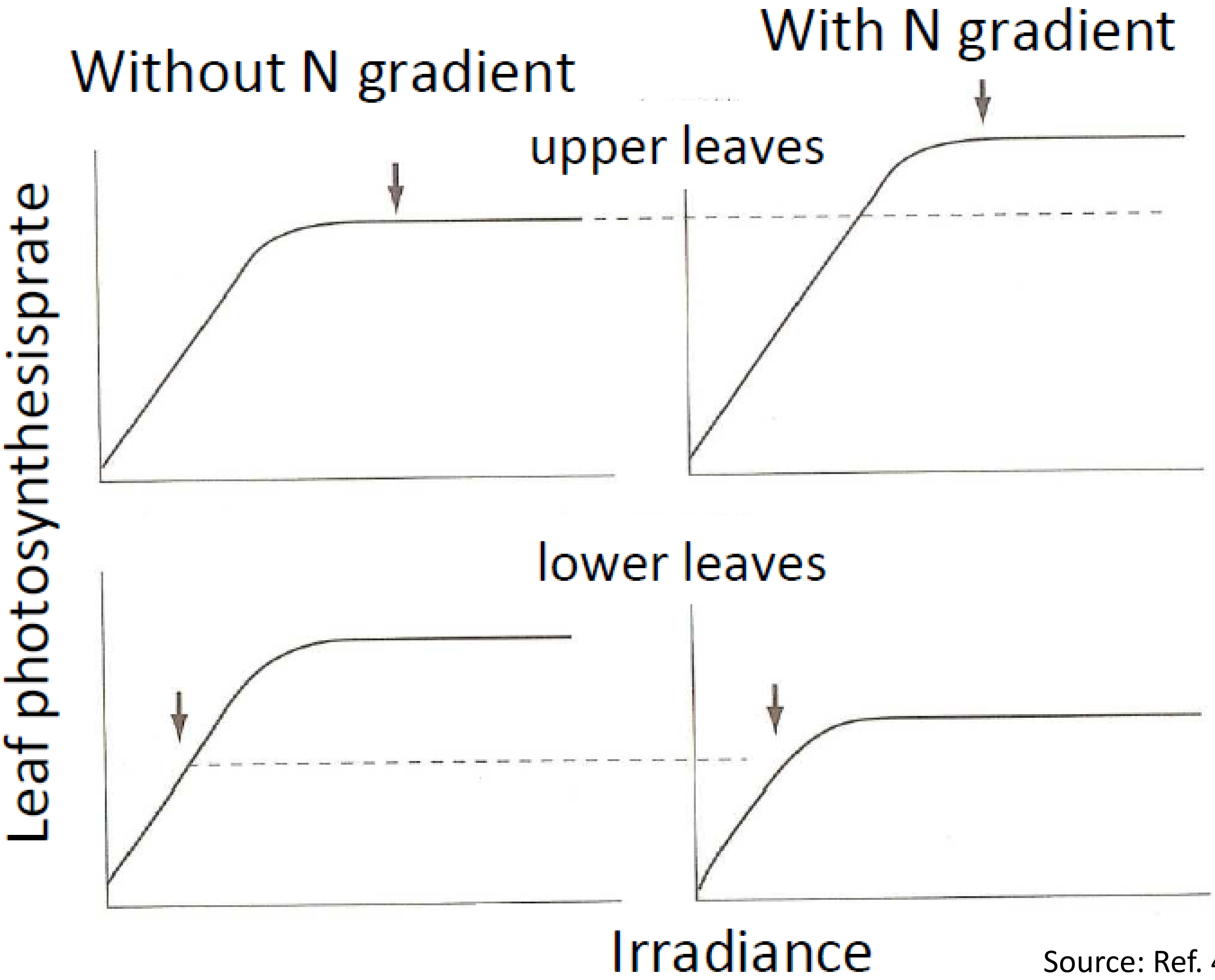
Source: Ref. 4.

Fig. 22. Hirose-Werger Model for photo-synthesis with N gradient for optimum light use.



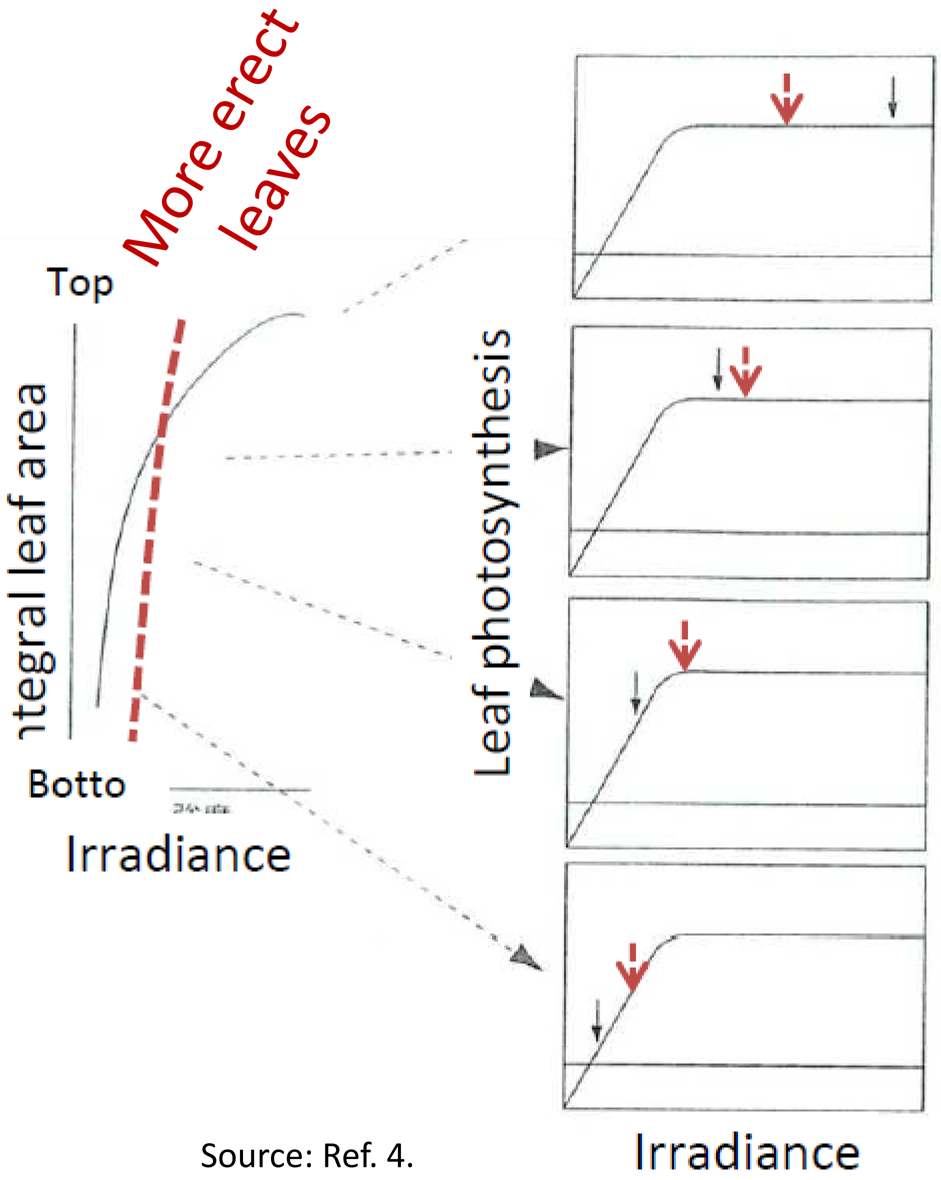
Source: Ref. 4.

Fig. 23. Effect of leaf N gradient on canopy photosynthesis



Source: Ref. 4.

Fig. 24. Effect of altered irradiance profile on canopy photo-synthesis.



Source: Ref. 4.

Plants can alter resource allocation for more efficient use of the resources, e.g. Nitrogen, light.

Distributing assimilates (C, N…)

Fig. 25. Temporal changes in rice plant biomass (A) and nitrogen content (B) throughout a season.

