AGRY 515 2008

- Ca
- Mg
- Fe
- Etc

Fig. 1. Ca is not uniformly distributed in / between cells. (Fig. 8.25 in Marschner, 1995)

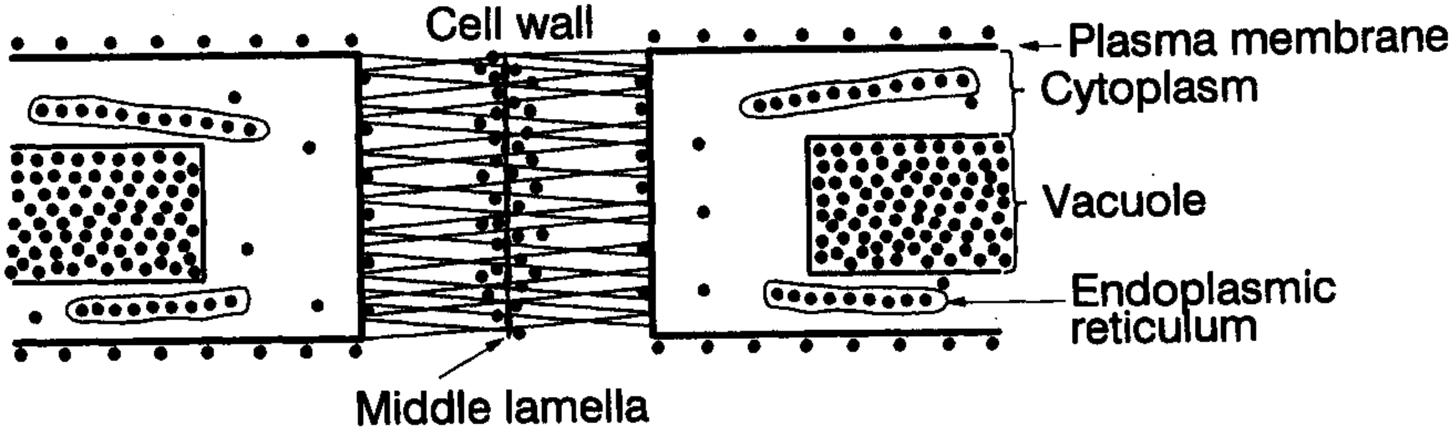


Fig. 8.25 Schematic representation of two adjacent cells with a typical distribution of calcium (●).

Fig. 2. Ca as a micronutrient and 2nd messenger. (Fig. 8.29 in Marschner, 1995.)

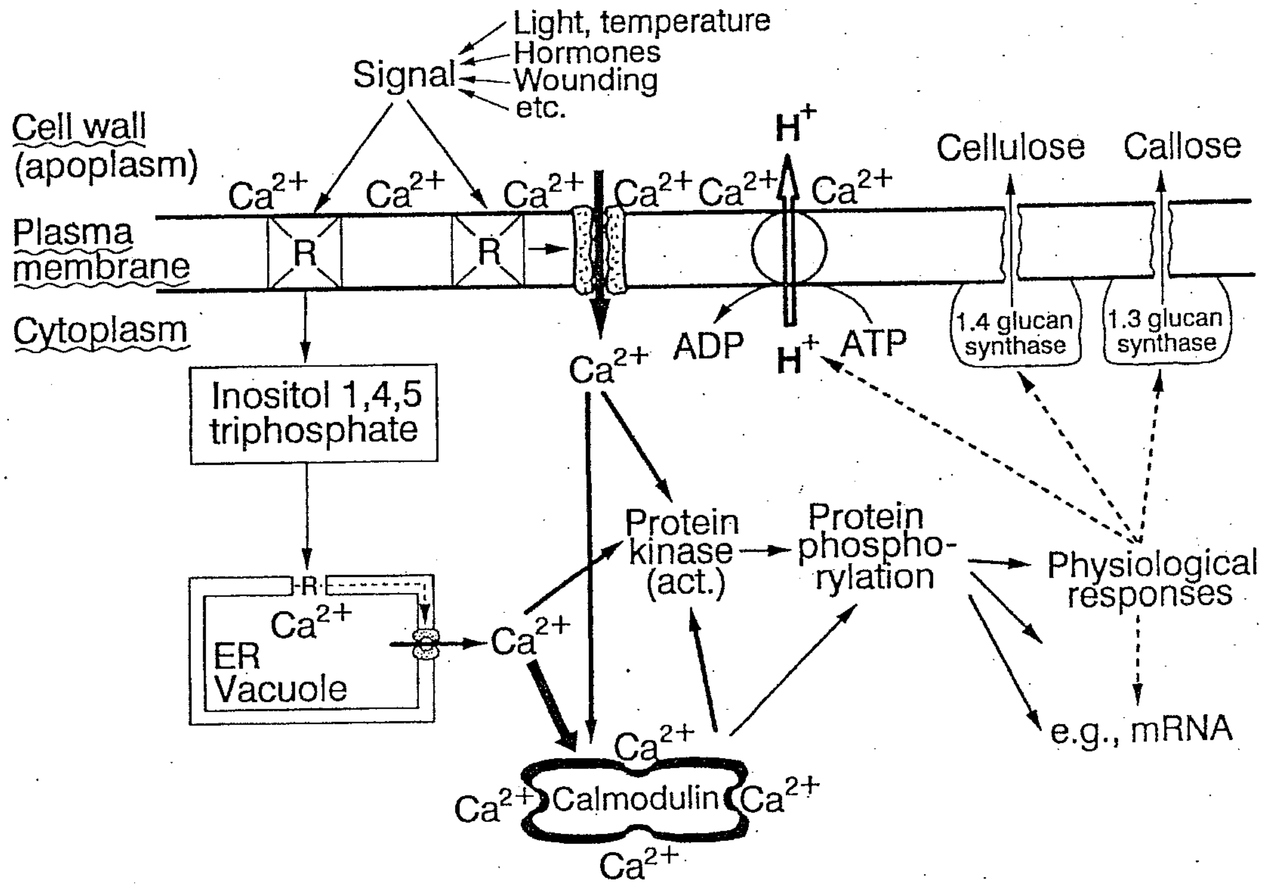


Fig. 3. Schematic of role of Ca in calmodulin (Hort. Science (1985) 20:347-352).

