RESPON TANAMAN TERHADAP CEKAMAN LINGKUNGAN

DEFINISI CEKAMAN

Cekaman adalah segala kondisi perubahan lingkungan (abiotik dan biotik) yang mungkin akan menurunkan atau merugikan pertumbuhan dan perkembangan tanaman.

Penyebab: Terjadinya penurunan kecepatan proses metabolisme di dalam sel tanaman

Produk: Perubahan dimensi (panjang, leebar, luas dan volume) organ dan senyawa kimia yang dihasilkan tanaman

BENTUK PERBUHAN TERHADAP CEKAMAN

- Bersifat Balik (Reversible): Perubahan dapat pulih seperti kondisi tidak ada cekaman (elastis)
- Bersifat Permanen (Irreversible): Perubahan bersifat tetap (plastic)

JENIS CEKAMAN

- Biotik : Cekaman yang disebabkan oleh infeksi atau kompetisi dengan organisme lainnya
- Abiotik (Fisik atau Kimiawi): Cekaman yang disebabkan oleh:

1. Temperatur (Tinggi dan Rendah)
2. Air (Kekeringan dan Tergenang)
3. Cahaya (Sinar UV dan Inonisasi sinar X, sinar γ)
4. Kimiawi (Salinitas, gas, herbisida, pupuk, dll)
5. Angin, Tekanan, Suara, Magnetik, Elektrik, dll

ADAPTASI TANAMAN TERHADAP CEKAMAN

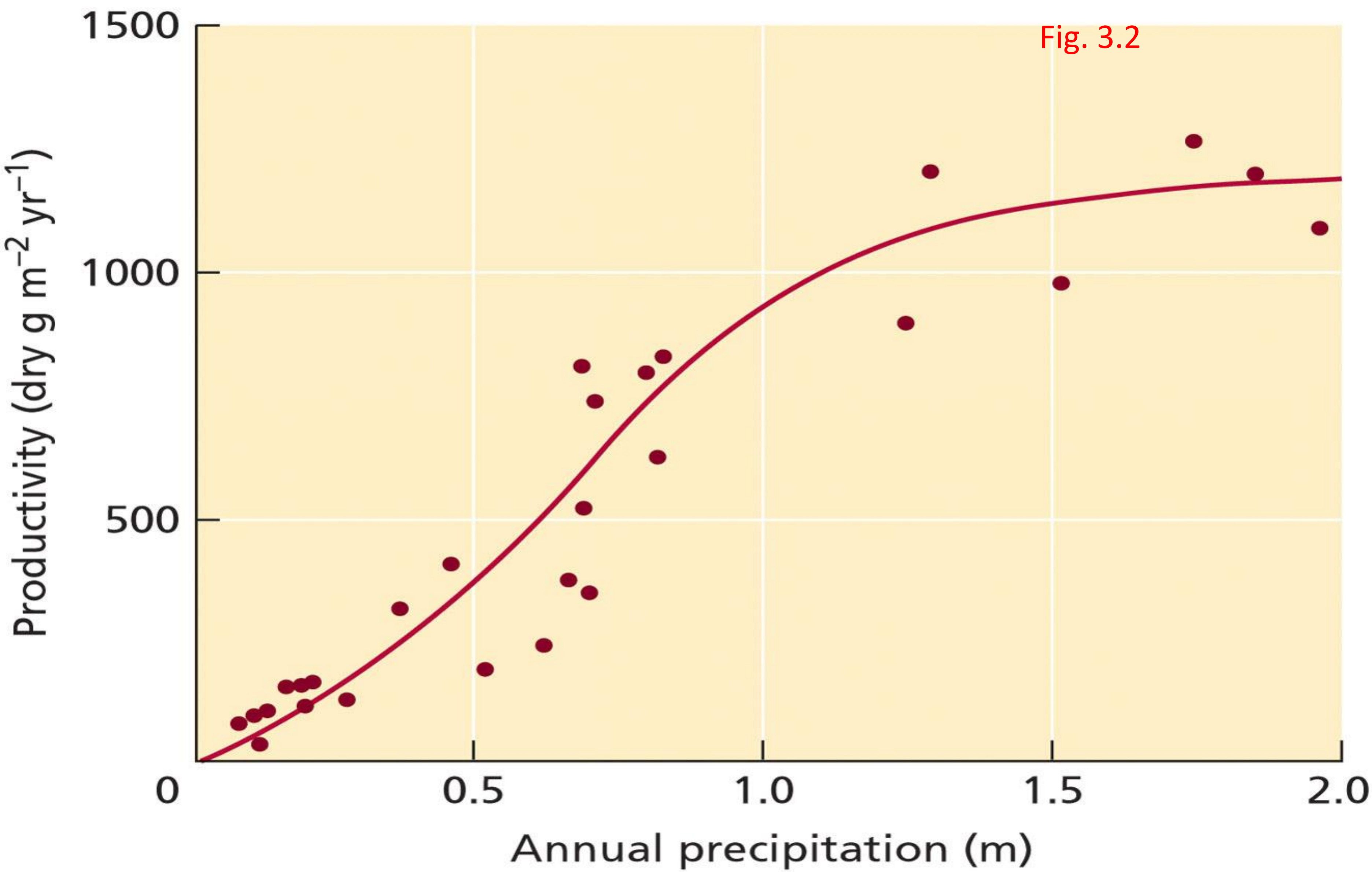
CEKAMAN	KONDISI KETAHANAN CEL TANAMAN TERHADAP CEKAMAN UNTUK KEBERLANGSUNGAN HIDUPNYA	
	AVOIDANCE	TOLERANCE
Temperatur Rendah	Hangat (warm)	Dingin (cold)
Temperatur Tinggi	Sejuk (cool)	Panas (hot)
Kekeringan	Potensial air tinggi	Potensial air rendah
Cahaya	Absorpsi yang rendah	Absorpsi yang tinggi
Salinitas (Konsentrasi tinggi)	Konsentrasi garam rendah	Konsentrasi garam tinggi
Genangan (defisit Oksigen)	Kandungan Oks. tinggi	Kandungan Oks. rendah