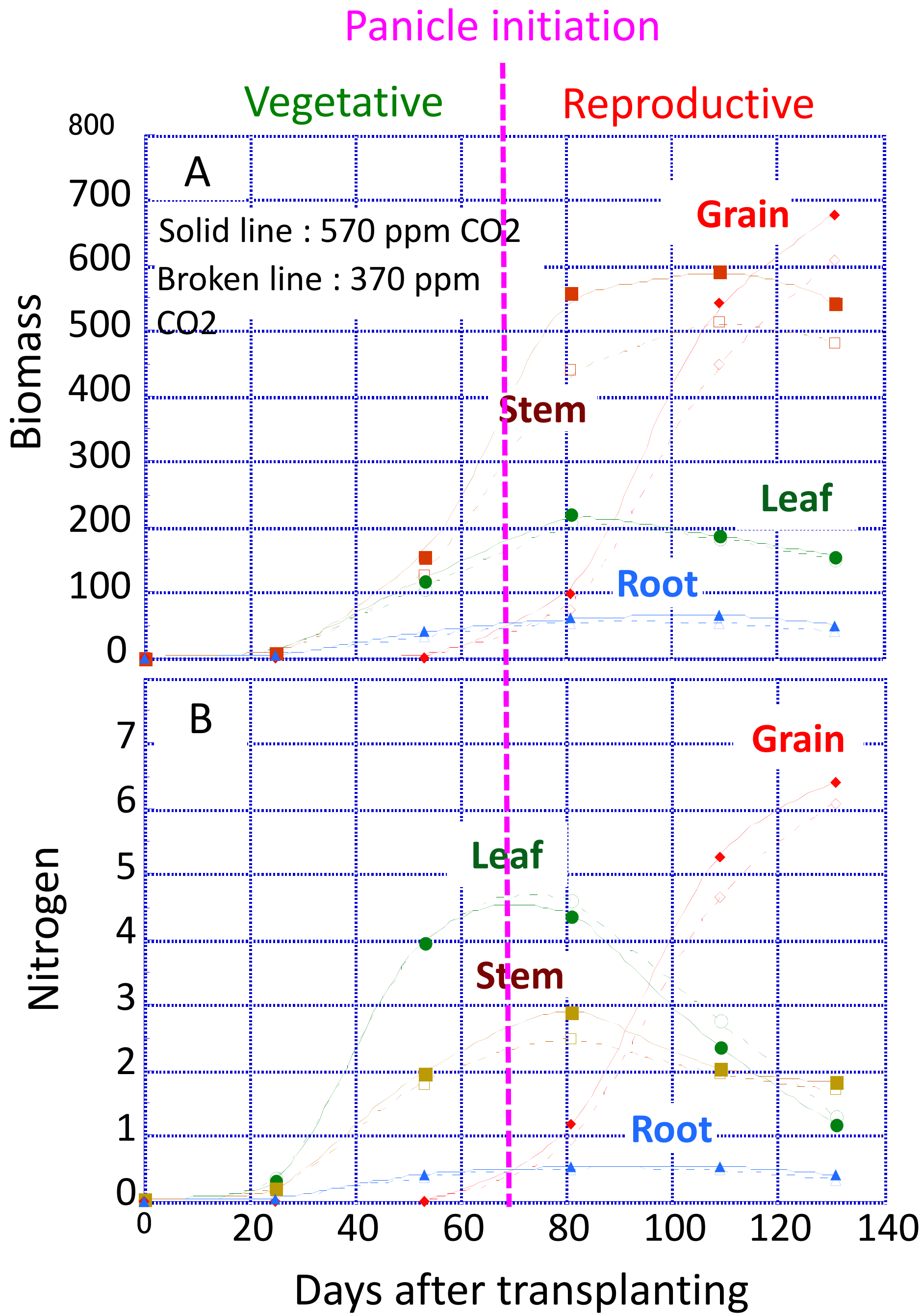
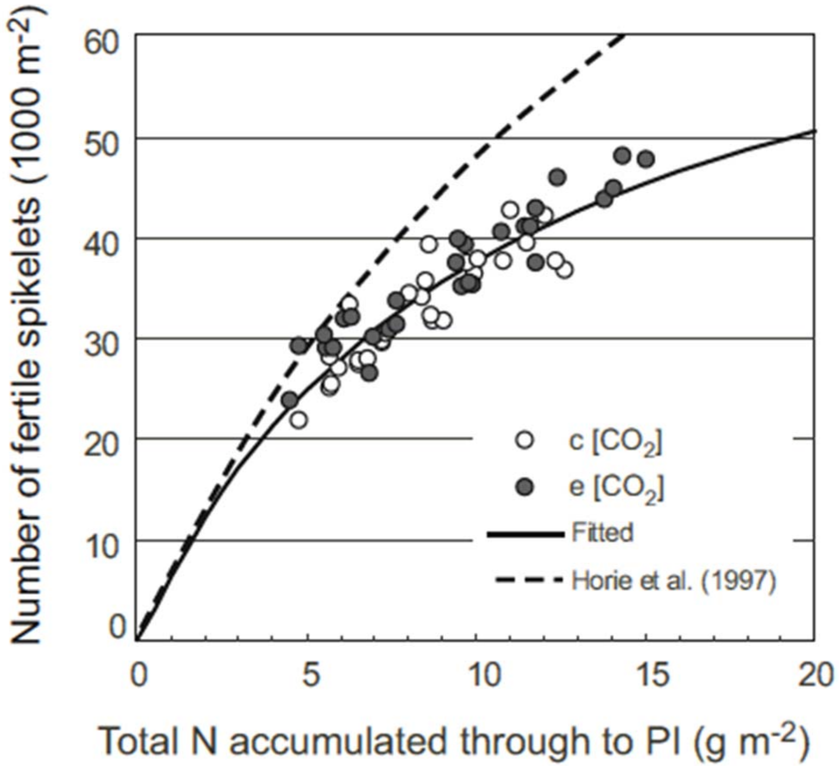


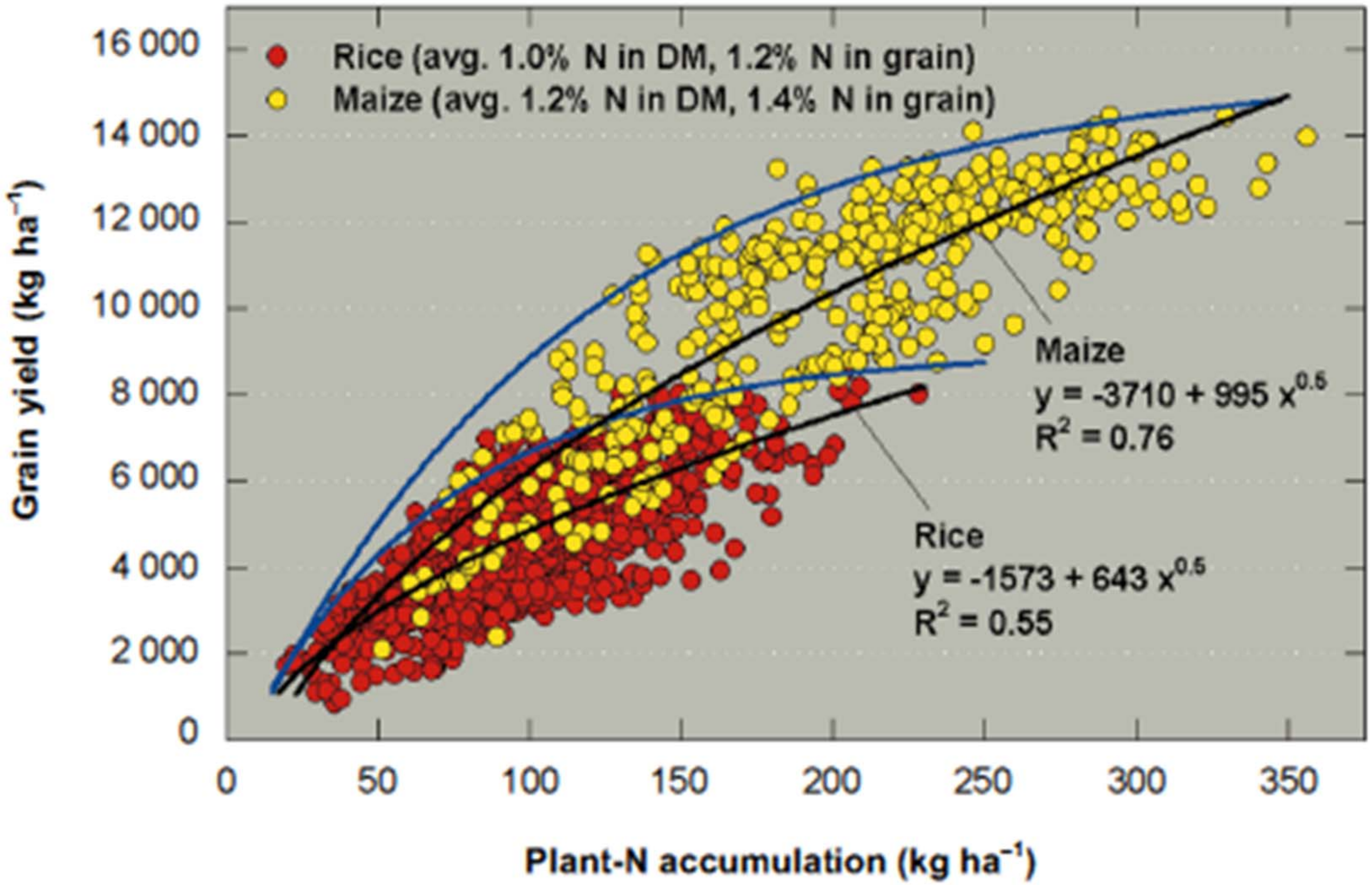
Fig. 26. Relationship between nitrogen accumulation and number of fertile grains.



PI (Panicle initiation): flower initiation
Spikelets: grains
e[CO_2]: elevated CO_2 concentration
c[CO_2]: ambient CO_2 concentration

Kobayashi et al. (2006) In: *Managed ecosystems and CO_2: case studies, processes, and perspectives.* Springer, Berlin Heidelberg New York.