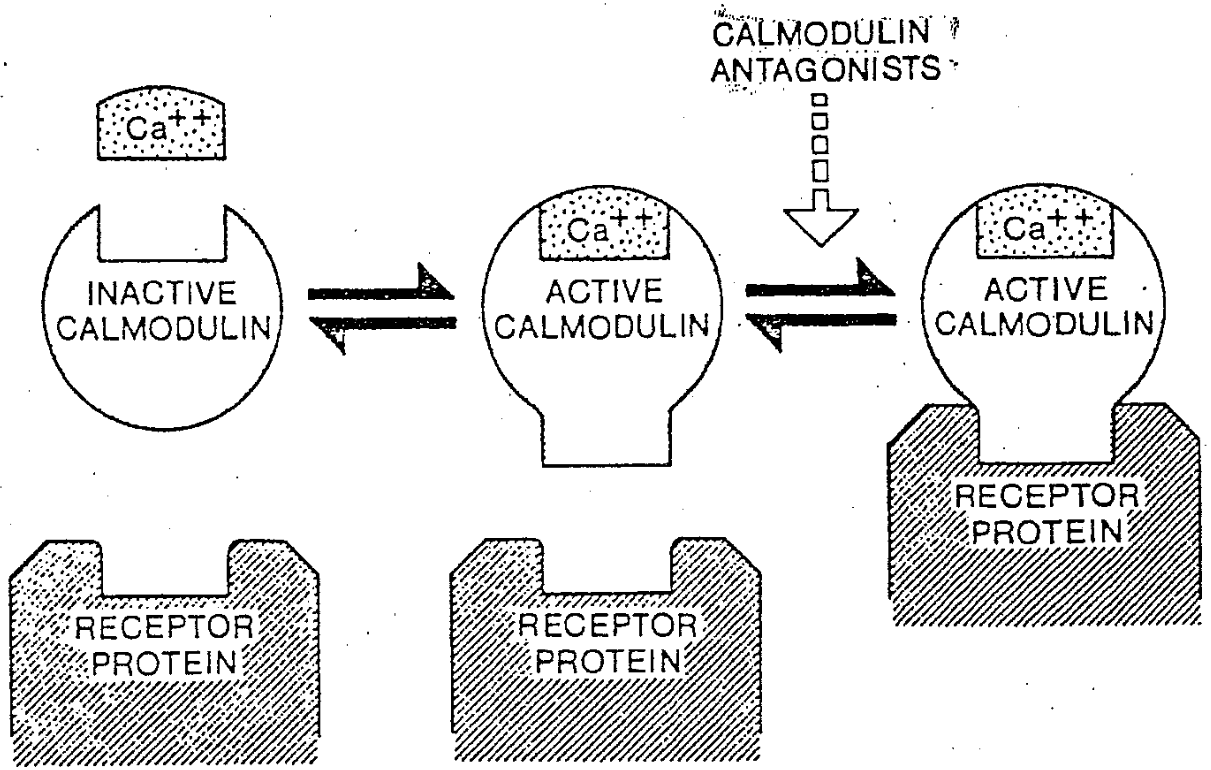
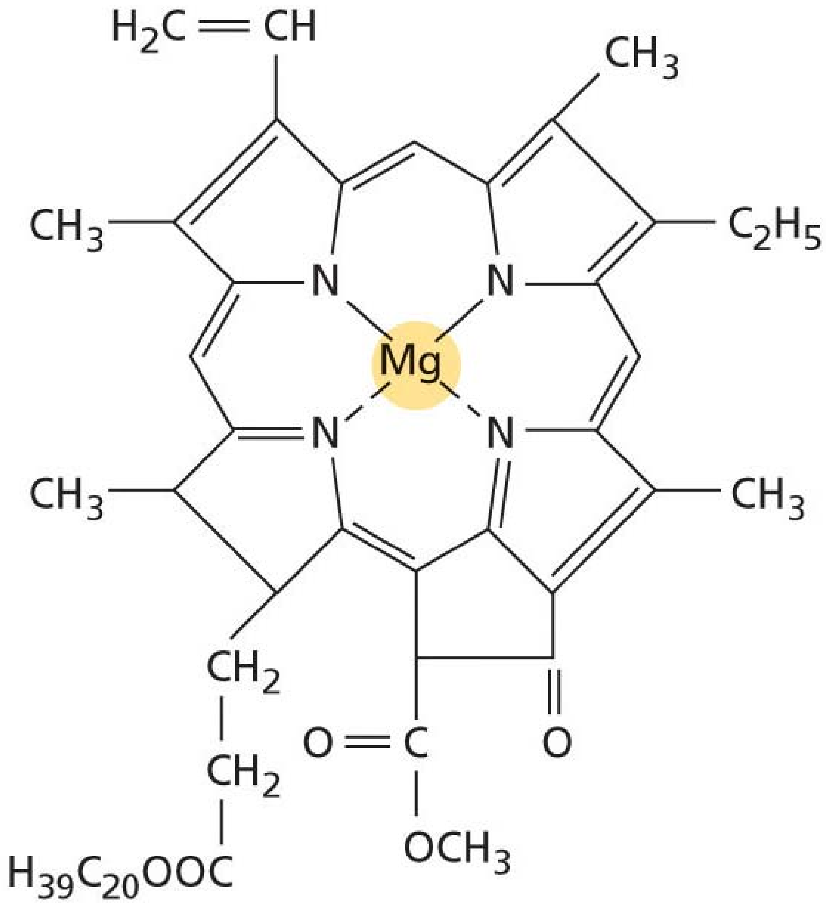


Fig. 1. Diagram illustrating the mechanism by which camlodulin mediates the biological action of Ca ions in plants. The first step involves the bindng of 4 Ca ions with the calmodulin molecule, thereby activating it. The activated calmodulin binds to the receptor protein (enzyme) and this leads to the active calmodulin-Ca-enzyme complex and the response is induced. If calmodulin antagonists are present (top arrow). the antagonists bind to the Ca-calmodulin complex, thus blocking the calmodulin response.

Fig 4. Mg is the central atom of chlorophyll molecule.

(B)



Chlorophyll *a*

PLANT PHYSIOLOGY, Third Edition, Figure 12.15 (Part 1)

Table 1. Chlorophyll content and Mg deficiency on fully expanded oat leaves. (Michael, 1941)

Mg Supply	Chlorophyll	Mg Content	Total Mg in Chlorophyll
	mg/g dry weight	mg/g dry weight	%
Plus Mg	10.4	5.1	10
Minus Mg	4.5	1.0	24

Fig. 5. Mg-dependent reactions can be categorized by general type such as transfer of phosphate (Marschner, 1995, p.280)