CEKAMAN KEKERINGAN PADA TANAMAN

WATER STRESS

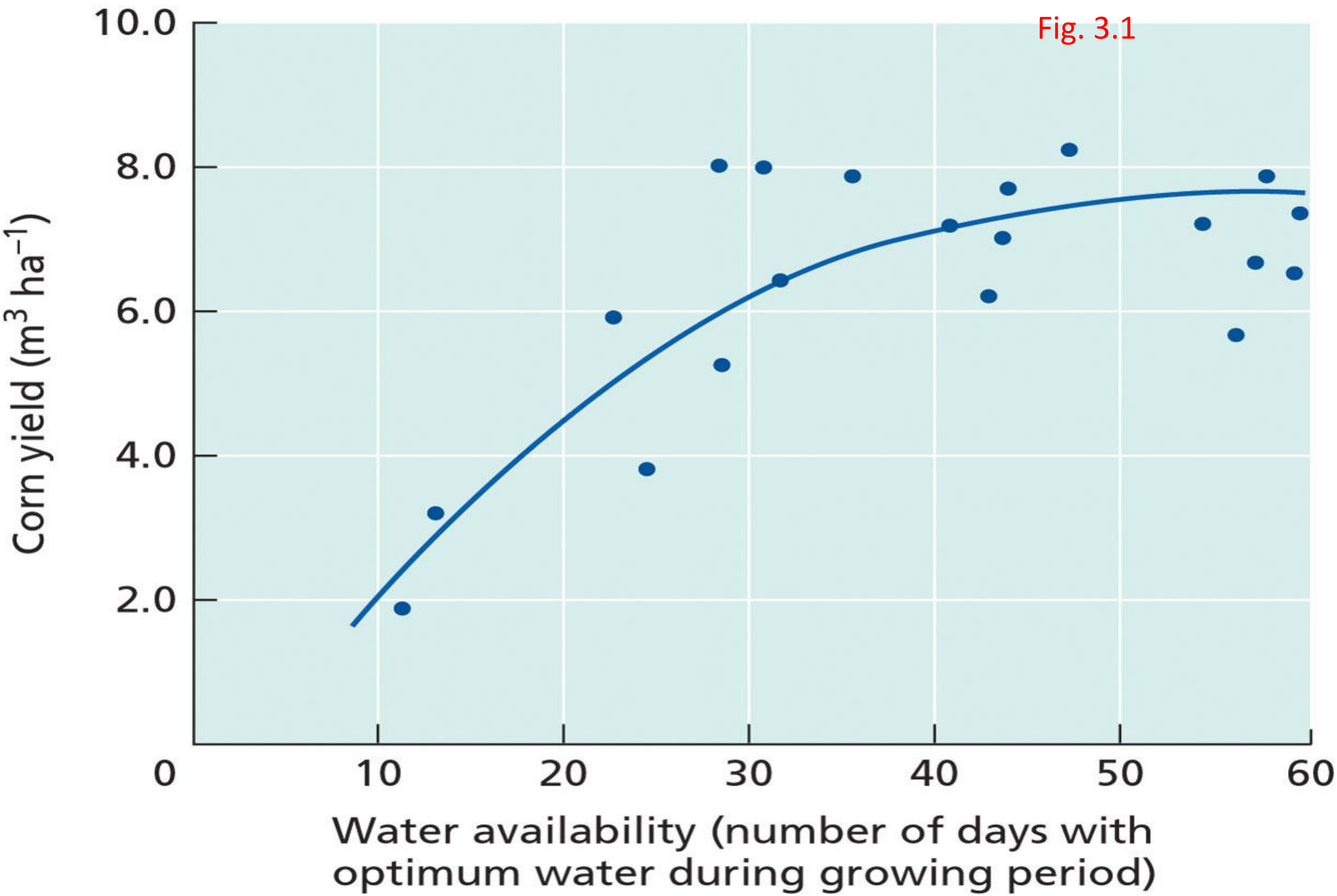
- Water related stresses could affect plants if the environment contains insufficient water to meet basic needs.
- Water logging
- Drought condition

Precipitation and productivity of global ecosystems



PLANT PHYSIOLOGY, Third Edition, Figure 3.2

Water Stress



PLANT PHYSIOLOGY, Third Edition, Figure 3.1 © 2002 Sinauer Associates, Inc.

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The timing of water stress is very important.

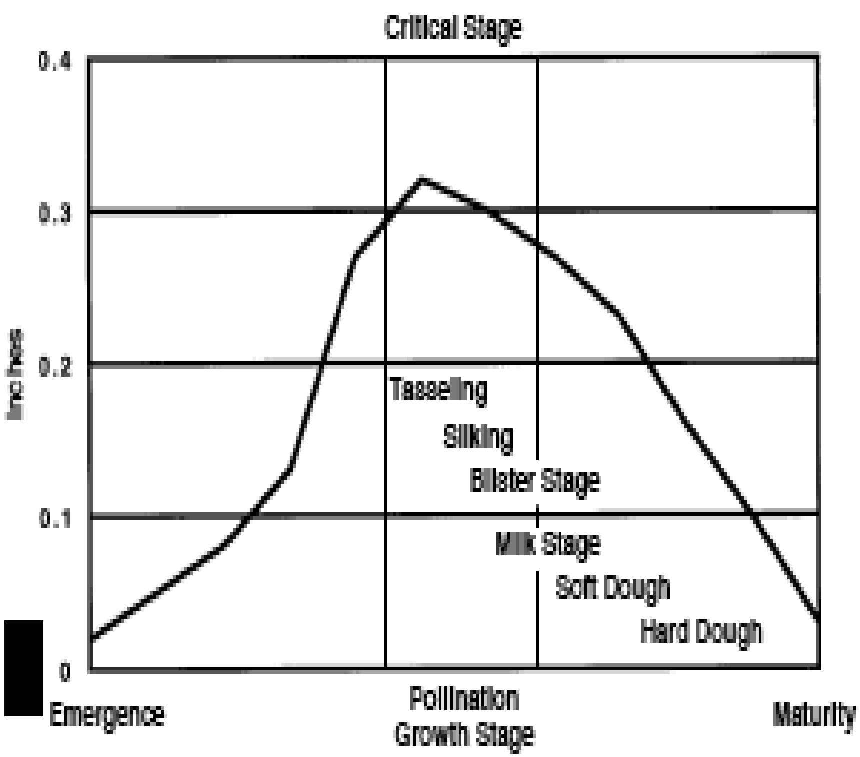


Figure 2. Daily water use by corn.

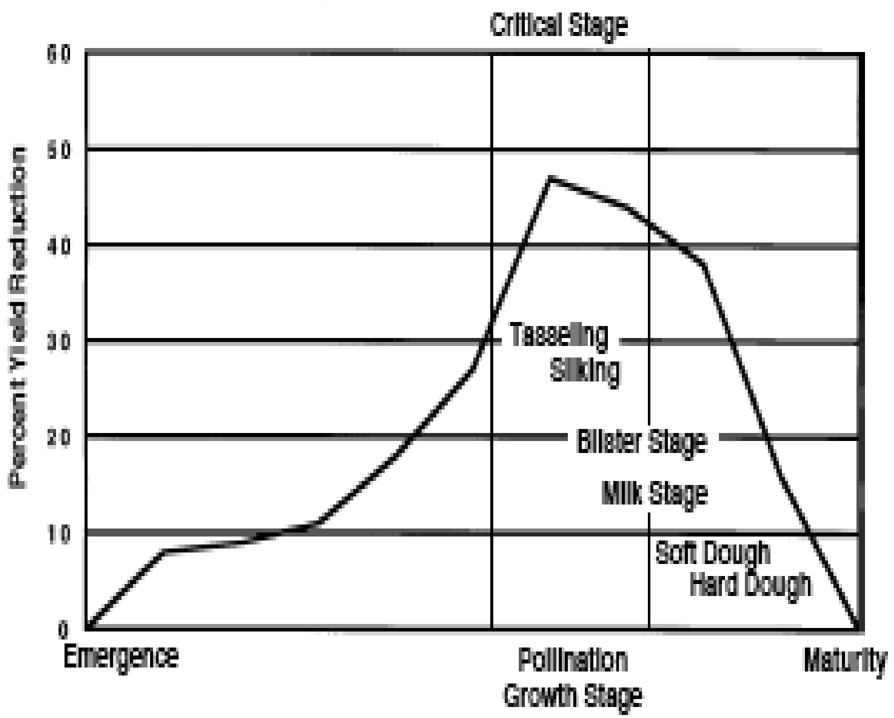


Figure 3. Corn yield reduction due to moisture stress.