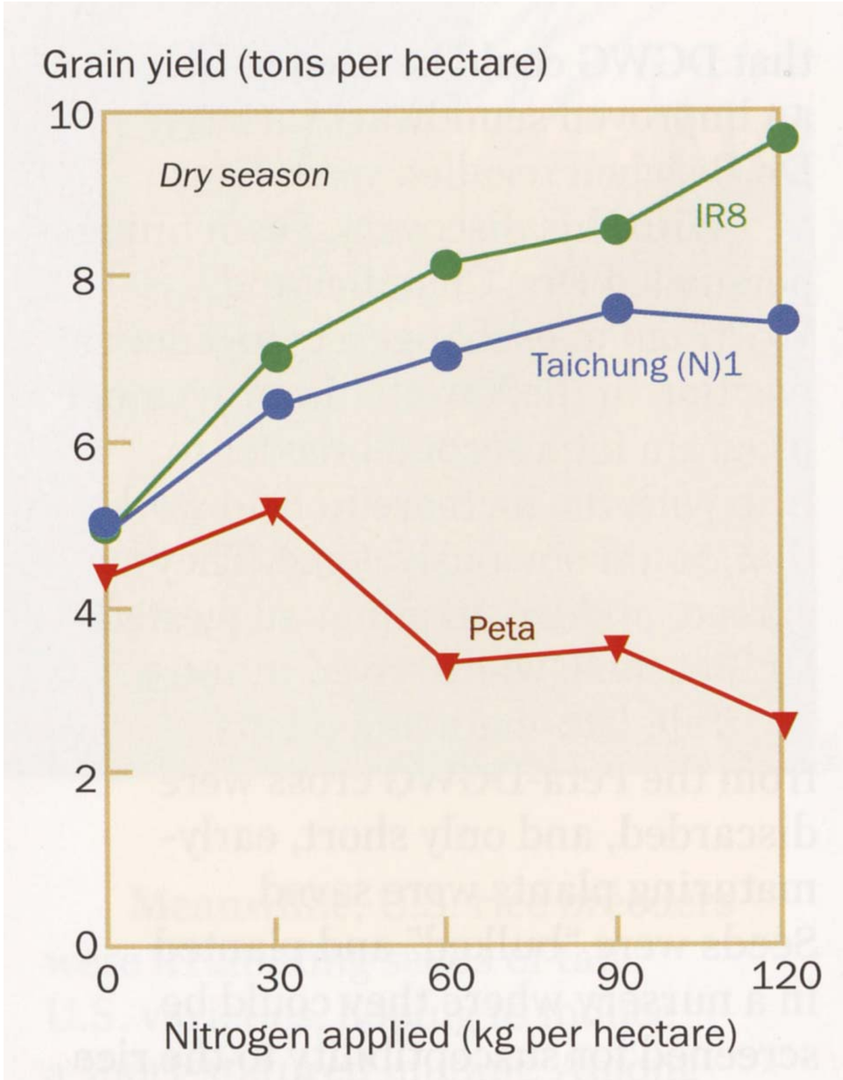
Fig. 27. Relationship between nitrogen accumulated by plants and grain yield in maize and rice



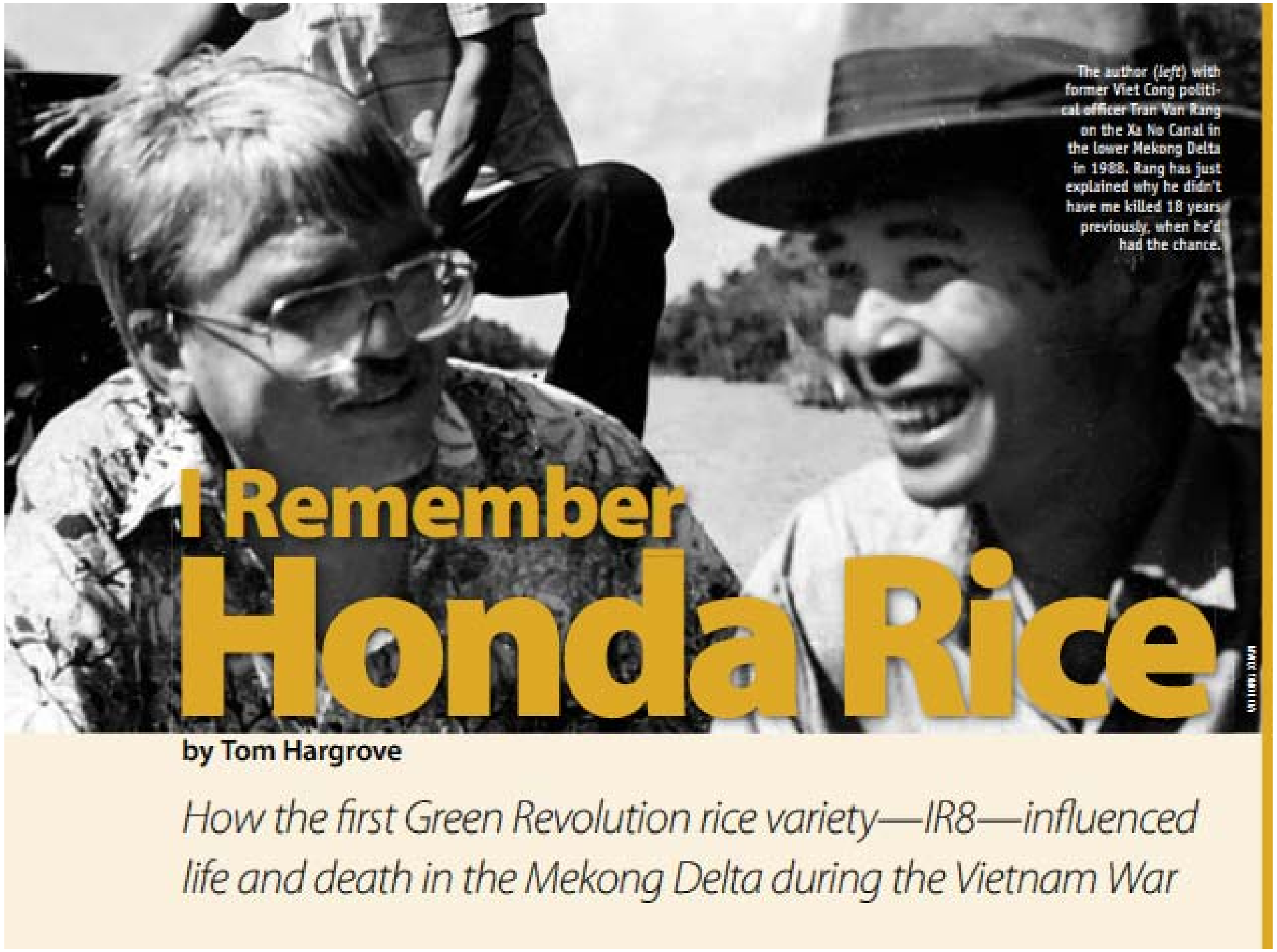
Source: Cassman K.G. et al. (2002). Ambio 31, 132-140.

Fig. 28. Response of IR8 and its parents to increased N application.

Source: Ref. 2



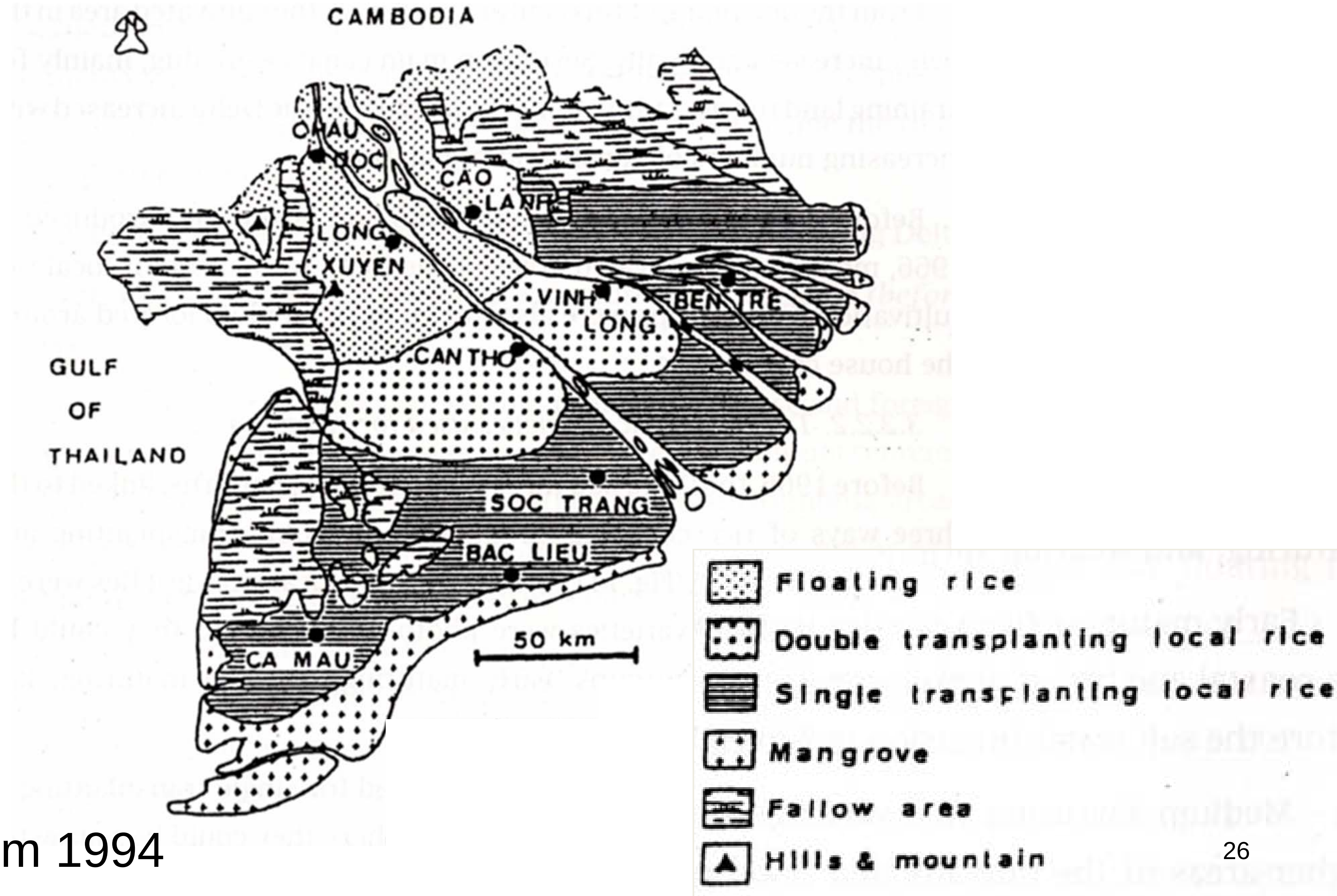
3. Breeding and intensification: how modern varieties increased crop production?