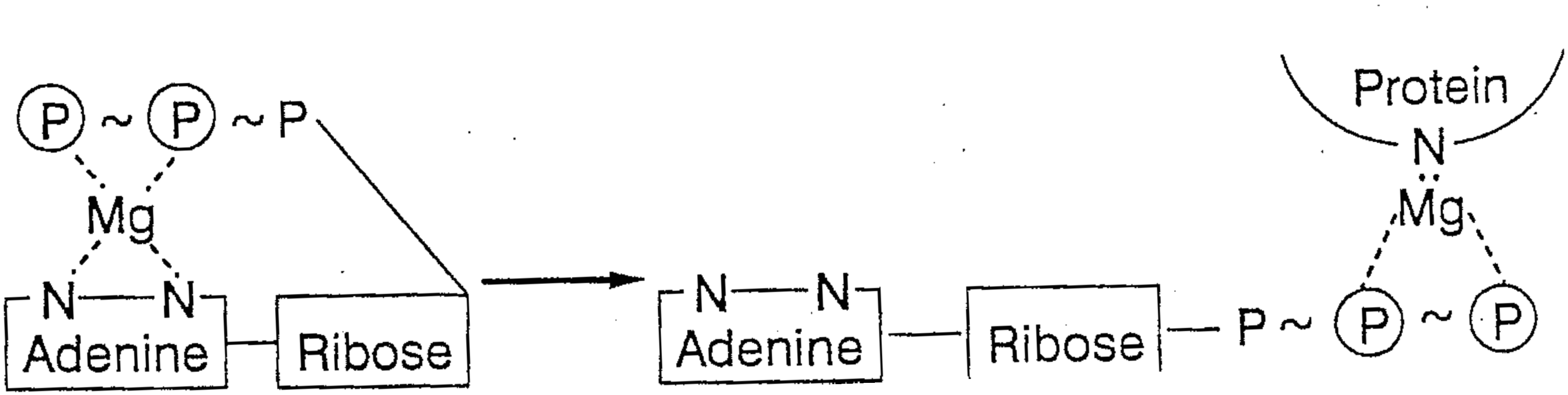
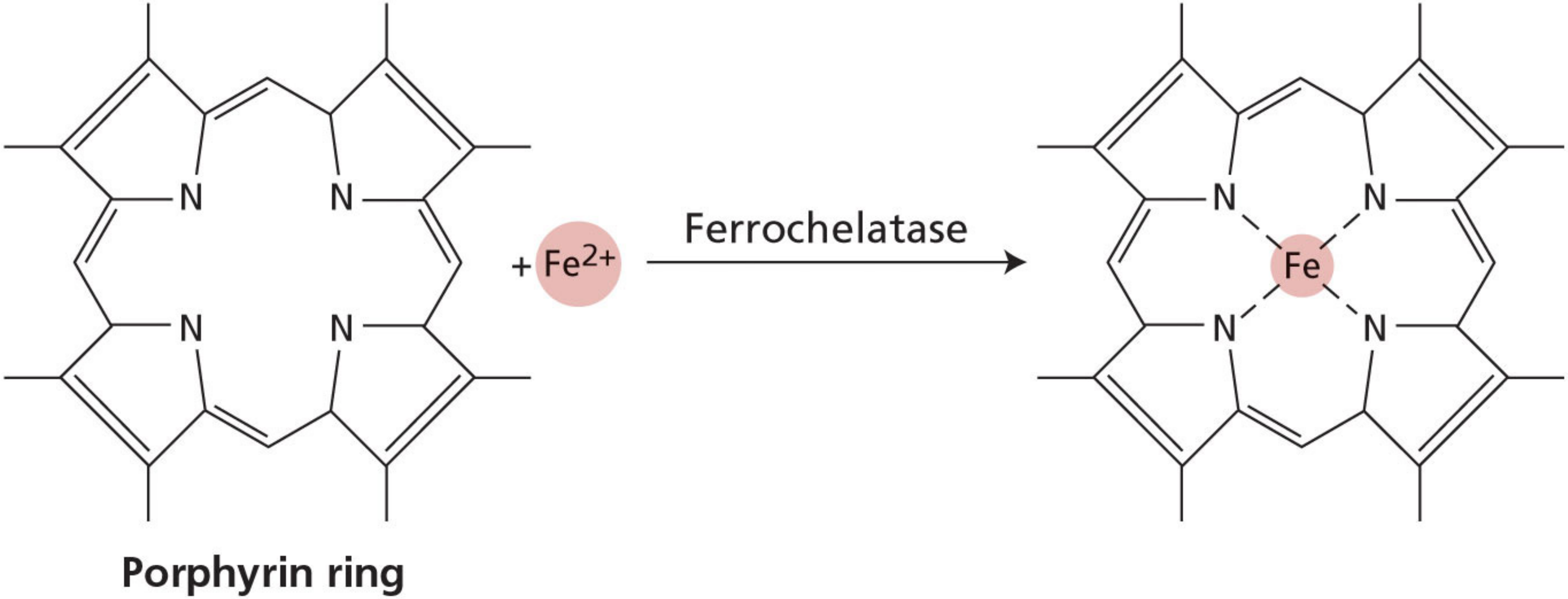
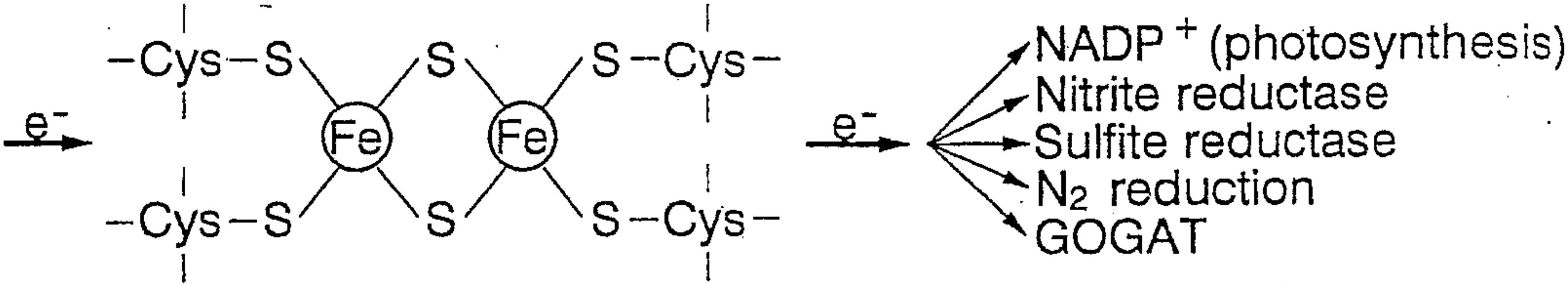


Fig. 6. Fe: Integral components of redox systems. E.g. Fe-N or heme proteins



PLANT PHYSIOLOGY, Third Edition, Figure 12.17 © 2002 Sinauer Associates, Inc.

Fig. 7. Fe: Integral components of redox systems. E.g. Fe-S proteins such as ferrodoxin



Marschner, 1995, p. 316.

Fig. 8. Fe essential in chlorophyll molecule synthesis (Fig. 9.1, Marschner, 1995).