TABLE 25.1
Yields of corn and soybean crops in the United States

Year	Crop yield (percentage of 10-year average)		
	Corn	Soybean	
1979	104	106	
1980	87	88	Severe drought
1981	104	100	
1982	108	104	
1983	77	87	Severe drought
1984	101	93	
1985	112	113	
1986	113	110	
1987	114	111	
1988	80	89	Severe drought

Source: U.S. Department of Agriculture 1989.

Drought stress and consequences for natural vegetation

RESPON FISIOLOGI TERHADAP KEKERINGAN

- Penurunan aktivitas fotosintesis akibat menutupnya stomata
- Terganggunya proses respirasi, tranpor eletron dan pembentukan ATP pada mitokondria
- Akumulasi senyawa metabolik bersifat hidrofilik
- Adanya ekspresi gen dan sintesis protein

RESPON BIOKIMIA TERHADAP KEKERINGAN

- Terbentuknya molekul hidrofilik untuk penyesuaian osmotik (osmotoc adjusment), seperti:
  - Asam Amino, gula alkohol, glisin-betain
  - Protein LEA yang menjaga fusi antara membran dengan makromolekul lainnya
  - Trehalose (disakarida) yang berfungsi selama perkembangan embrio dan pembungaan
  - Prolin yang berfungsi memproteksi integritas membran plasma dan menghilangkan ROS (reactive oxygen species)

RESPON MOLEKULER TERHADAP KEKERINGAN

- Perubahan dalam pola ekspresi dari gen yang produknya berperan dalam respon awal seperti transduksi (ABA dan ATHK), faktor transkripsi (protein kinase) dan translasi (HD-zip; Homeodomain-leucin zipper protein)
- Perubahan dalam pola ekspresi dari gen yang produknya berperan dalam respon akhir seperti transpor air, keseimbangan osmotik, cekanam oksidatif, dan perbaikan dari kerusakan.

4 MEKANISME ADAPTASI CEKAMAN KEKERINGAN

- Drought escape; Kemampuan tanaman untuk menyelesaikan siklus hidupnya sebelum adanya cekaman yang serius yang. Mekanisme ini meliputi:

1. Umur berbunga dan panen yang cepat
2. Perkembangan Plastisitas (periode pertumbuhan tergantung defisit air)
3. Re-mobilisasi asimilat pre-anthesis ke biji

4 MEKANISME ADAPTASI CEKAMAN KEKERINGAN

- Dehydration avoidance; Kemampuan memelihara potensial air tetap tinggi dengan cara memperbaiki serapan air, menyimpanannya dalam sel tanaman, dan mengurangi hilangnya air. Mekanisme ini meliputi:
  1. Meningkatkan kedalaman akar
  2. Membentuk sistim perakaran yang efisien
  3. Meningkatkan laju dan jumlah pengangkutan air ke tajuk
  4. Mengurangi penjerapan panas melalui penggulungan daun
  5. Pengurangan pengupan daun

4 MEKANISME ADAPTASI CEKAMAN KEKERINGAN

- Dehydration tolerance; Kemampuan menjaga proses metabolisme tetap berlangsung normal meskipun pada kondisi kekurangan air dan potensial air jaringan rendah. Mekanisme ini meliputi:
  1. Pengaturan osmotik (proses induksi akumulasi solute dalam sel)
  2. Meningkatkan elastisitas sel
  3. Mengurangi ukuran sel
  4. Resistensi protoplasma

4 MEKANISME ADAPTASI CEKAMAN KEKERINGAN

- Drought recovery; Kemampuan mengembalikan proses metabolisme setelah mengalami cekaman kekeringan. Mekanisme ini penting manakala cekaman terjadi pad awal pertumbuhan.
  1. Pengaturan osmotik (proses induksi akumulasi solute dalam sel)
  2. Meningkatkan elastisitas sel
  3. Mengurangi ukuran sel
  4. Resistensi protoplasma

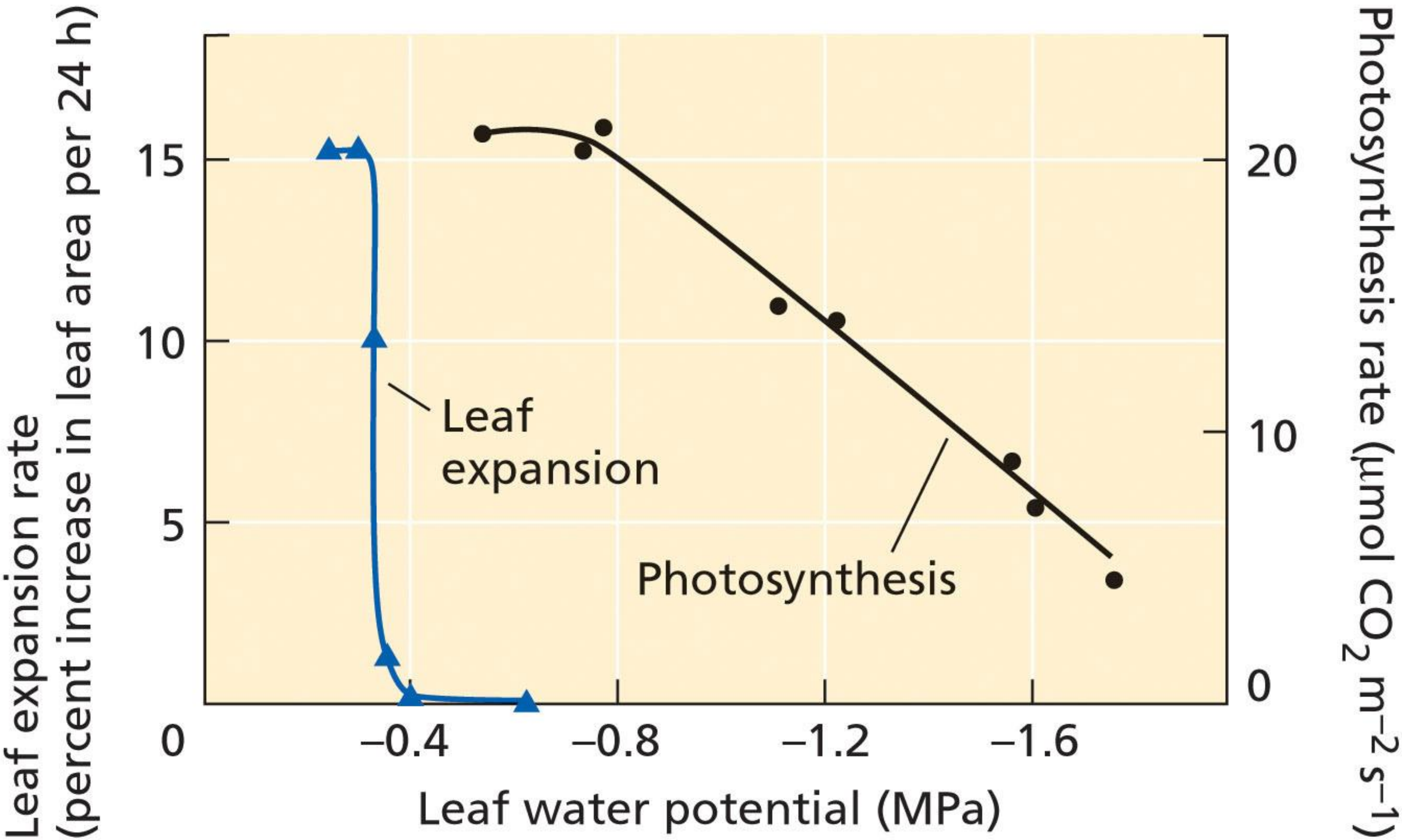
Effects of water stress that reduce growth