Question

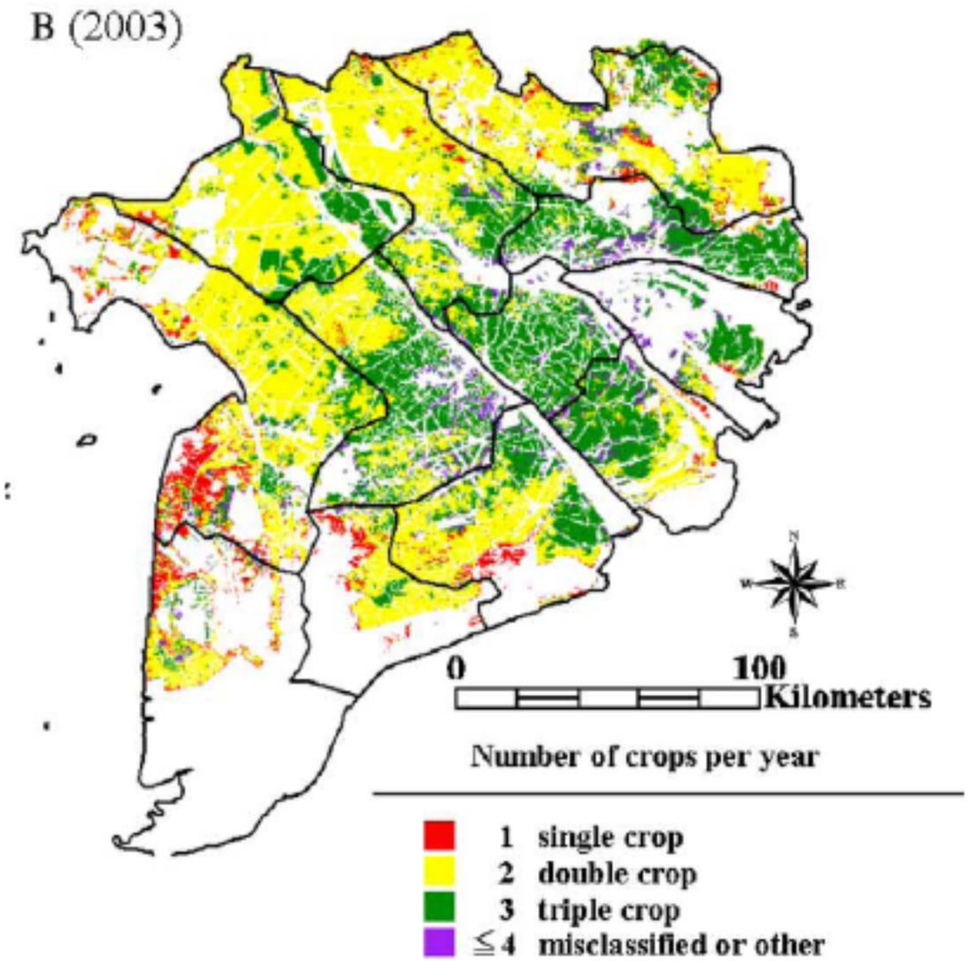
- Read the story of IR8 or Honda-Rice in Ref. 2 and summarize what was most impressive for you.

Land use of Mekong Delta in early 1970's



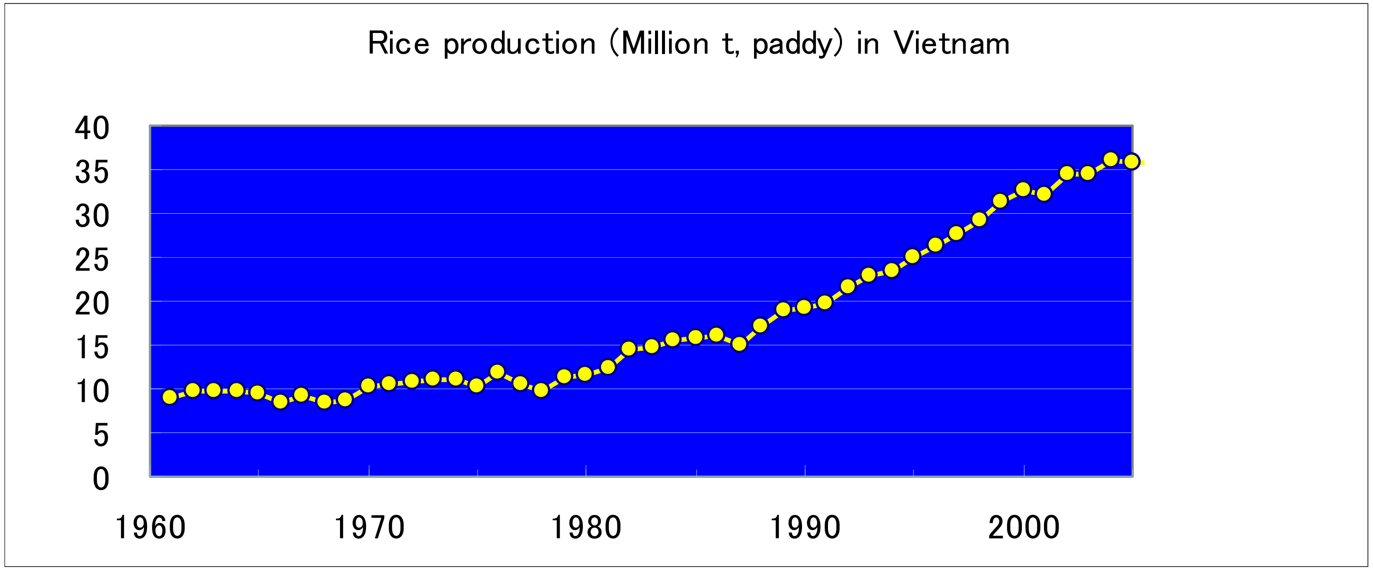
Chiem 1994

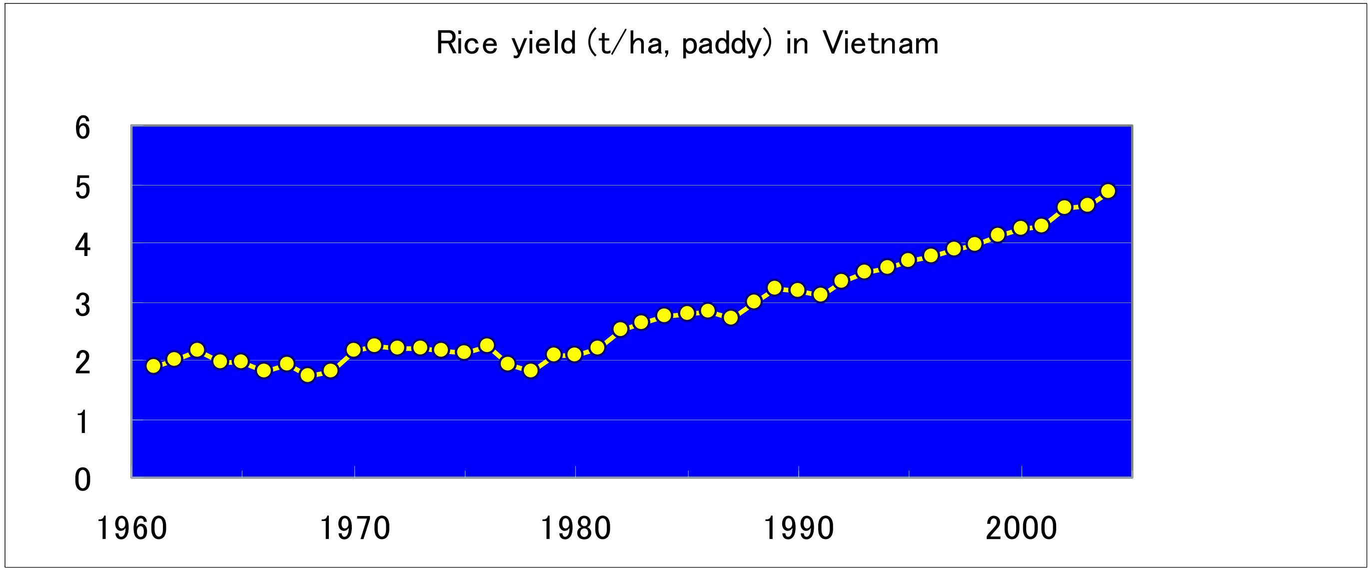
Rice cropping system in Mekong Delta in 2003



Sakamoto et al. (2006). Remote Sensing and Environ. 100, 1-6.