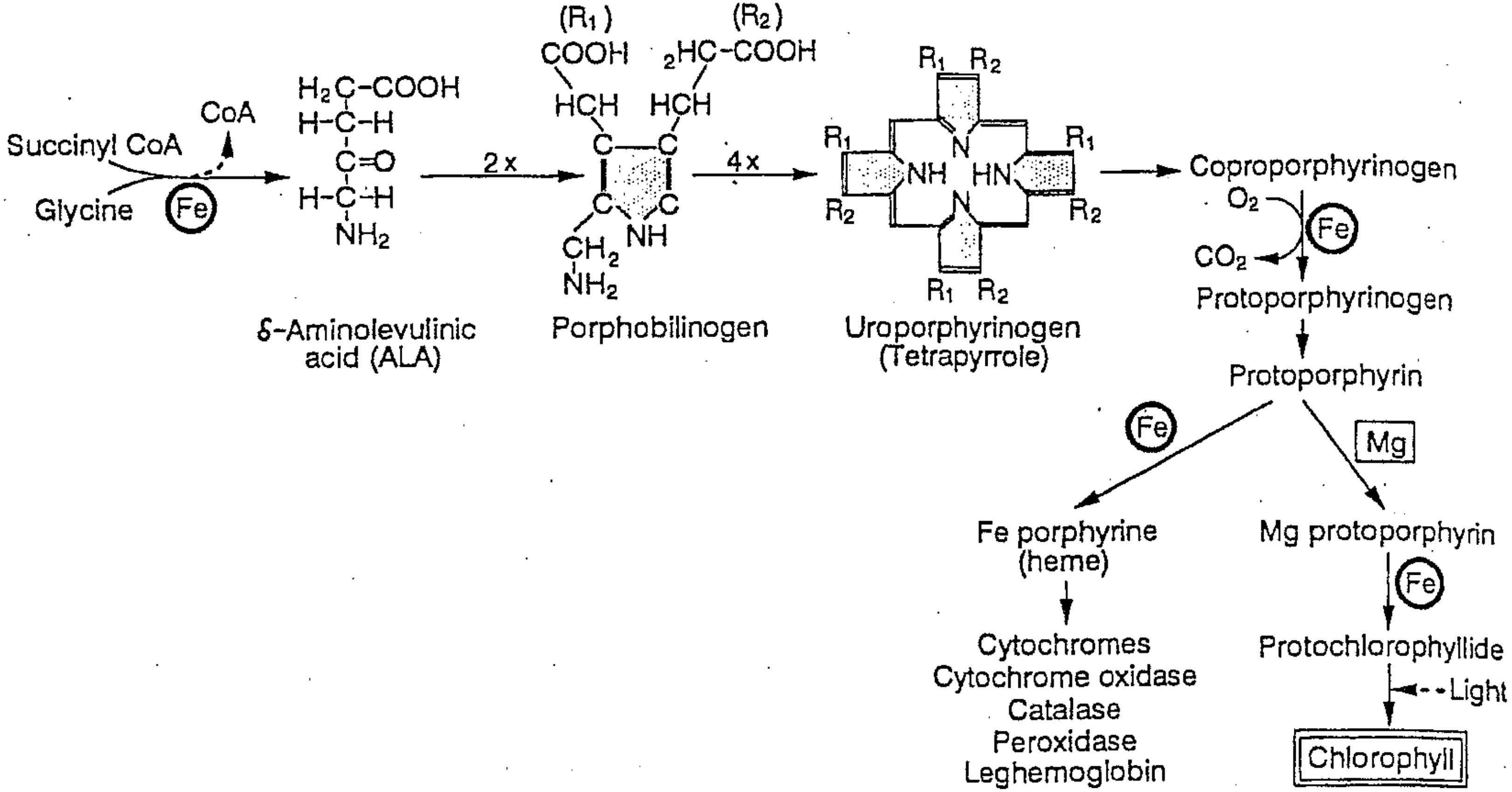
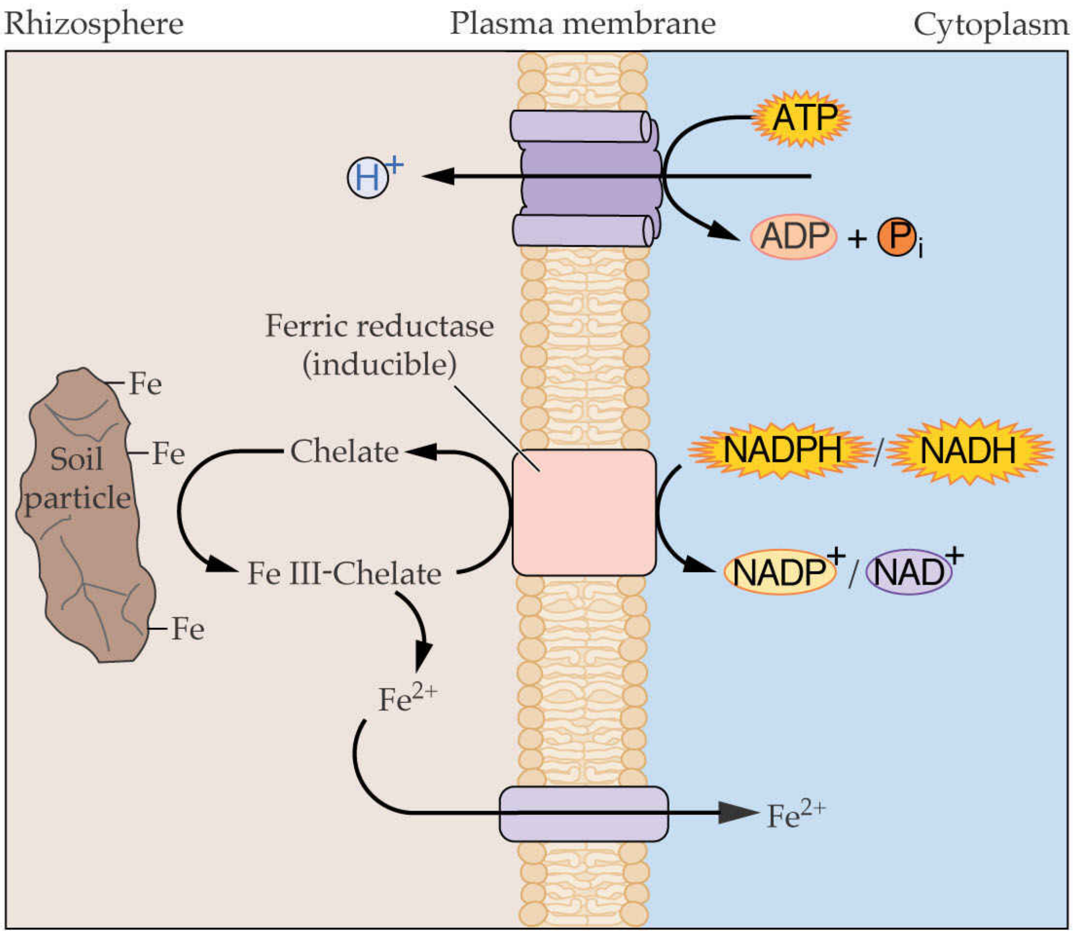


Fig. 9.1 Role of iron in the biosynthesis of heme coenzymes and chlorophyll.

Fig. 9. Fe deficiency and Strategy 1. (ASPB Fig. 23.23, similar to Fig. 2.27, Marschner, 1995.)

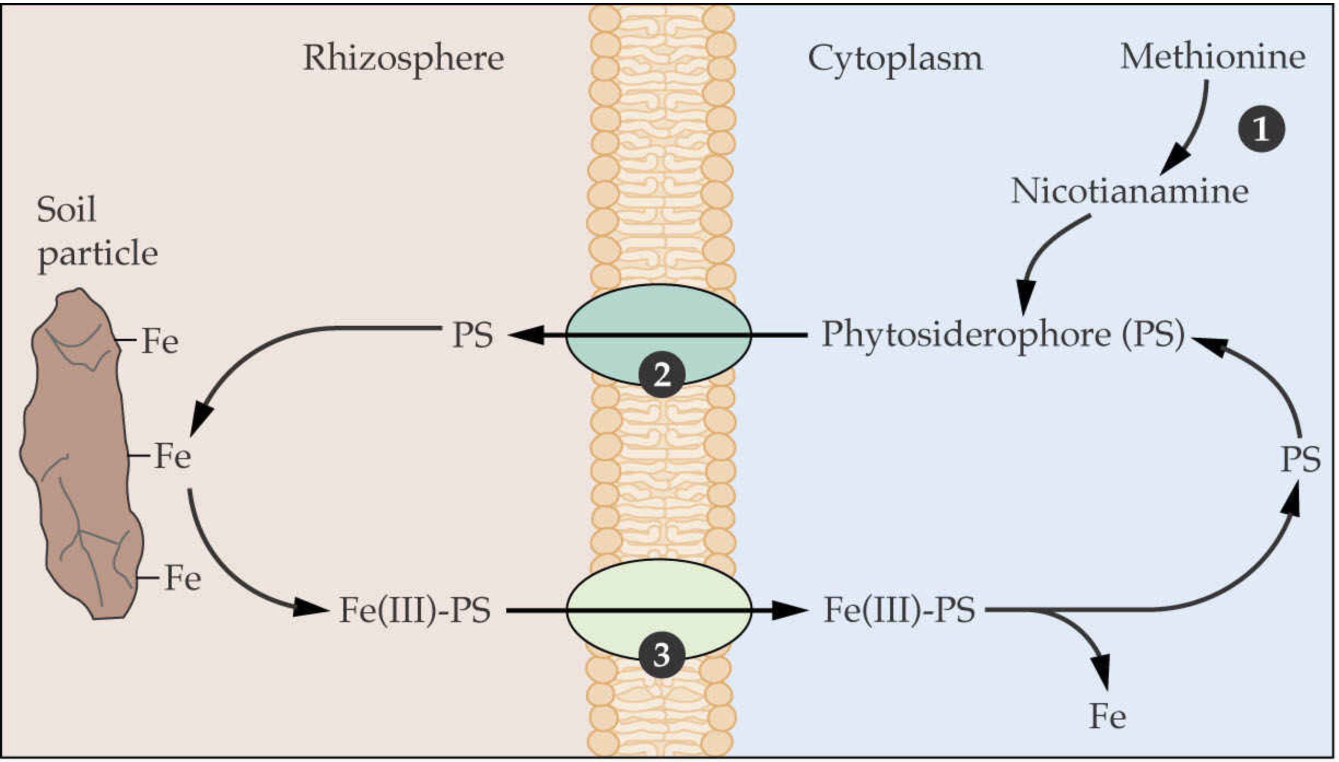


Step 1: Stimulated H+ Efflux pump

Step 2: Increased release of reductants / chelators

Step 3: Fe(II) crosses membrane via transporter or channel

Fig. 10. Fe deficiency and Strategy 2. (ASPB, similar to Fig. 23.30, Marschner, 1995.)



Step 1: Enhanced synthesis of PS (e.g. mugineic acid)

Step 2: Enhanced release of PS

Step 3: Translocation / translocator of Fe(III)PS across membrane.

Note: PS transport system may also apply to: Zn(II), Cu(II), and Mn(II)

Fig. 11. Mn in PSII and MnSOD (Fig. 5.1, Marschner, 1995).