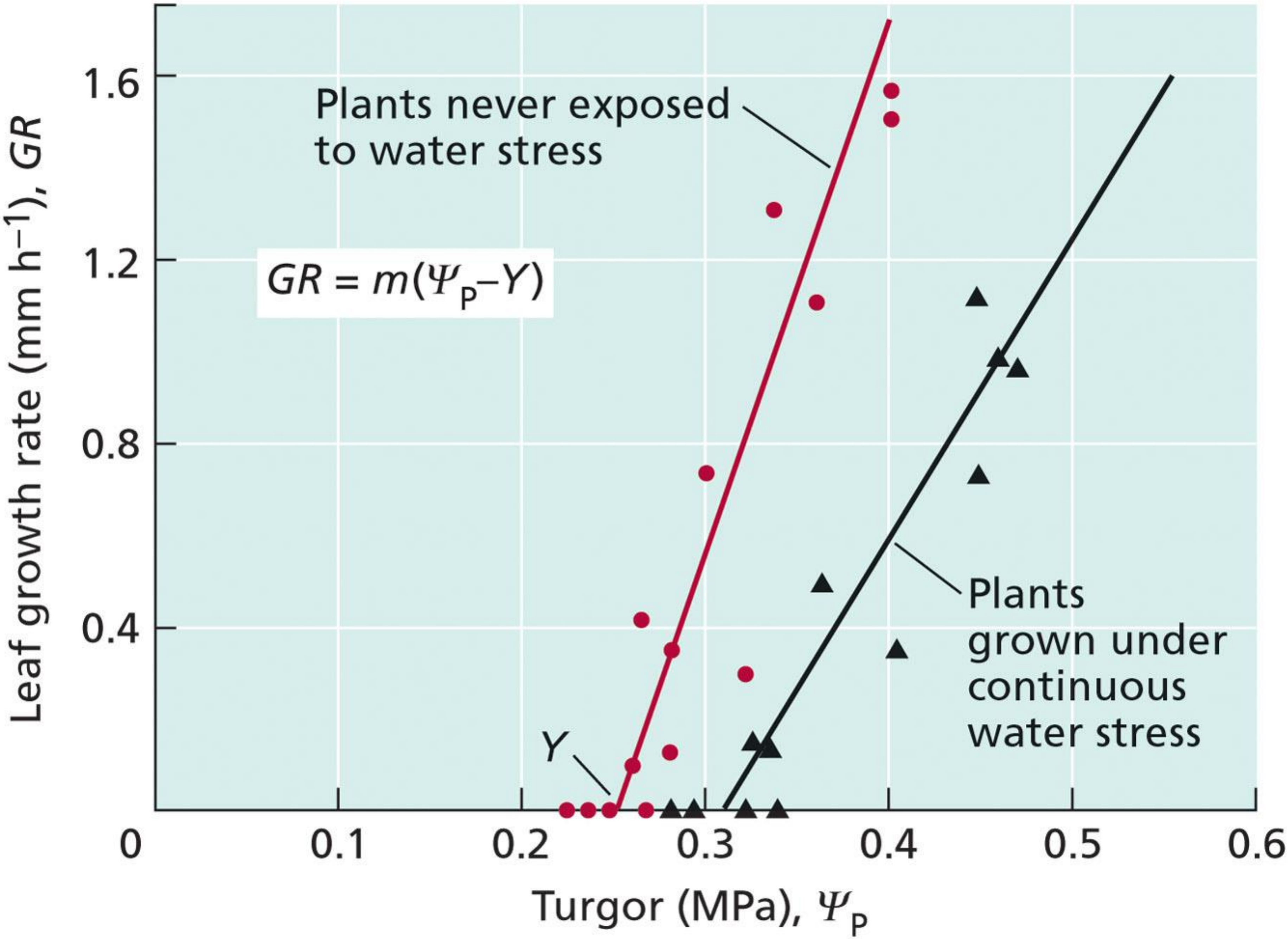
1. Reduction in cell and leaf expansion

2. Reduction in photosynthesis, due first to decreased stomatal conductance, then to inhibition of chloroplast metabolism.

