Environmental Factors Rainfall and Irrigation

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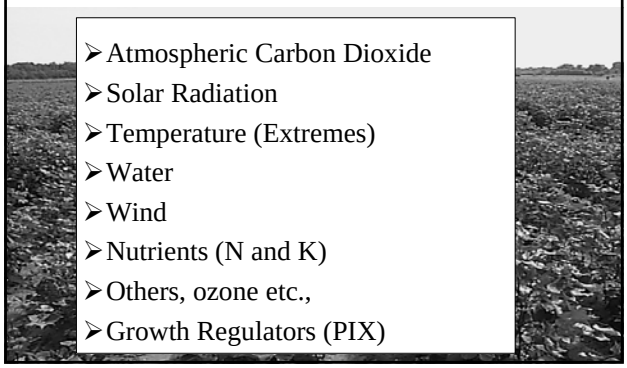
Environmental and Cultural Factors Limiting Potential Yields



- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature (Extremes)
- Water
- Wind
- Nutrients (N and K)
- Others, ozone etc.,
- Growth Regulators (PIX)

Water and Irrigation - Objectives

The objectives of this lecture are to:

- Learn about the importance of water for ecosystem services, and to learn about the availability of fresh water for industrial, human and irrigation purposes.
- Learn about irrigation trends across major regions.
- Learn about the influence of water on plants and ecosystems in general.
- Learn about water content of various plant parts.
- Learn about the interrelationships between soil, root, leaf water potential and transpiration relationships under water deficit conditions.

Water

Water plays essential roles in plants as a:

- ✓ Constituent
- ✓ Solvent
- ✓ Reactant in various chemical processes
- ✓ Maintenance of turgidity

Therefore, everyone who grows plants, whether a single plant in pot or hundreds of acres of corn or cotton, is aware of the importance of water for successful growth, and finally economic product or yield.

Water

- Water on a global scale is plentiful. However,
  - ✓ 97% of it is saline
  - ✓ 2.25% is trapped in the glaciers and ice
  - ✓ the rest, 0.75% is available in fresh water aquifers, rivers and lakes.
- About 70% of the available fresh water is used for agricultural production, 22% for industrial purposes, and 8% for domestic purposes.
- Increasing competition for domestic and industrial purposes is likely reduce the water available for agriculture in the future.

World's fresh water ecosystems and goods and services

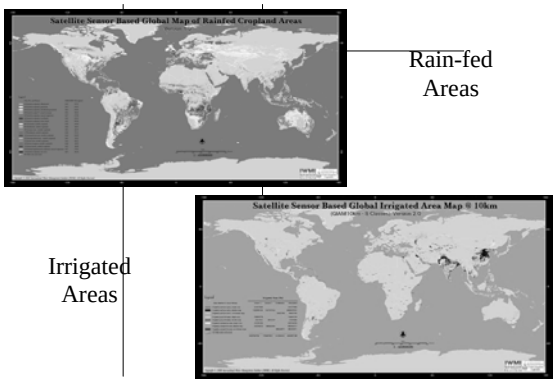
- Fresh water ecosystems occupy less than 1% of Earth's surface but deliver goods and services of enormous global value.
  - ✓ Inland fisheries capture accounts 12% of all fish consumed by humans.
  - ✓ Irrigated agriculture supplies amounts about 40% of the world's food crops.
  - ✓ Hydropower provides about 20% of world's electricity production.
  - ✓ About 12% of all animal species live in fresh water, and most other species depend in some way on fresh water ecosystems for their survival.

Water and Plants

- Plants use large amounts of water in the growth process, with important consequences for agriculture and the distribution of plant communities.
- The distribution of plants over the earth's surface is controlled by the availability of the water (amount and seasonal distribution of precipitation) where ever temperature permits growth.
- Water is involved in nearly every aspect of plant activity, ranging from the transport of mineral nutrients and metabolites to growth, metabolism, and gene action.