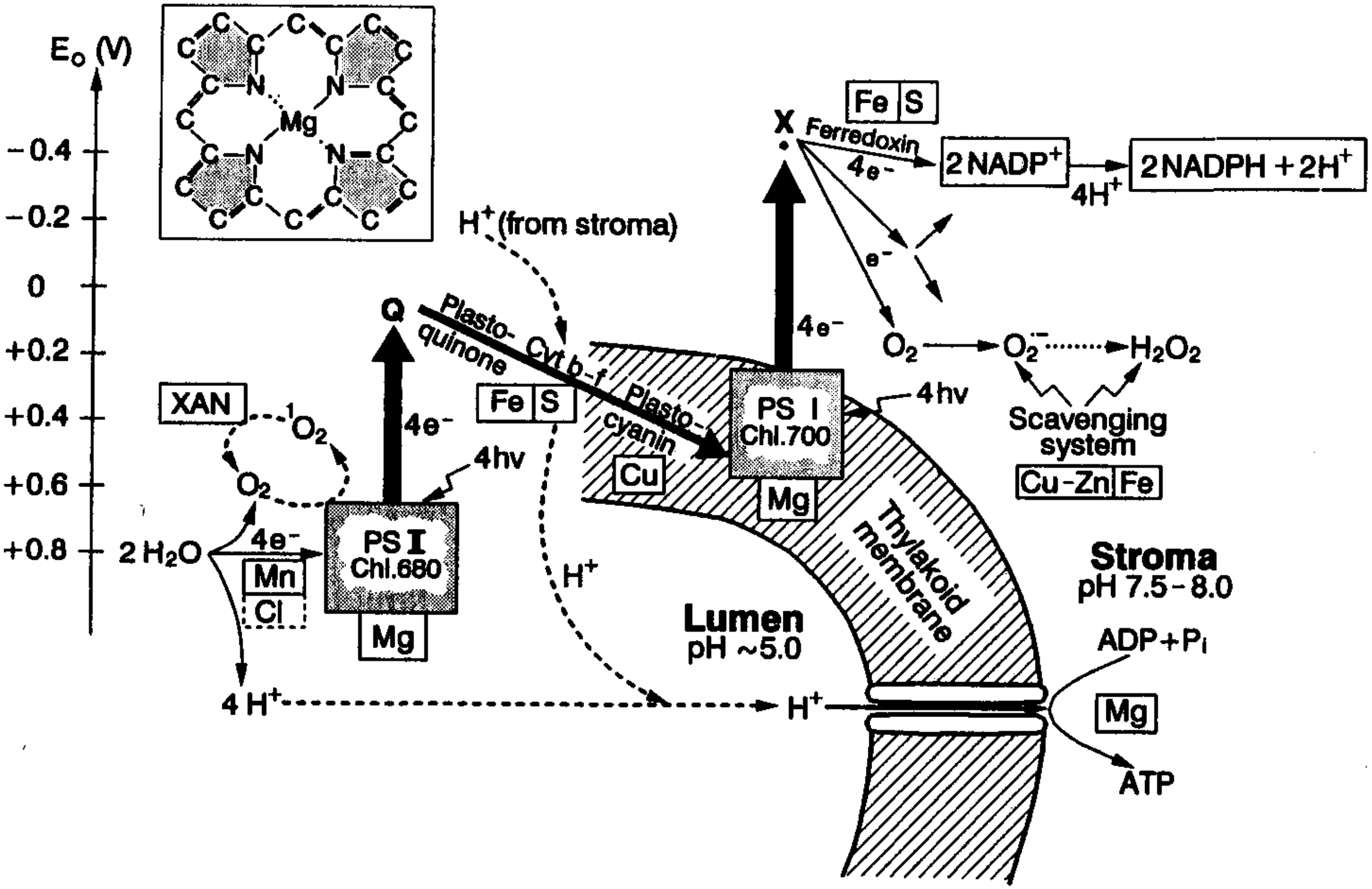


Fig. 5.1 Photosynthetic electron transport chain with photosystems II and I (PS II; PS I) and photophosphorylation. Q, Quencher; X, unknown compound; Cyt, cytochrome; XAN, xanthophyll cycle. (*Inset*) Section of the porphyrin structure of chlorophyll with the central atom magnesium.

Fig. 12. MnSOD (also Fe, CuZnSODs) necessary in aerobic organisms

$$O_2 + e^- \longrightarrow O_2^{\overline{\cdot}} \quad \text{(Superoxide)}$$

$$O_2^{\overline{\cdot}} + O_2^{\overline{\cdot}} + 2H^+ \xrightarrow[\text{dismutase (SOD)}]{\text{Superoxide-}} H_2O_2 \quad \text{(Hydrogen peroxide)} + O_2$$

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

Marschner, 1995, p. 325.

Marschner, 1995, p. 316.

Fig. 13. Protein synthesis depends on Zn (Fig. 9.17, Marschner, 1995).

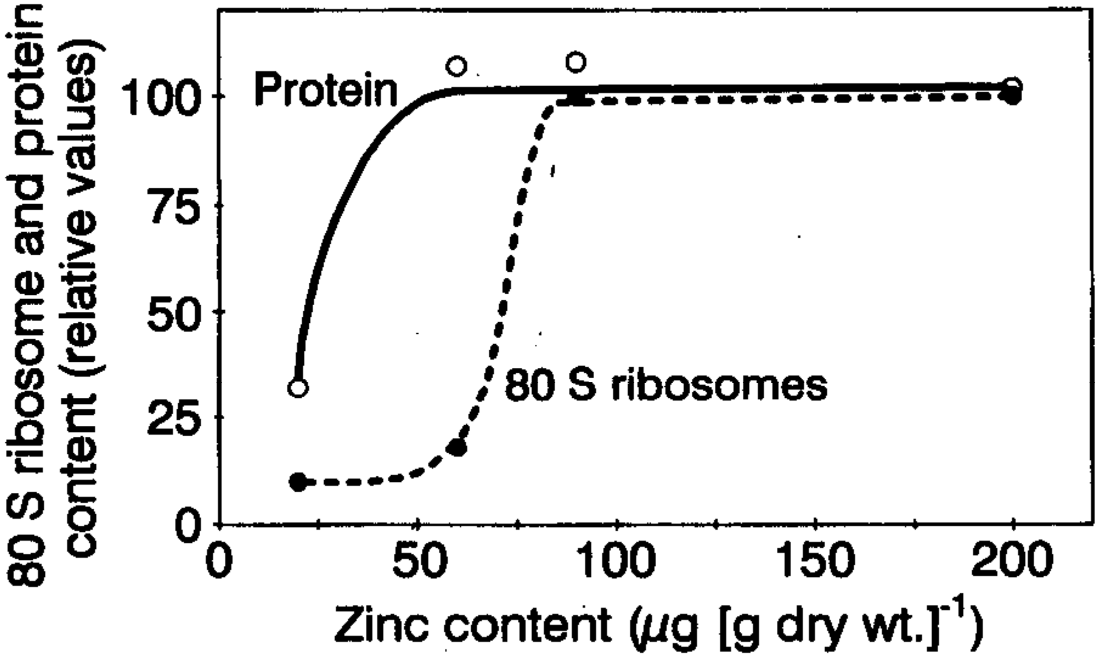


Fig. 9.17 Relationship between content of zinc, 80S ribosomes and protein in the soluble fraction of rice shoot meristematic tissue. (From Kitagishi *et al*., 1987.)

Table 2. Cu has a number of critical roles in photosynthesis (Table 9.9, Marschner, 1995).