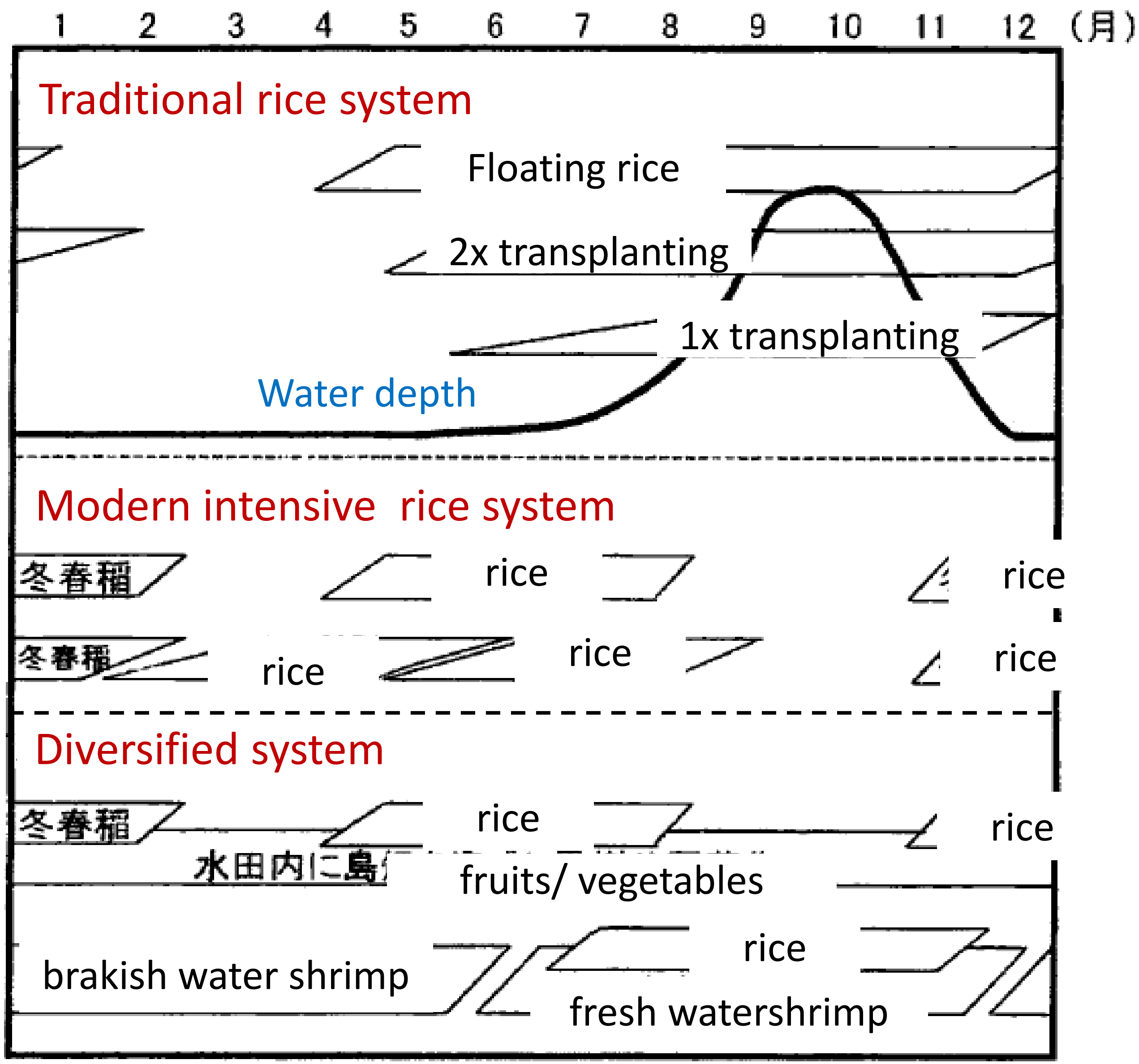
Rice production in Vietnam





FAOSTAT:
http://faostat.fao.org/site/291/default.aspx

Changes in rice cropping in Mekong Delta



河野(2004) 熱帯での営農. 熱帯生態学(長野編)

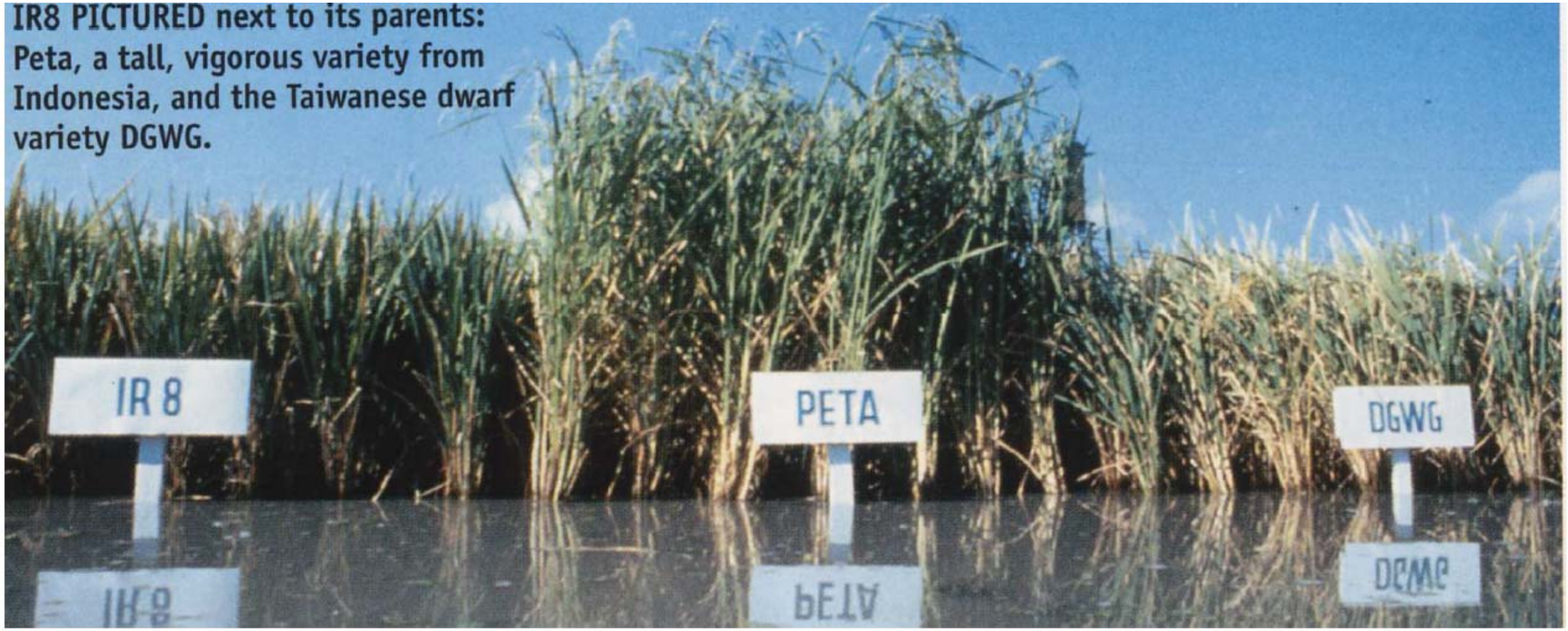
Fig. 31. Wheat harvest in a 16th Century drawing by Abel Grimmer after Pieter Brugel in 1570.

Fig. 32. Wheat cultivars that contributed to the Green Revolution.

From left to right: 'Shiro-Daruma', 'Turkish Red', 'Norin-10', 'Sonora 63', and 'Pitic 62'.