Irrigated Cropland – World Statistics

Global Distribution - Rain-fed and Irrigated Areas



Rain-fed Areas

Irrigated Areas

Worldwide Distribution of Irrigated Areas - 1984

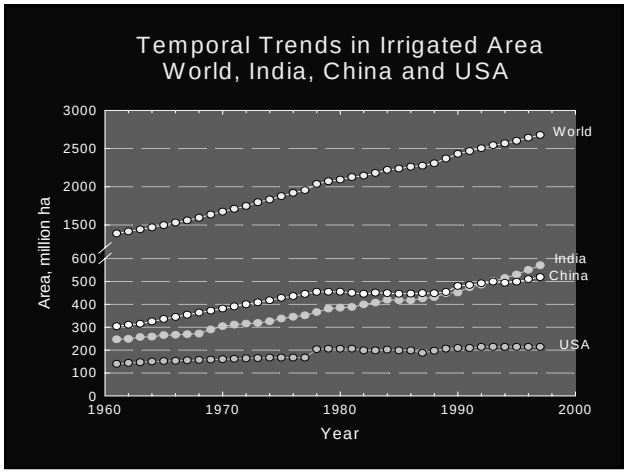
(Adapted from Hoffman et al., 1990)

Country	Irrigated area million ha	Percent of world total	Percent of cultivated area
Asia	137	62	30
North America	25	9	8
Russia	21	9	8
Europe	16	7	11
Africa	10	5	6
South America	8	4	6
Central America	7	3	18
Australia and Oceania	2	1	4
Developing countries	160	71	20
Industrial countries	66	29	9
World	226	100	15

Countries with major irrigated areas, 1996

(Adapted from Hoffman et al., 1990)

Country	Irrigated area million ha	% of country's cultivated land irrigated
India	55	33
China	47	48
Russia	21	9
United States	19	10
Pakistan	16	77
Indonesia	7.3	34
Iran	5.8	39
Mexico	5.3	21
Spain	3.3	16
Turkey	3.3	12
Thailand	3.2	16
Egypt	3.2	100
Japan	3.0	63
Italy	3.0	25
Romania	3.0	28



Water Status and Plant Growth

Water content of various plant tissues expressed as

	Plant parts	Water content (%)	Reference
Roots	Barley, apical portion	93.0	Kramer and Wiebe (1952)
	Pinus taeda, apical portion	90.2	Hodgson (1953)
	P. taeda, mycorrhizal roots	74.8	Hodgson (1953)
	Carrot, edible portion	88.2	Chatfield and Adams (1940)
	Sunflower, average of entire root system	71.0	Wilson *et al.* (1953)
Stems	Asparagus stem tips	88.3	Daughters and Glenn (1946)
	Sunflower, average of entire stems on 7-week-old plant	87.5	Wilson *et al.* (1953)
	Pinus banksiana	48.0–61.0	Raber (1937)
	Pinus echinata, phloem	66.0	Huckenpahler (1936)
	P. echinata, wood	50.0–60.0	Huckenpahler (1936)
	P. taeda, twigs	55.0–57.0	McDermott (1941)
Leaves	Lettuce, inner leaves	94.8	Chatfield and Adams (1940)
	Sunflower, average of all leaves on 7-week-old plant	81.0	Wilson *et al.* (1953)
	Cabbage, mature	86.0	Miller (1938)
	Corn, mature	77.0	Miller (1938)
Fruits	Tomato	94.1	Chatfield and Adams (1940)
	Watermelon	92.1	Chatfield and Adams (1940)
	Strawberry	89.1	Daughters and Glenn (1946)
	Apple	84.0	Daughters and Glenn (1946)
Seeds	Sweet corn, edible	84.8	Daughters and Glenn (1946)
	Field corn, dry	11.0	Chatfield and Adams (1940)
	Barley, hull-less	10.2	Chatfield and Adams (1940)
	Peanut, raw	5.1	Chatfield and Adams (1940)

[a]From Kramer (1983).