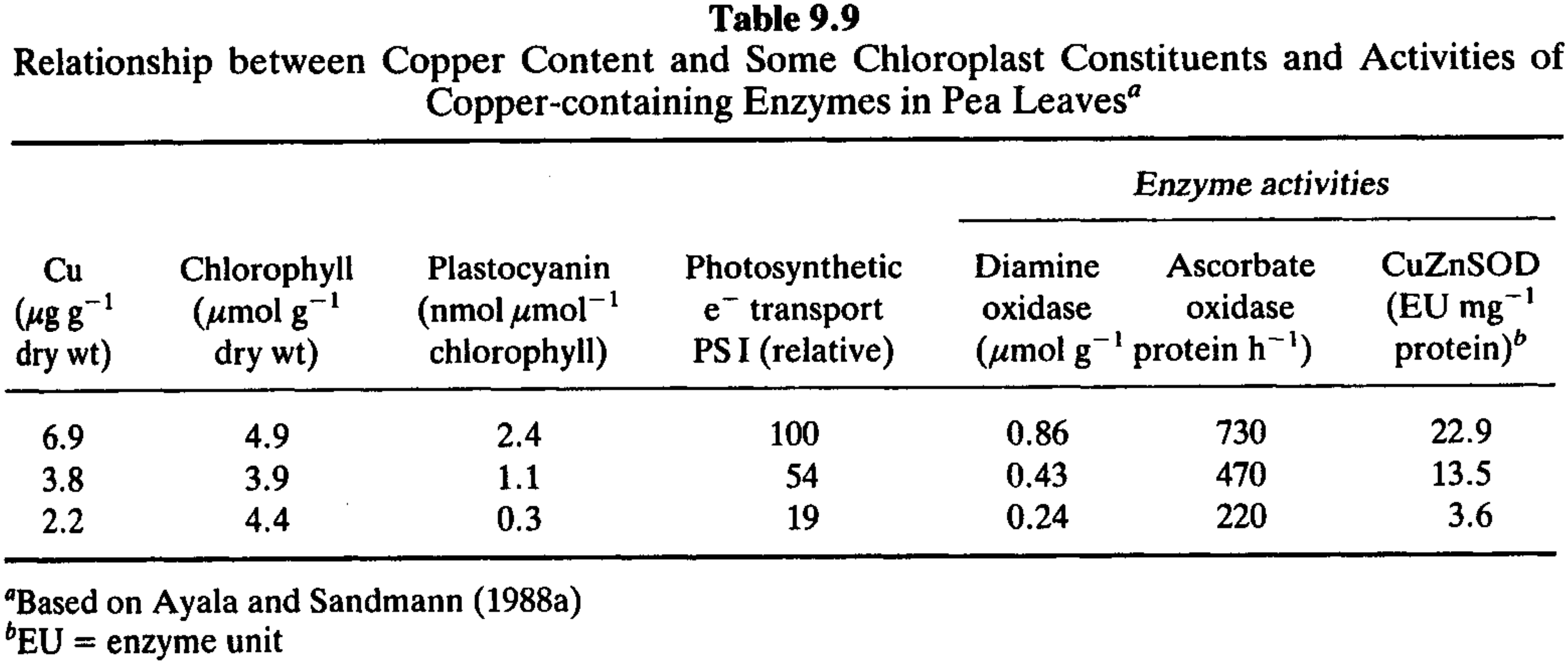


Table 9.9
Relationship between Copper Content and Some Chloroplast Constituents and Activities of Copper-containing Enzymes in Pea Leaves[a]

				Enzyme activities		
Cu (μg g^{-1} dry wt)	Chlorophyll (μmol g^{-1} dry wt)	Plastocyanin (nmol μmol^{-1} chlorophyll)	Photosynthetic e$^-$ transport PS I (relative)	Diamine oxidase (μmol g^{-1} protein h^{-1})	Ascorbate oxidase (μmol g^{-1} protein h^{-1})	CuZnSOD (EU mg^{-1} protein)[b]
6.9	4.9	2.4	100	0.86	730	22.9
3.8	3.9	1.1	54	0.43	470	13.5
2.2	4.4	0.3	19	0.24	220	3.6

[a] Based on Ayala and Sandmann (1988a)
[b] EU = enzyme unit

Table 3. Mo is critical to N metabolism and Mo requirement depends on the plant and on the source of N (Table 9.33, Marschner, 1995).

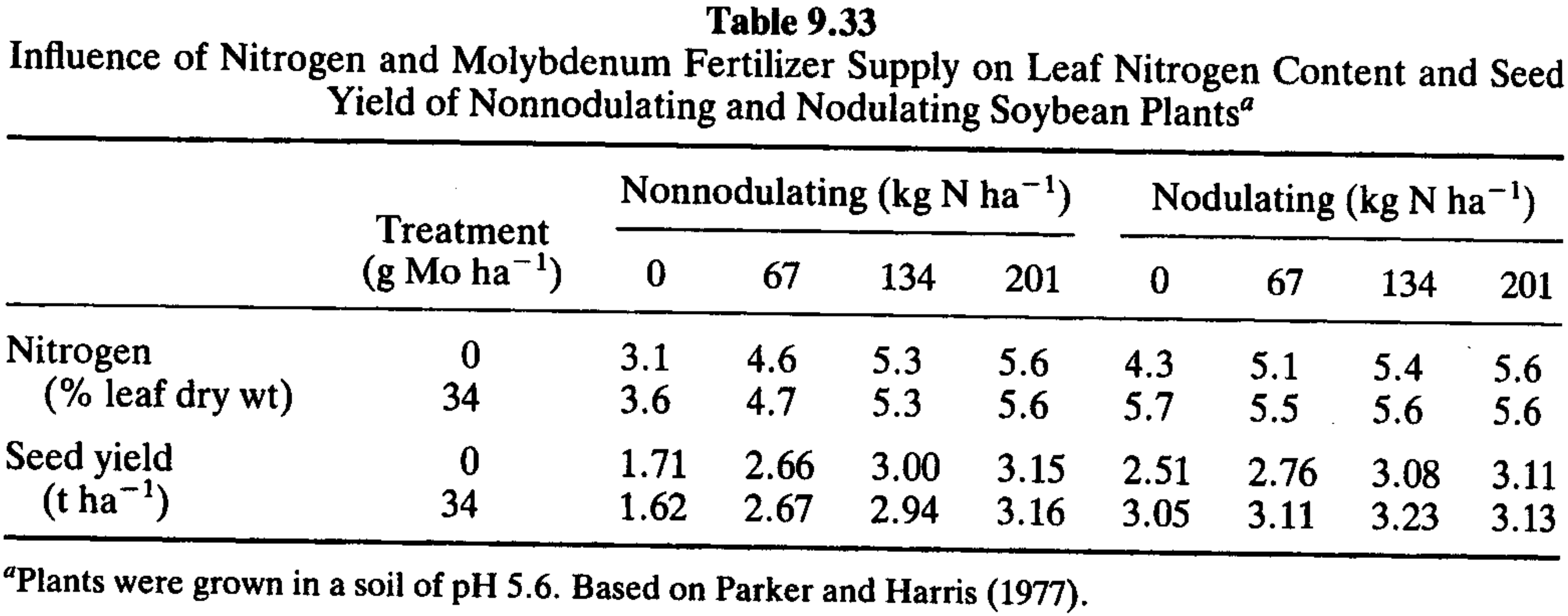


Table 9.33

Influence of Nitrogen and Molybdenum Fertilizer Supply on Leaf Nitrogen Content and Seed Yield of Nonnodulating and Nodulating Soybean Plants[a]

	Treatment ($g\ Mo\ ha^{-1}$)	Nonnodulating ($kg\ N\ ha^{-1}$)				Nodulating ($kg\ N\ ha^{-1}$)			
		0	67	134	201	0	67	134	201
Nitrogen (% leaf dry wt)	0	3.1	4.6	5.3	5.6	4.3	5.1	5.4	5.6
	34	3.6	4.7	5.3	5.6	5.7	5.5	5.6	5.6
Seed yield ($t\ ha^{-1}$)	0	1.71	2.66	3.00	3.15	2.51	2.76	3.08	3.11
	34	1.62	2.67	2.94	3.16	3.05	3.11	3.23	3.13

[a] Plants were grown in a soil of pH 5.6. Based on Parker and Harris (1977).