3. Altered allocation - greater investment in non-photosynthetic tissues such as roots & mycorrhizae

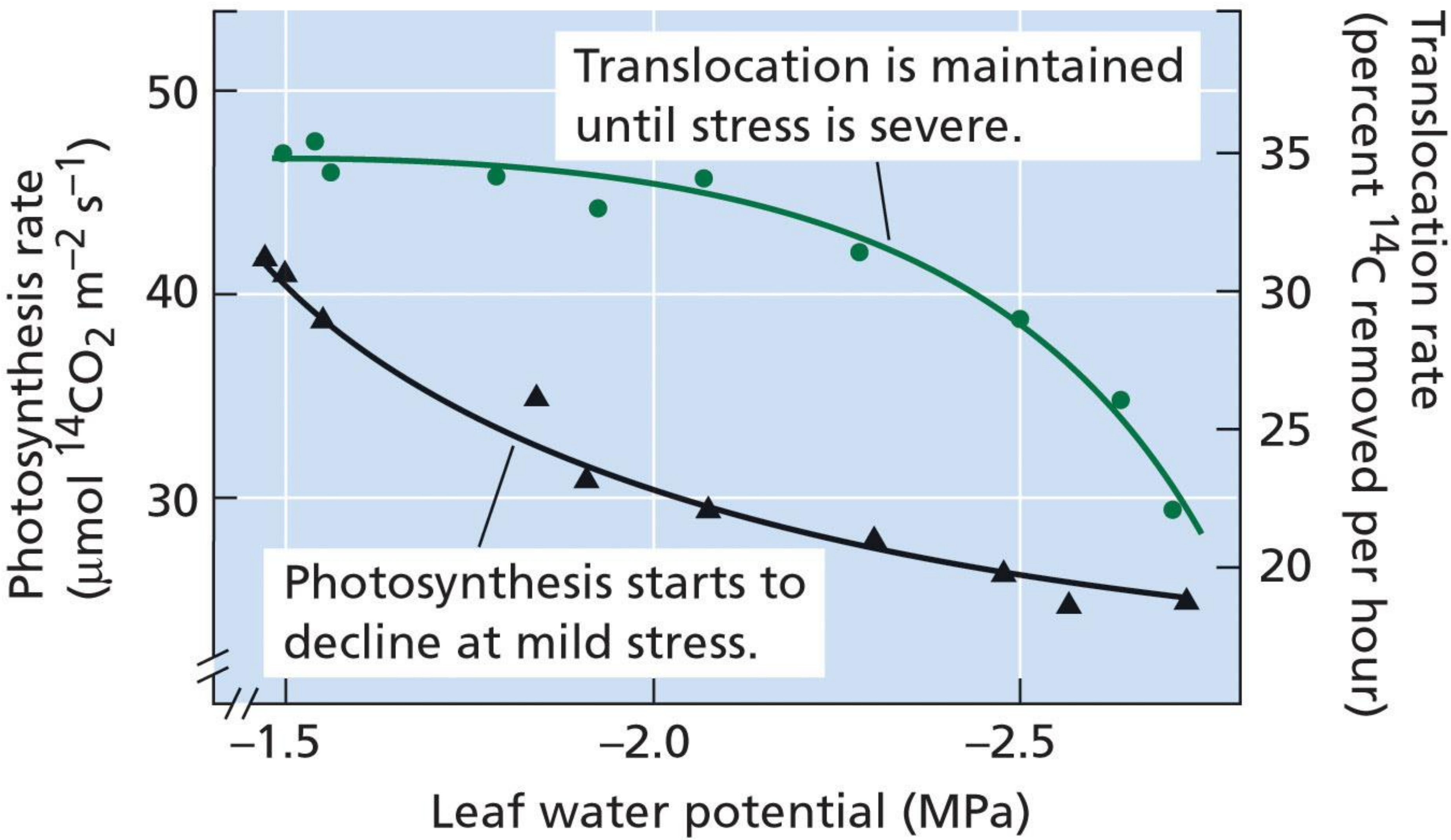
Leaf expansion is very sensitive to water deficit.





Leaf growth rate (mm h−1), GR
1.6
1.2
0.8
0.4
0
0.1
0.2
0.3
0.4
0.5
0.6
Turgor (MPa), Ψ_P
Plants never exposed to water stress
GR = m(Ψ_P–Y)
Y
Plants grown under continuous water stress

Phloem translocation seems to be less sensitive to water stress than photosynthesis.

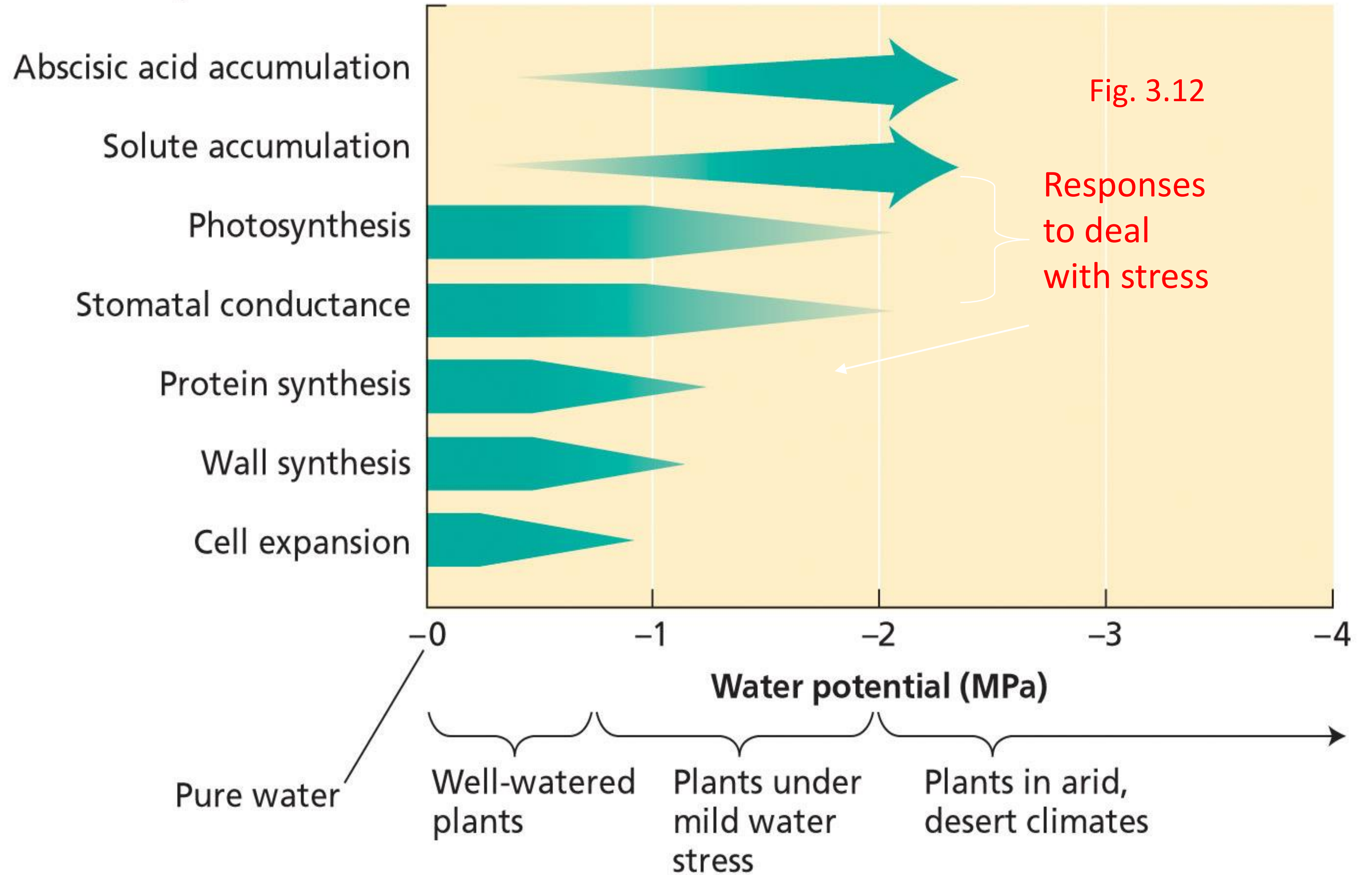


Why is leaf expansion so sensitive to drought?