Area of Total World Land Surface Subject to Environmental Limitations of Various Types

Limitation	Area of world soil subject to limitation (%)
Drought	27.9
Shallow soil	24.2
Mineral excess or deficiency	22.5
Flooding	12.2
Miscellaneous	3.1
None	10.1
Total	100
Temperature	14.8 (over laps with other stresses)

Water

Table 12.1 Record Yields, Average Yields, and Yield Losses Due to Diseases, Insects, Weeds, and Unfavorable Physicochemical Environments for Major U.S. Crops[a]

Crop	Record[b] yield	Average[c] yield	Average losses[c] Diseases	Insects	Weeds	Physicochemical[d]
Maize	19,300	4,600	836	836	697	12,300
Wheat	14,500	1,880	387	166	332	11,700
Soybean	7,390	1,610	342	73	415	4,950
Sorghum	20,100	2,830	369	369	533	16,000
Oat	10,600	1,720	623	119	504	7,630
Barley	11,400	2,050	416	149	356	8,430
Potato	94,100	28,200	8,370	6,170	1,322	50,000
Sugar beet	121,000	42,600	10,650	7,990	5,330	54,400
Mean percentage of record yield	100	21.5	5.1	3.0	3.5	66.9

Note. Values are kilograms per hectare. Record and average yields are as of 1975.
[a]In the original work (Boyer, 1982), weed losses were considered to be physicochemical because the losses were attributable to competition for light, nutrients, and so on. On the other hand, weeds are of biological origin and it may be argued that the losses should be included with insects and diseases. For simplicity, the latter approach is taken here, which slightly alters the values calculated for each loss in comparison with Boyer (1982).
[b]From Wittwer (1975).
[c]Calculated according to U.S. Department of Agriculture (1965).
[d]Physicochemical losses calculated as record yield—(average yield + disease loss + insect loss + weed loss).

Distribution of Insurance Indemnities and Crop Losses in the US – 1939 to 1978

Table 12.3 Distribution of Insurance Indemnities for Crop Losses in the United States from 1939 to 1978[a]

Cause of crop loss	Proportion of payments (%)
Drought	40.8
Excess water	16.4
Cold	13.8
Hail	11.3
Wind	7.0
Insect	4.5
Disease	2.7
Flood	2.1
Other	1.5

[a]From U.S. Department of Agriculture (1979).

Range of Soils and Available and Non-available Water

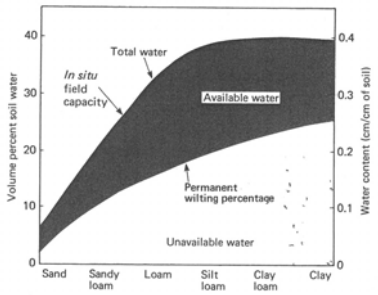


Figure 4.1 Diagram showing the relative amounts of available and unavailable water in soils ranging in texture from sands to clay. Amounts are expressed as percentages of soil volume and centimeters of water per centimeter of soil. After Cassel (1983), from Kramer (1983).

Net Primary Production and Precipitation

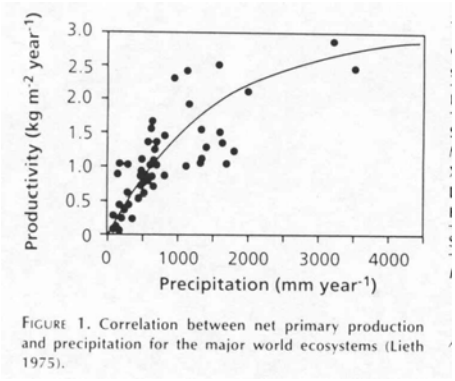
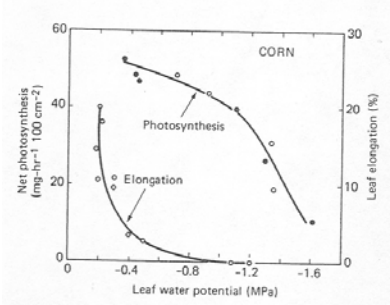


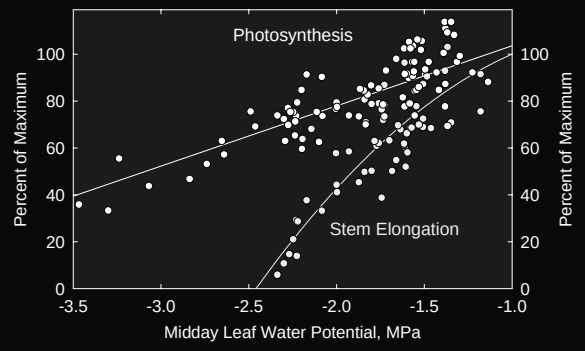
FIGURE 1. Correlation between net primary production and precipitation for the major world ecosystems (Lieth 1975).