Table 4. When Mo deficiency is severe specific symptoms develop (Table 9.35, Marschner, 1995).

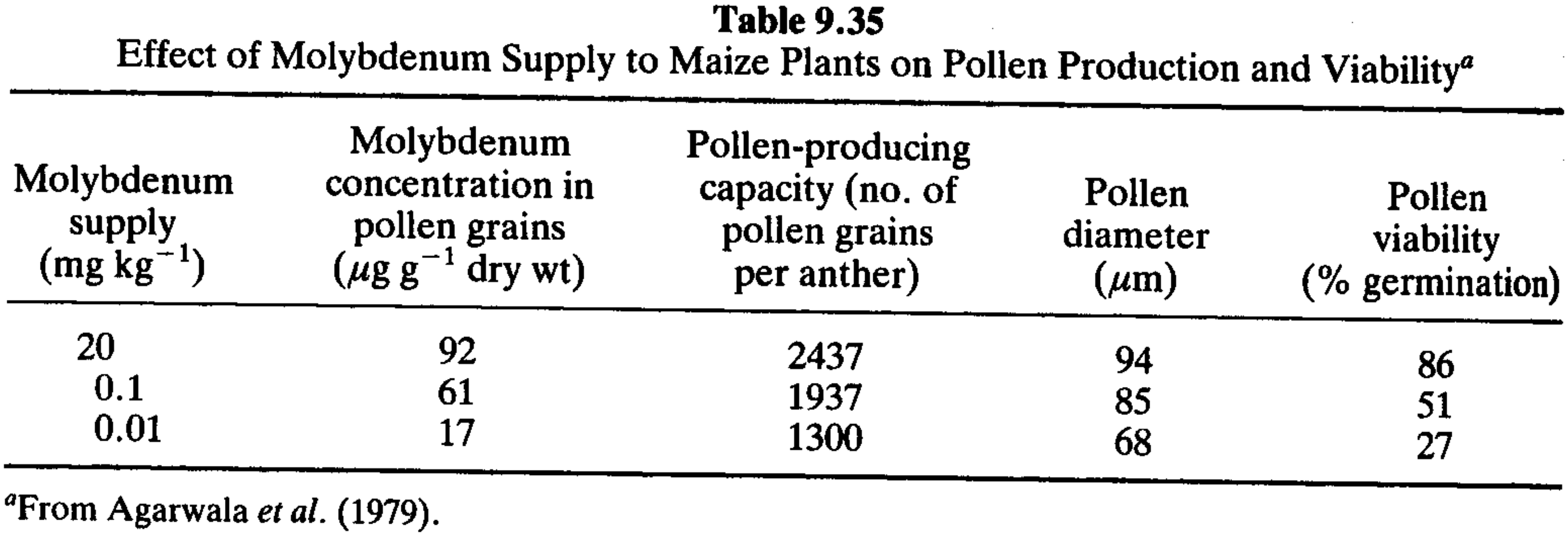


Table 9.35

Effect of Molybdenum Supply to Maize Plants on Pollen Production and Viability[a]

Molybdenum supply (mg kg^{-1})	Molybdenum concentration in pollen grains (μg g^{-1} dry wt)	Pollen-producing capacity (no. of pollen grains per anther)	Pollen diameter (μm)	Pollen viability (% germination)
20	92	2437	94	86
0.1	61	1937	85	51
0.01	17	1300	68	27

[a] From Agarwala *et al*. (1979).

Fig. 14. B is essential in membrane integrity but can be partially substituted by germaniam (Fig. 9.30, Marschner, 1995).

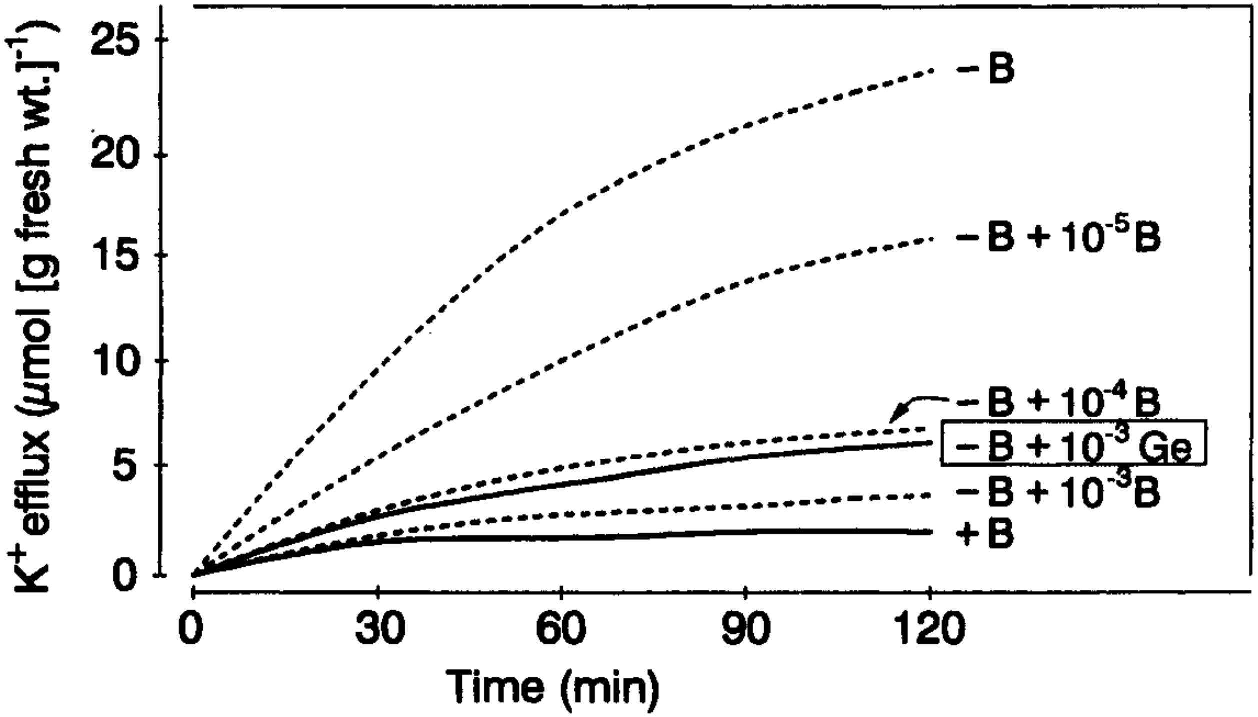


Fig. 9.30 Potassium efflux from intact boron-sufficient (+B) and boron-deficient (−B) expanding sunflower leaves and effect of external supply (10^{-5}–10^{-3} M) of boron or germanium (Ge) at zero time (−B + B; −B + Ge treatment). (Cakmak and Kurz, unpublished.)