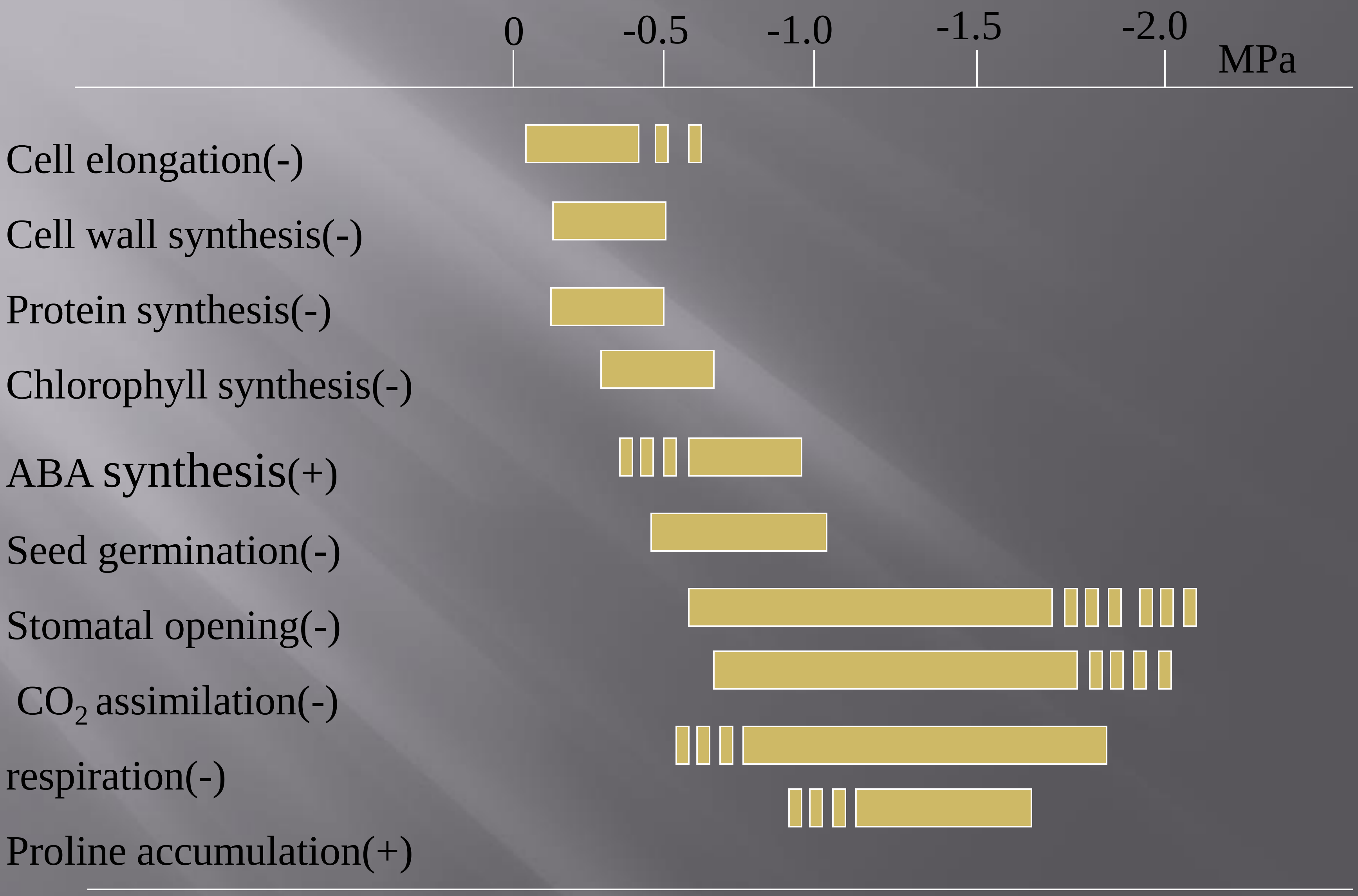
$$\Psi_W = \Psi_S + \Psi_P$$

Leaf expansion is slowed by water stress because turgor pressure declines.

Physiological changes due to dehydration:



- Metabolism relevant to water sensitive to range of water
- Inhibit (-) promotion (+)



Responses to water stress

Osmotic adjustment

Stomatal closure

- hydropassive - guard cell dehydration
- hydroactive - guard cell metabolism; ABA, solutes, etc.

Leaf abscision and reduced leaf growth

- reduces surface area for water loss
- Smaller leaves lose more heat via convective heat loss

Water uptake from the soil happens when soil potential is higher than plant water potential

Osmotic adjustment helps plants cope with water stress.