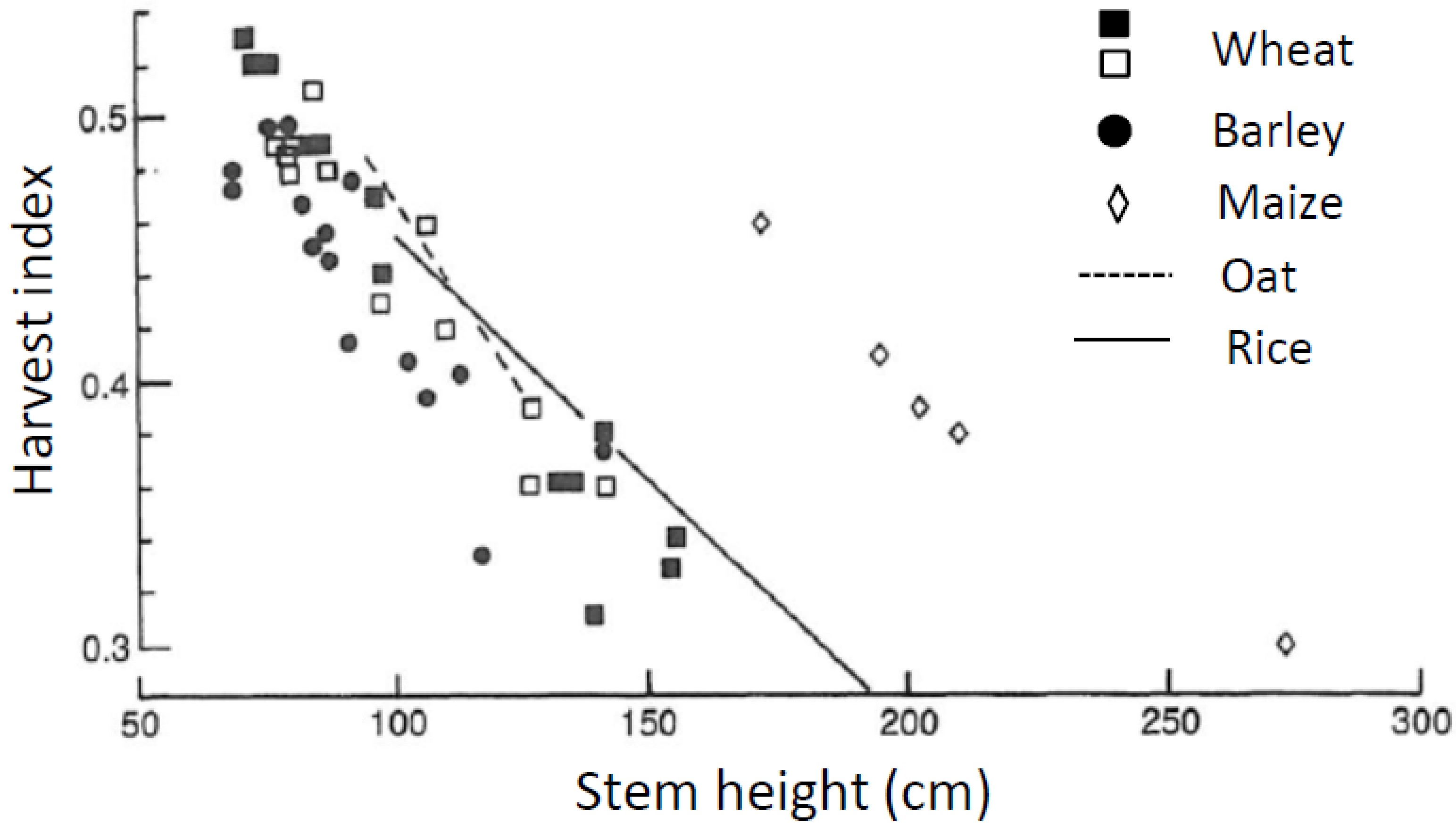
Source: Ref. 2.

Fig. 33. The rice cultivar IR8 and its parental varieties.



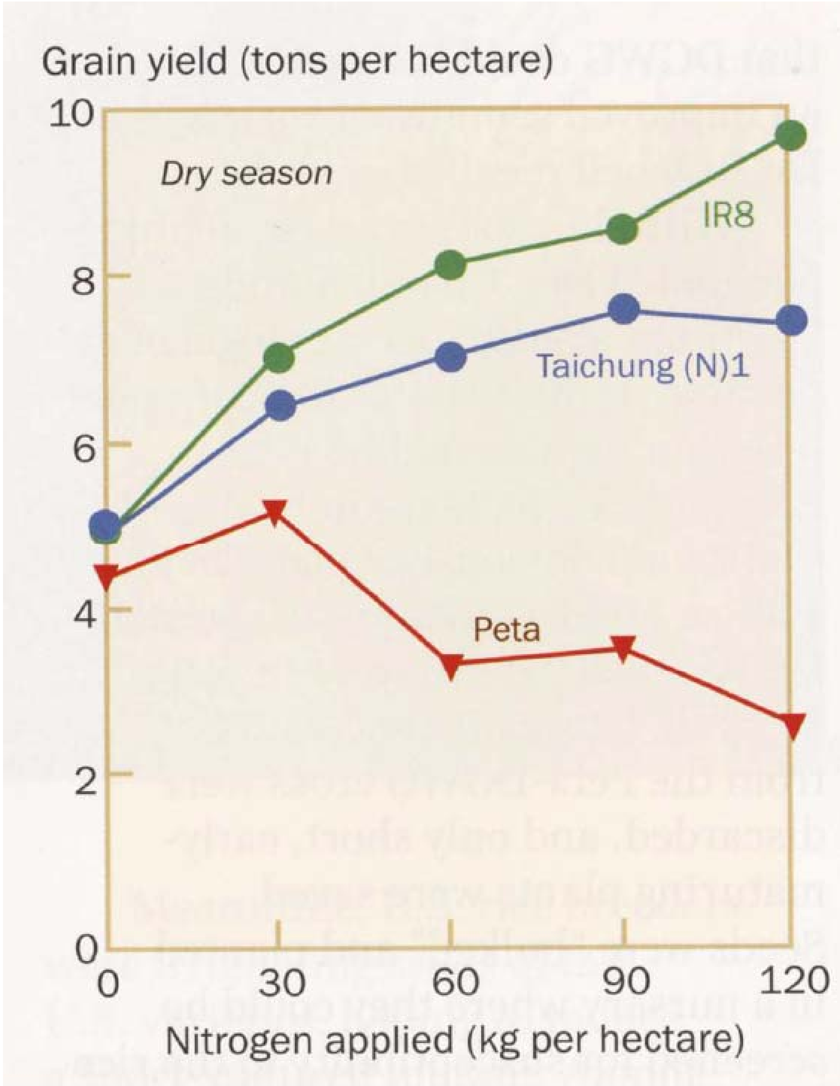
Source: Ref. 3.

Fig. 34. Relationship between stem height and harvest index in wheat, barley, maize, oat, and rice.



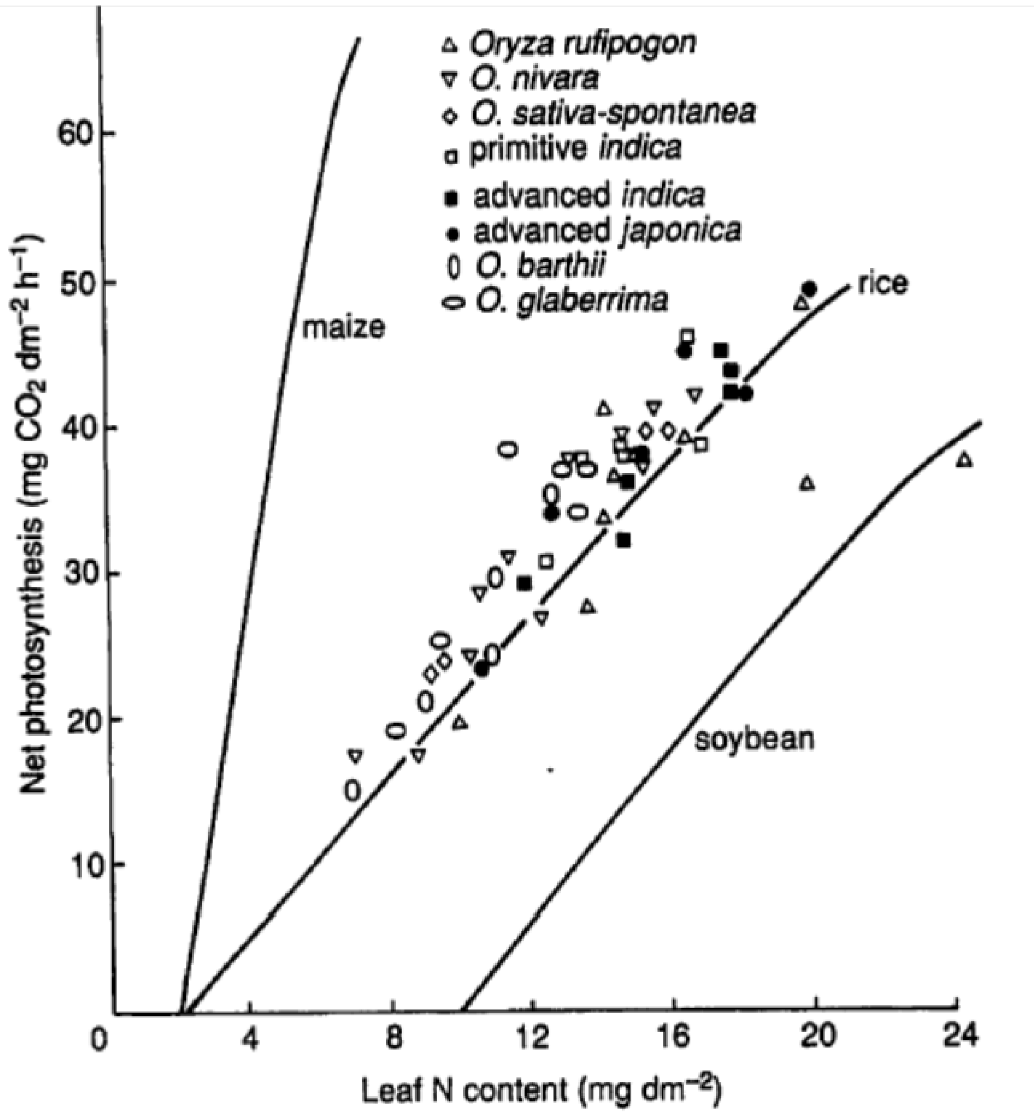
Source: Ref. 1

Fig. 35. Yield response of IR8 and its parents to increased N application.



Source: Ref. 3.