Table 5. In higher plants, urease is the only known Ni containing enzyme; -Ni plants experience urea toxicity (Table 9.29, Marschner, 1995)

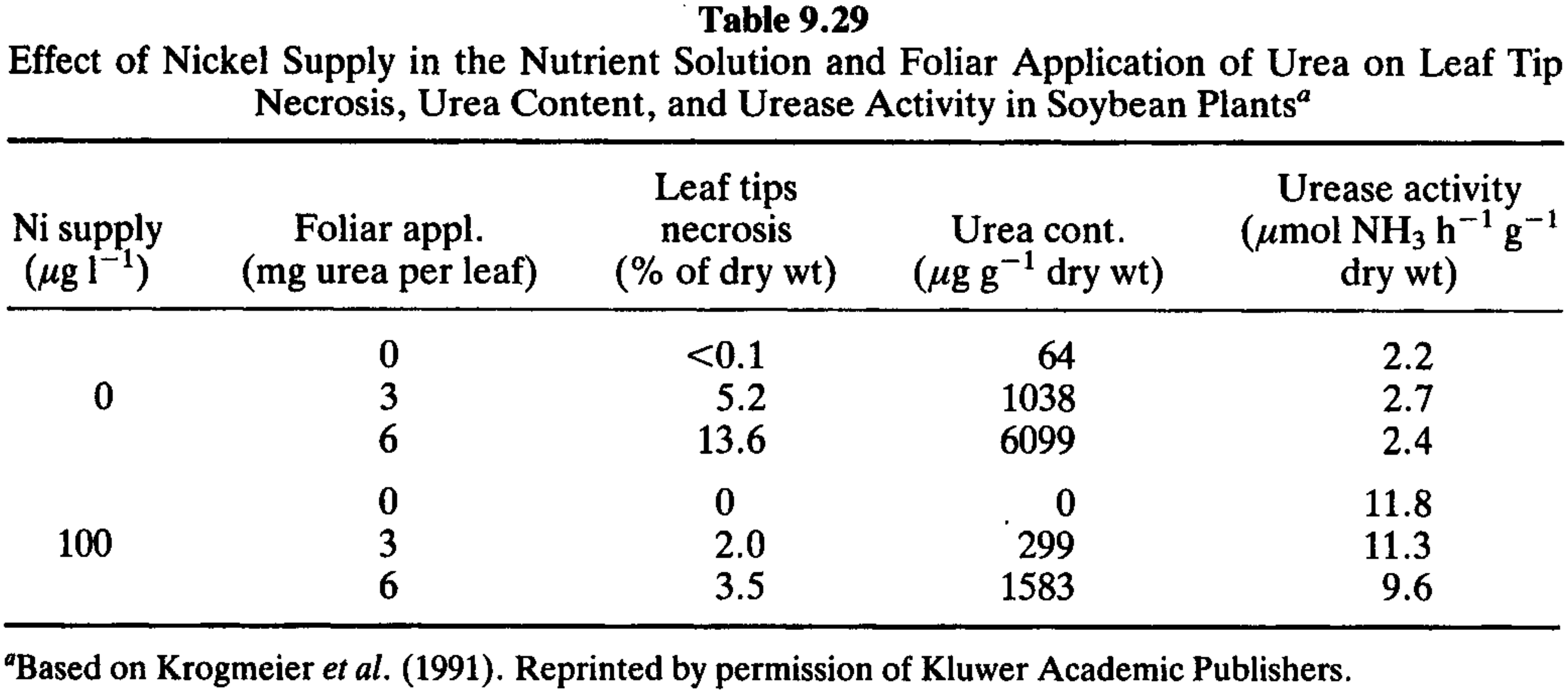


Table 9.29

Effect of Nickel Supply in the Nutrient Solution and Foliar Application of Urea on Leaf Tip Necrosis, Urea Content, and Urease Activity in Soybean Plants[a]

Ni supply (μg l^{-1})	Foliar appl. (mg urea per leaf)	Leaf tips necrosis (% of dry wt)	Urea cont. (μg g^{-1} dry wt)	Urease activity (μmol NH_3 h^{-1} g^{-1} dry wt)
0	0	<0.1	64	2.2
	3	5.2	1038	2.7
	6	13.6	6099	2.4
100	0	0	0	11.8
	3	2.0	299	11.3
	6	3.5	1583	9.6

[a] Based on Krogmeier *et al.* (1991). Reprinted by permission of Kluwer Academic Publishers.

Table 6. Cl stimulates H+ pumping at the tonoplast (Table 9.45, Marschner, 1995).

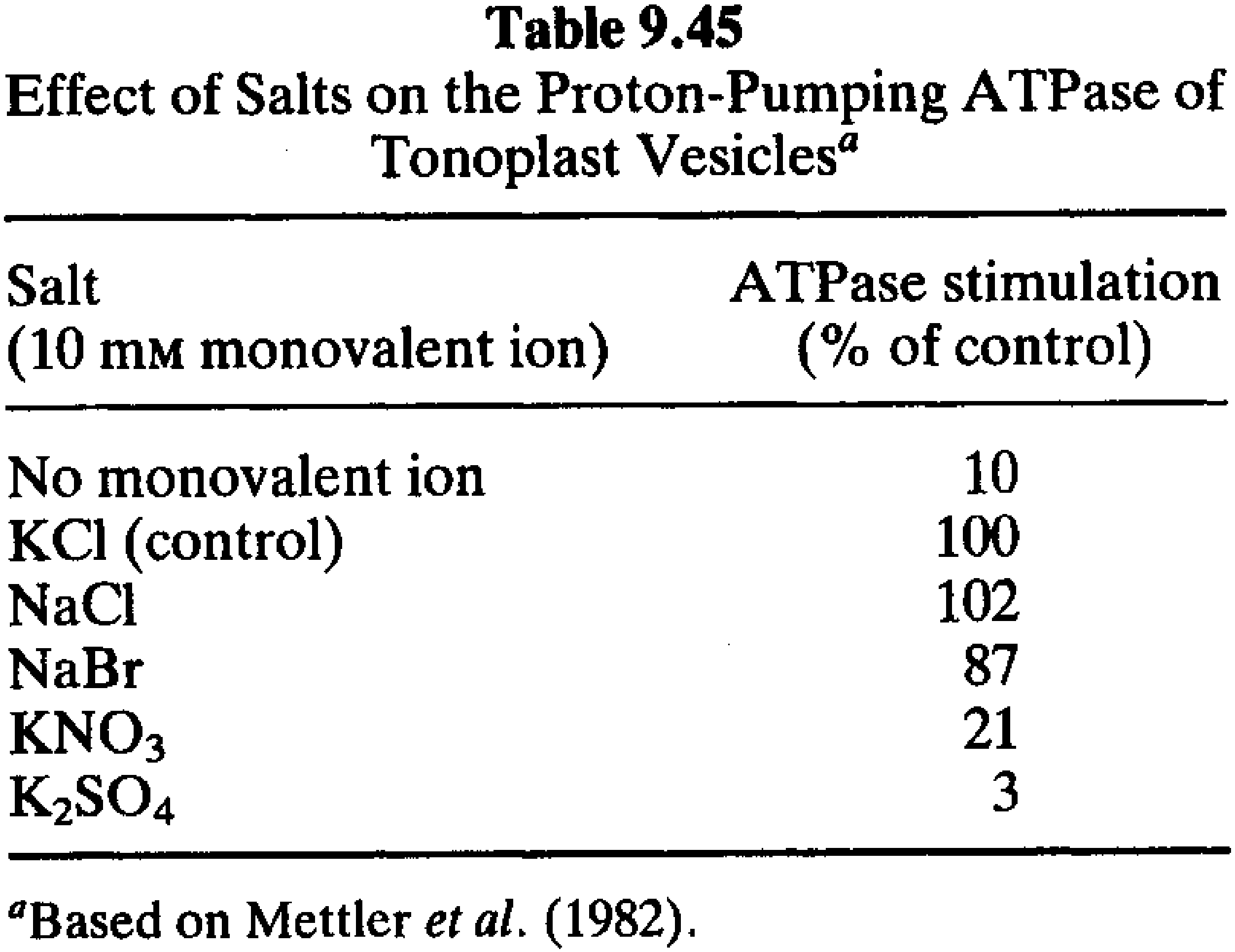


Table 9.45

Effect of Salts on the Proton-Pumping ATPase of Tonoplast Vesicles[a]

Salt (10 mM monovalent ion)	ATPase stimulation (% of control)
No monovalent ion	10
KCl (control)	100
NaCl	102
NaBr	87
KNO_3	21
K_2SO_4	3

[a] Based on Mettler *et al.* (1982).