1. $\Psi_W = \Psi_S + \Psi_P$

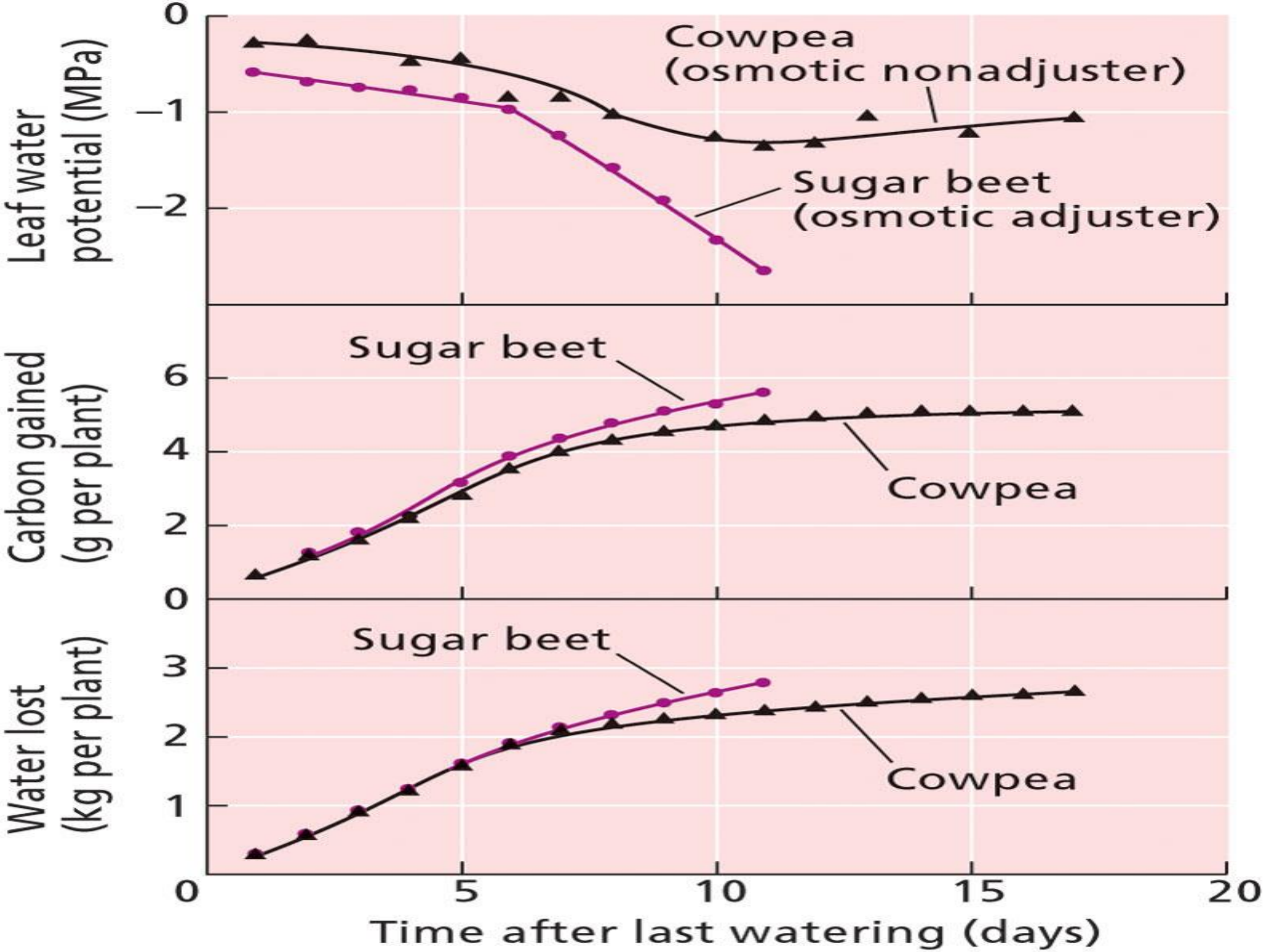
A decrease in Ψ_S helps maintain turgor, Ψ_P, even as total water potential decreases.

Osmotic adjustment is a net increase in solute content per cell.

Many solutes contribute to osmotic adjustment.
K^+, sugars, organic acids, amino acids

Osmotic adjustment may occur over a period days.

Costs of osmotic adjustment: synthesis of organic solutes, maintenance of solute gradients, and "opportunity costs", energy the could be used for other functions



PLANT PHYSIOLOGY , Third Edition, Figure 25.6

A very important drought response: stomatal closure

Advantage: less loss of water

Disadvantage: less transport of CO_2.

Mechanism:

1- loss of water from stomatal cells, turgor drops, stoma closes

2- cell actively decrease solute concentration

$$\Psi_W = \Psi_S + \Psi_P$$

Solute potential rises (less negative), turgor drops, stoma closes

Responses to water stress

Increased root growth

- with reduced leaf expansion, more C translocated to roots
- increases water supply

Increased wax deposition on leaf surface

- reduces cuticular transpiration, increases reflection

Induction of CAM in facultative CAM plants

- in response to water or osmotic stress

Effects of drought on photosynthesis are generally minor

1- early effect: mostly via stomatal closure
2- late effect: metabolic breakdown

Also many responses at the cellular level:

Proteins increase and decrease in response to water stress

One special group of proteins:
LEA-proteins (late embryogenesis abundant)

Accumulate in dehydrating leaves, and during seed ripening

Function: protection of membranes (hydrophylic proteins)
prevention of random crystallization of proteins

1.1.2.2. Methods to increase the resistance

（1）Selection of cultivars with high resistance to drought，high yield and quality.

（2）drought hardening

Seed priming special technology to control seed water absorption and re-drying slowly

（3）Suitable fertilizer application：

Application of more P、K to plants.

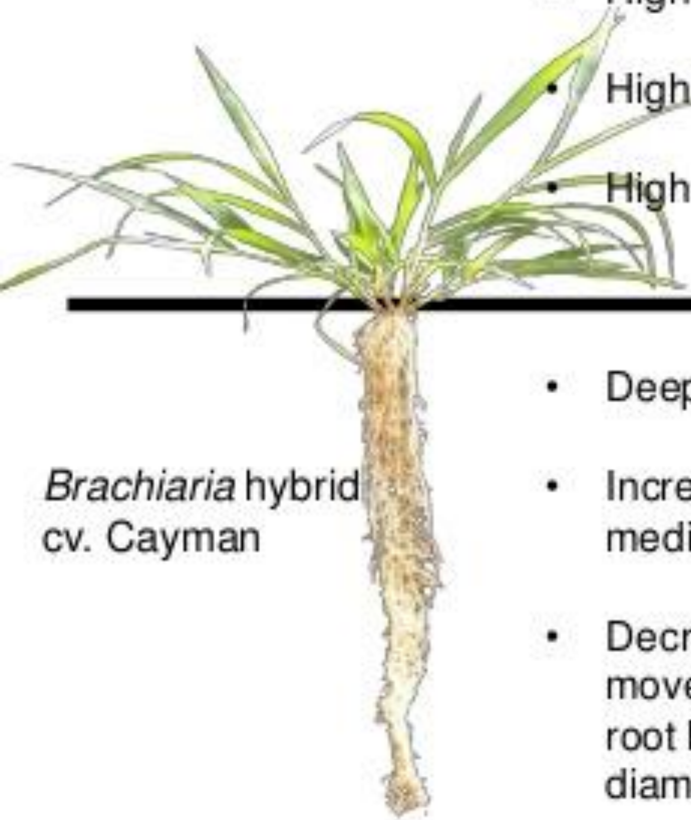
（4）Chemical regents application

Soaking in 0.25% $CaCl_2$ or 0.05% $ZnSO_4$ solution.