Fig. 36. Responses of leaf photosynthesis to leaf N content in maize, soybean and rice relatives

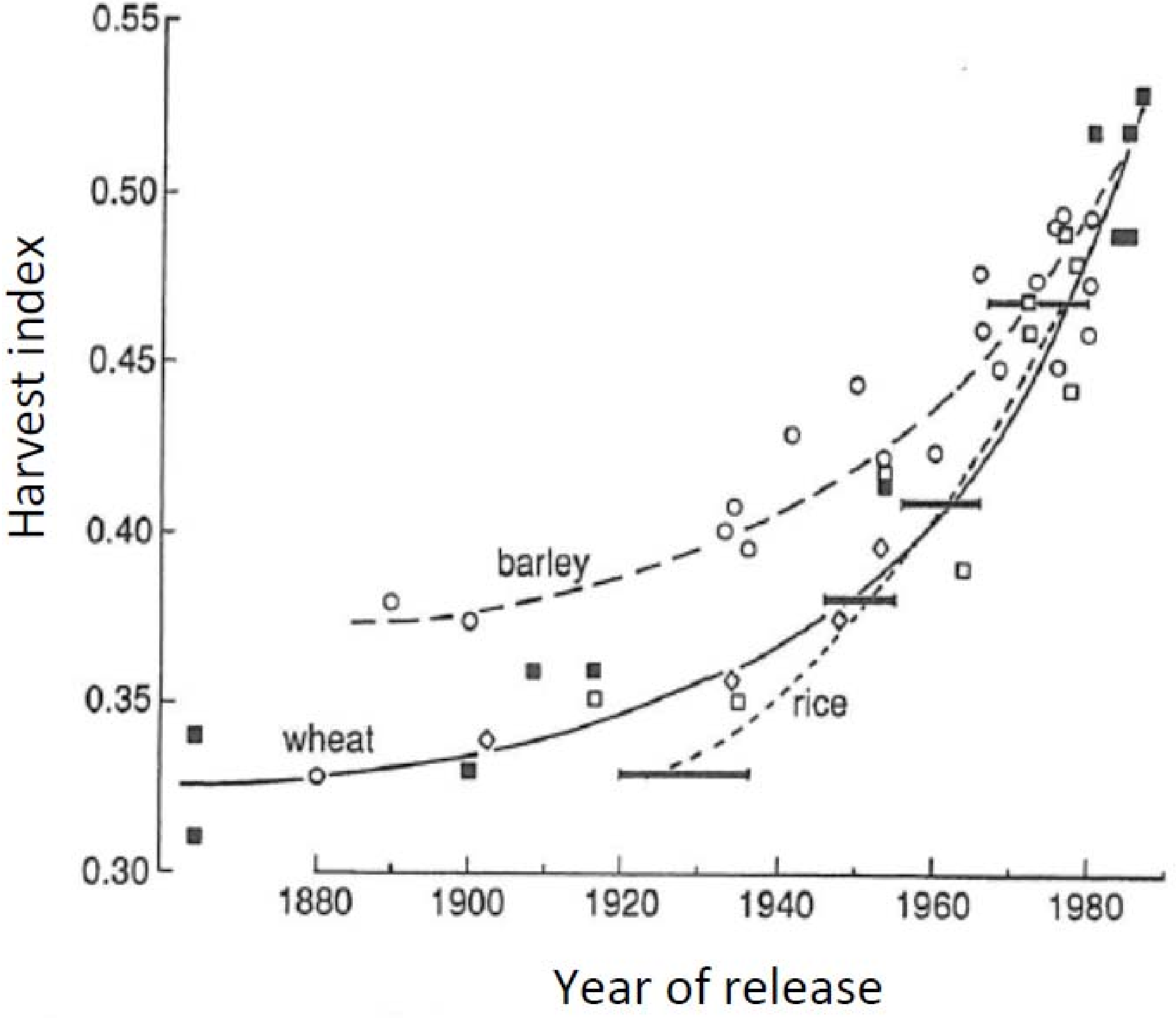


Source: Ref. 1

3. Breeding: how modern varieties got the higher yield than traditional ones?

- Shorter stature: reduced plant height (Figs. 31-33) with erect leaves, increased Harvest Index (Fig. 34), and higher yield under greater N application (Fig. 35), which raised leaf photosynthetic rate in either wild, traditional or modern species (subspecies) of rice (Fig. 36).

Fig. 37. Increase of harvest index in wheat, barley and rice.



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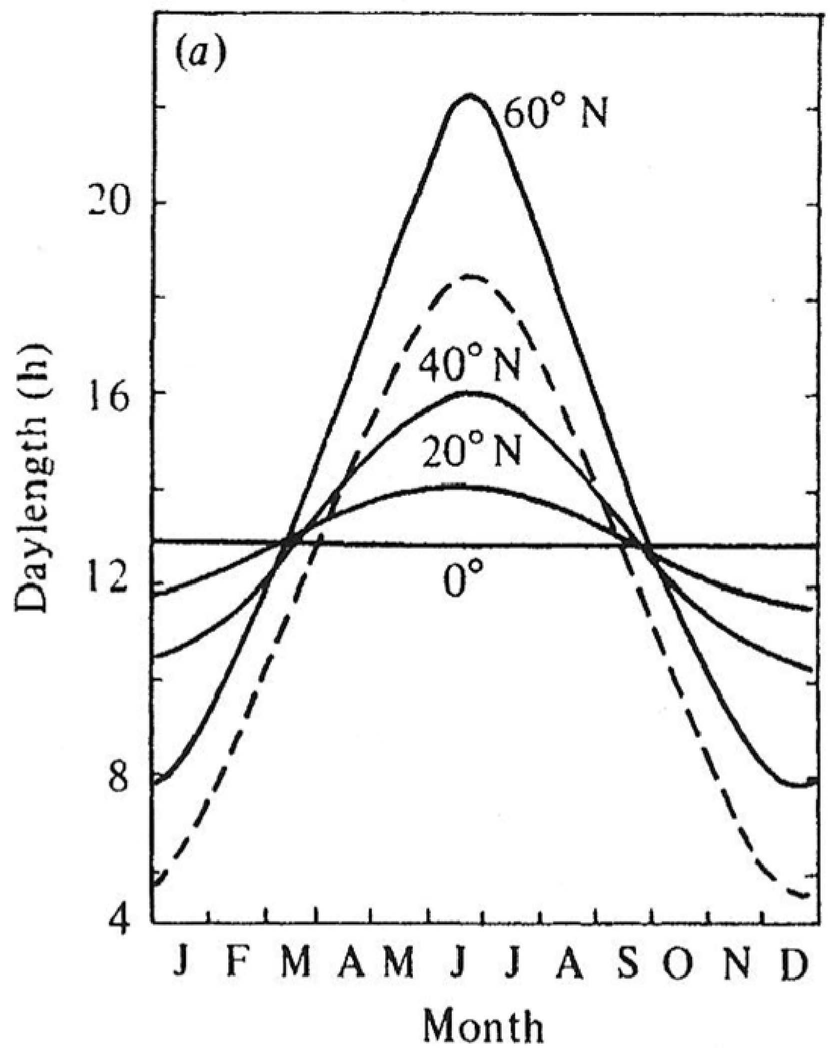
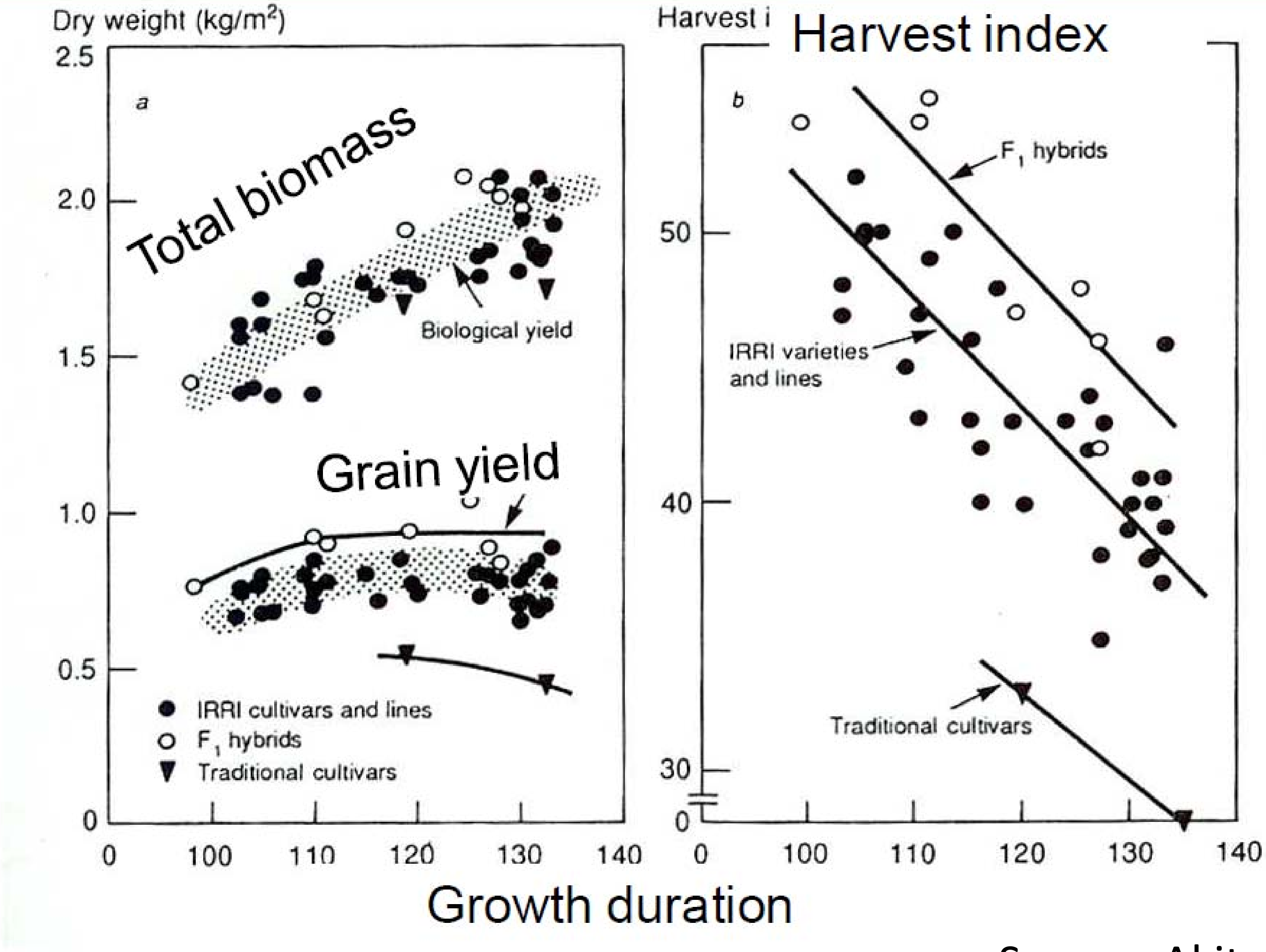
- Shorter growth duration with diminished photoperiod sensitivity:
    - Photoperiodism and heat-sum: biological calendars (Fig. 38).
    - Growth duration: higher HI (Fig. 39) and introduction of dry season crop (Fig. 40) with higher yield due to higher solar irradiance (Fig. 41).