Relationship among Leaf Water Potential, Leaf Elongation, and Photosynthesis of Corn.

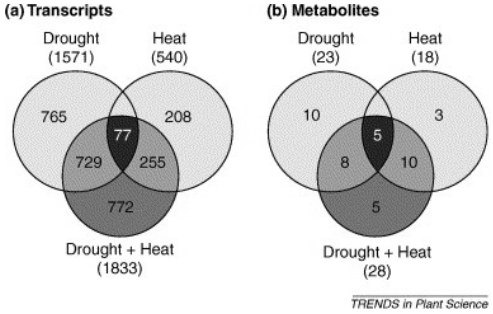


Note that leaf elongation almost ceases before there is much significant reduction in photosynthesis (Kramer, P.J, and JS. Boyer. 1995, page 19)

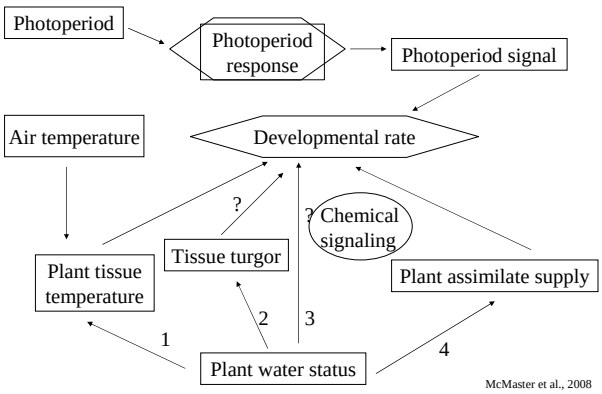
Photosynthesis, Vegetative Growth - Environment Response to Drought



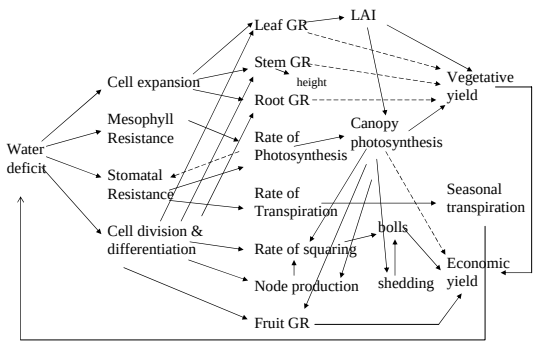
Water Stress and Molecular Biology



Water and Plant Development

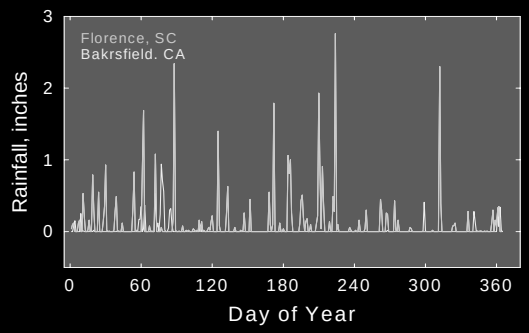


Water and Plant Growth and Sequence of Events

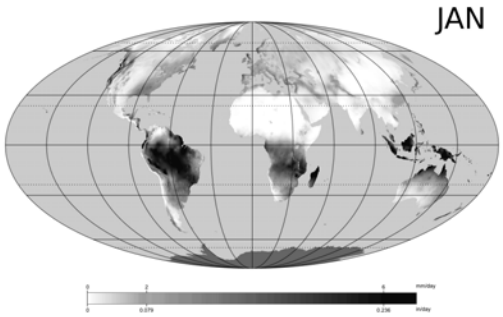


Rainfall Trends

Rainfall - Seasonal Trends
Bakersfield, CA and Florence, SC - 1991



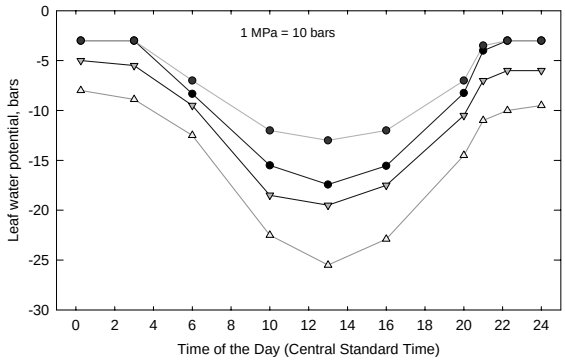
Global Rainfall –Temporal and Seasonal Trends