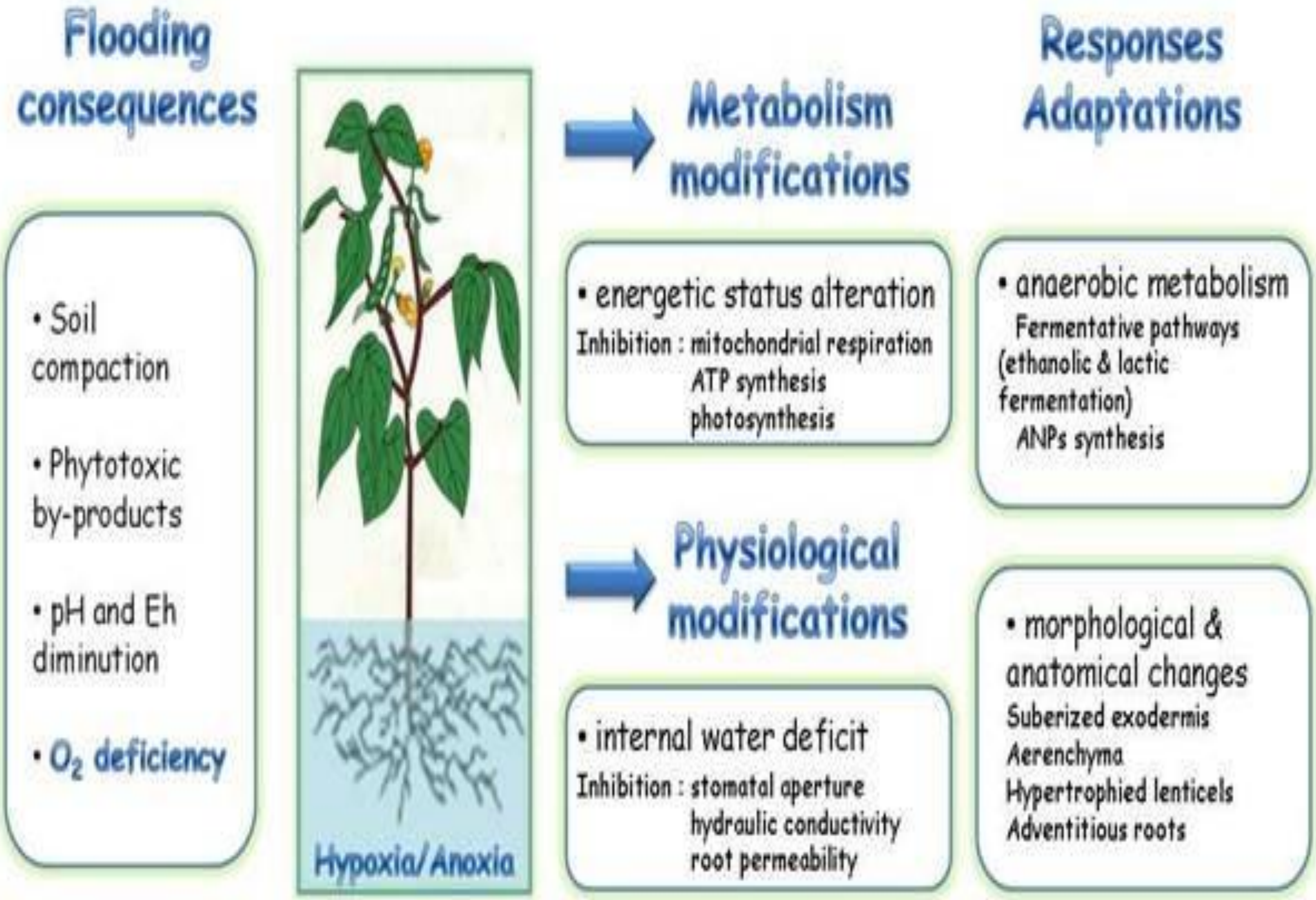
Application of plant substance: ABA, CCC etc

Drought

Drought resistance (avoidance/tolerance)	Assessment methods
• High stomatal conductance	• Leaf gas exchange/porometry • Infrared thermometry • Carbon isotope discrimination???
• Delayed leaf senescence	• Chlorophyll content (SPAD)
• High quantum yield	• Chlorophyll fluorescence
• High osmotic adjustment	• Relative water content in leaves
• High transpiration efficiency	• Weighing each container on a regular basis
• Deep root systems • Increased root length density in medium and deep soil layers	• Vertical distribution of roots in soil cylinders (120 cm height x 22 cm width; 80 cm height x 7.5 cm width)
• Decreased resistance to water movement from soil by increasing root hair growth and xylem diameters	• Micrographs from root cross sections



Brachiaria hybrid cv. Cayman


Flooding consequences
• Soil compaction
• Phytotoxic by-products
• pH and Eh diminution
• O_2 deficiency
Hypoxia/Anoxia
Metabolism modifications
• energetic status alteration
Inhibition : mitochondrial respiration
ATP synthesis
photosynthesis
Physiological modifications
• internal water deficit
Inhibition : stomatal aperture
hydraulic conductivity
root permeability
Responses Adaptations
• anaerobic metabolism
Fermentative pathways (ethanolic & lactic fermentation)
ANPs synthesis
• morphological & anatomical changes
Suberized exodermis
Aerenchyma
Hypertrophied lenticels
Adventitious roots

2.2 Resistance of plant to flood

Flood injury: moisture injury and flooding injury.

Moisture injury is caused by soil space filled with water and without air.

flooding injury: whole plant or part of shoot is submerged to water while flooding

2.2.1 Injures of flood to plant

Flood is actual deficiency in O_2

Anything increases in soluble O_2, the injury will decrease. And anything decreases in soluble O_2, the injury will increase.

Such as slowly streaming water less damage than static water.

(1) Injury in morphology and anatomy by O_2 deficiency： growth↓， leaf yellowish (nutrition deficiency）， root darkness（low Eh）, epinasty（Eth), air root(IAA, Eth), stem hollow (tissue degradation caused by Eth ）.

(2) Injury in metabolism by O_2 deficiency: photosynthesis ↓——stomatal block, inhibition of CO_2 entrance . Anaerobic respiration↑, toxicants: alcohol， acetaldehyde， NH_3, lactate , H_2S。

(3) Nutrition disorder：

absorption ↓， soil N、P、K、Ca loss but H_2S、Fe、Mn ↑， microelements poison.

(4) Changes in plant hormones： IAA and CTK ↓. ACC synthesis in root and release of Eth in shoot.

(5) Mechanical damage and infection by harmful organism

2.2.2 Mechanism of resistance to flood

Resistance is different in plants:hydrophytes>land plants， rice>rape>barley; O.sativa>O.japonica ，and in growth stages : seedling >other stages,

(1) Tolerance in tissues：Well-developed aerenchyma。

(2) Tolerance in metabolism：mitochondria well develops in anaerobic conditions, succinic acid dehydrogenase↑， tolerance to ethanol ; PPP instead of EMP，NR↑，Glutamate dehydrogenase ↑。

MATERI PRESENTASI

- ADAPTASI TANAMAN TERHADAP CEKAMAN TANAH MASAM
- ADAPTASI TANAMAN TERHADAP CEKAMAN KETERSEDIAAN FOSFOR RENDAH
- ADAPTASI TANAMAN TERHADAP CEKAMAN SULFAT MASAM
- ADAPTASI TANAMAN TERHADAP CEKAMAN INTENSITAS CAHAYA RENDAH
- ADAPATASI TANAMAN TERHADAP CEKAMAN SUHU TINGGI
- ADAPTASI TANAMAN TERHADAP CEKAMAN SALINITAS