Fig. 38. Daylength at various latitudes.



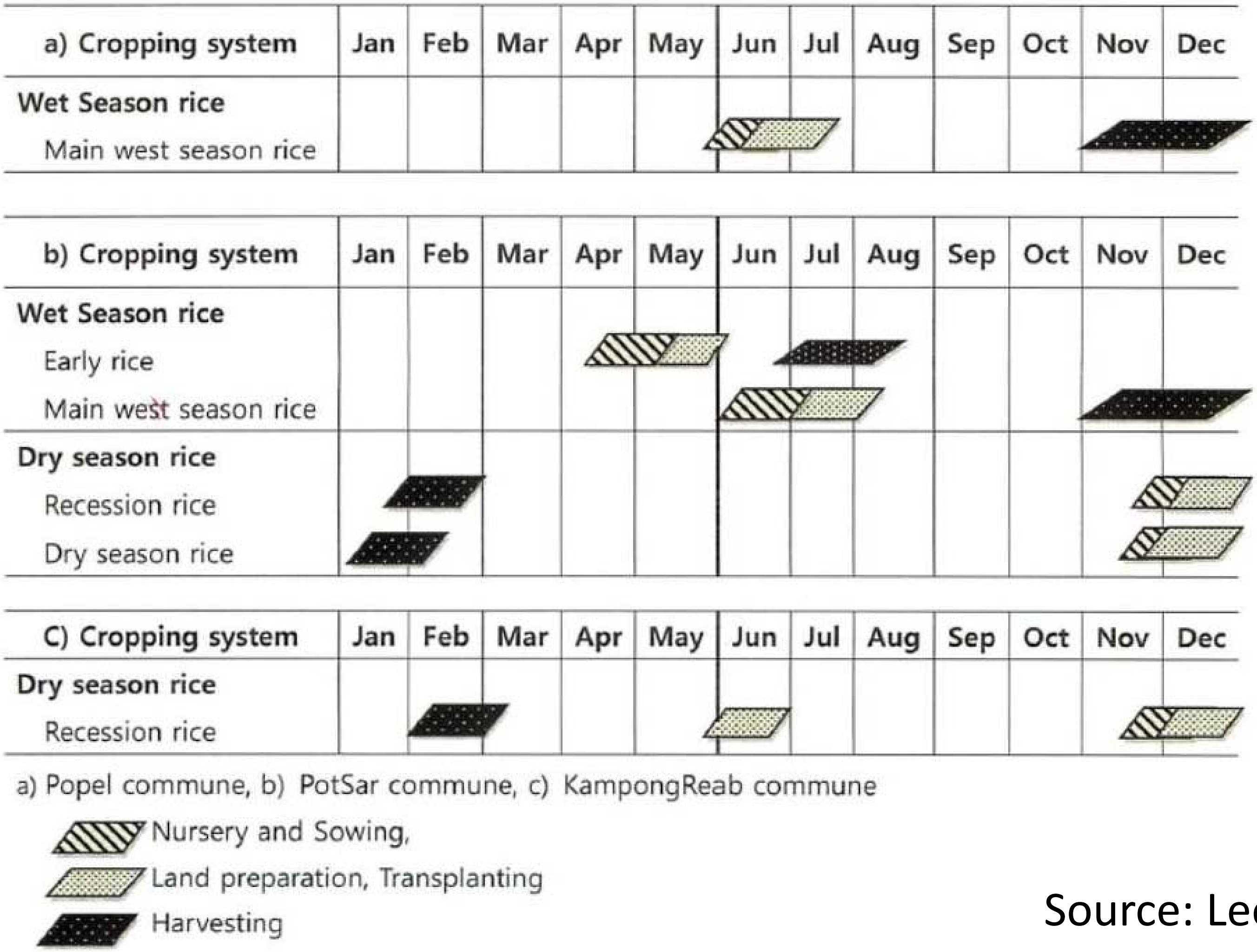
Source: Ref. 4

Fig. 39. Relationships between harvest index and growth duration.



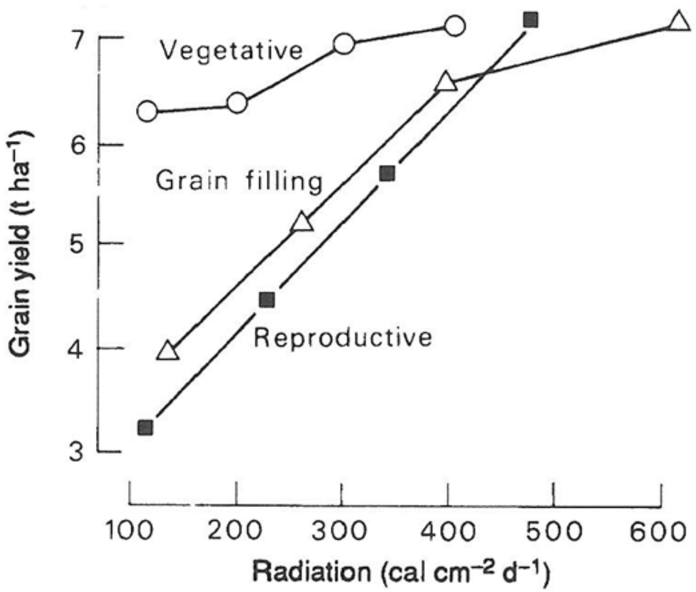
Source: Akita (1989)

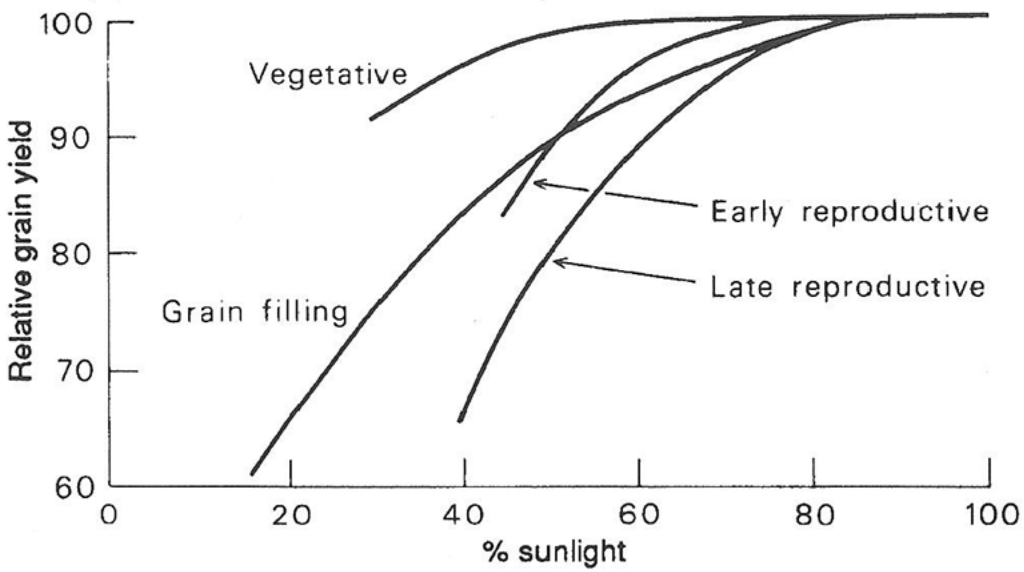
Fig. 40. Rice cropping system in a southern province of Cambodia



Source: Lee, YH

Fig. 41. Effect of solar irradiance on yield of rice (L) and wheat (R).





Source: Ref. 1

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- Why has the higher yield of modern varieties made sense?
    - Market-oriented crop production (read the story of IR8 or Honda-rice in Ref. 3).
    - Modern control of water, nutrients, and competing species.