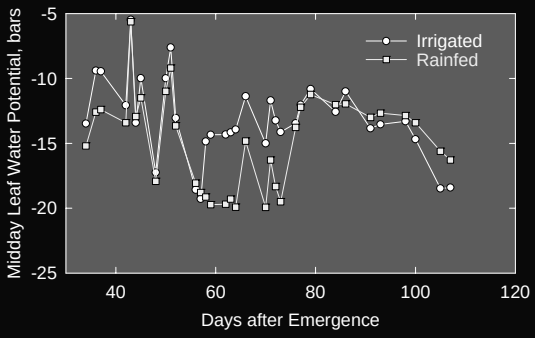
http://en.wikipedia.org/wiki/File:MeanMonthlyP.gif

Water Status
Seasonal and Diurnal Trends

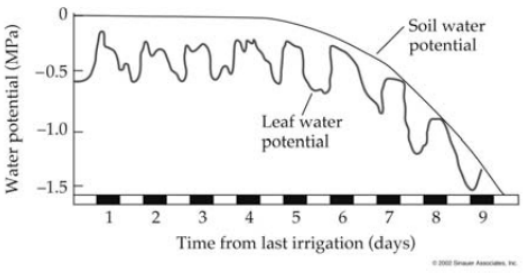
Leaf Water Potential - Diurnal Trends



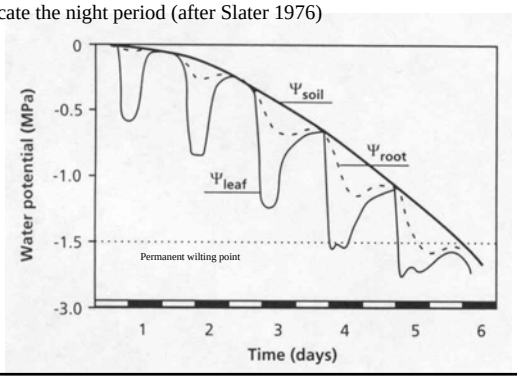
Seasonal Trends - Midday Leaf Water Potential
Irrigated and rainfed cotton, MSU North Farm -1995



Typical diurnal changes in leaf and soil water potentials of a transpiring plant rooted in soil allowed to dry from a water potential near zero to a water potential at which wilting occurs. The dark bars indicate the night period (after Slater 1976)



Typical diurnal changes in leaf, root and soil water potentials of a transpiring plant rooted in soil allowed to dry from a water potential near zero to a water potential at which wilting occurs. The dark bars indicate the night period (after Slater 1976)



Typical diurnal changes in transpiration rate, leaf, root and soil water potentials of a transpiring plant rooted in soil allowed to dry from a water potential near zero to a water potential at which wilting occurs. The dark bars indicate the night period (Fitter and Hay, 2002)

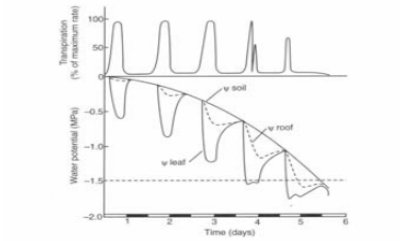


Figure 4.9

Schematic representation of the changes in leaf, root surface, and bulk soil water potentials, and in the rate of transpiration, associated with the exhaustion of the available soil water over a five day period. See text for full description (adapted from Slatyer, 1967).

Reference/Reading Material

- McMaster et al. 2008. Simulating crop phenological responses to water deficits, CSSA publication (Read).
- Volmar, K.M. and W. Woodbury. 1995. Plant-Water-Relationships. In: Handbook of Plant and Crop Physiology, by M. Pessarakli. Marcel Dekker, Inc, New York (Must Read).
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