BIOL 695

PLANT GROWTH and CROP PRODUCTION

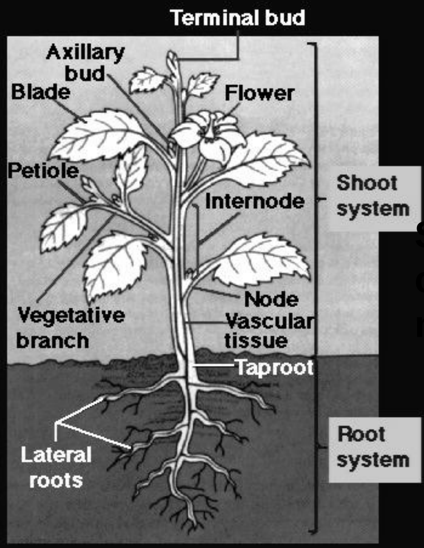
CHAPTER 5
Mengel et al., 5th Ed

ESSENTIAL GROWTH STAGES

- **Germination**
  - Initiated by H_2O & O_2 & Phytohormones
  - Utilizes CHO and amino acids from seed
- **Vegetative Stage**
  - Older leaves supply younger
  - Major addition of biomass
- **Reproductive Stage**
  - Flower initiation then pollination
- **Maturity**
  - Photosynthates mostly to storage tissue

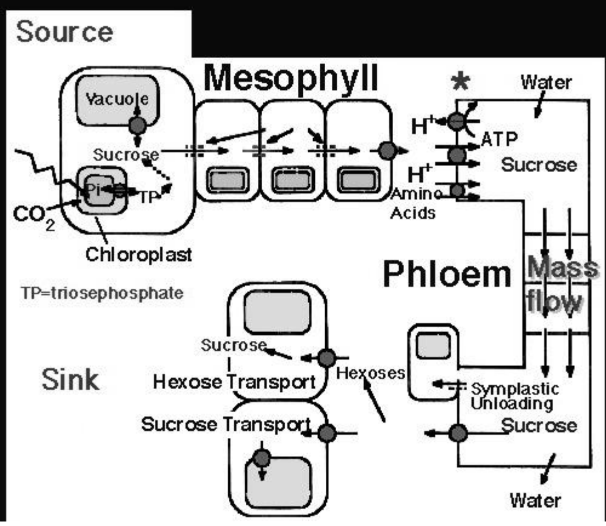
Growth Stages

Food production/
Food utilization
relationships
change as plant
ages;
i.e., source:sink
details
Relationship
changes



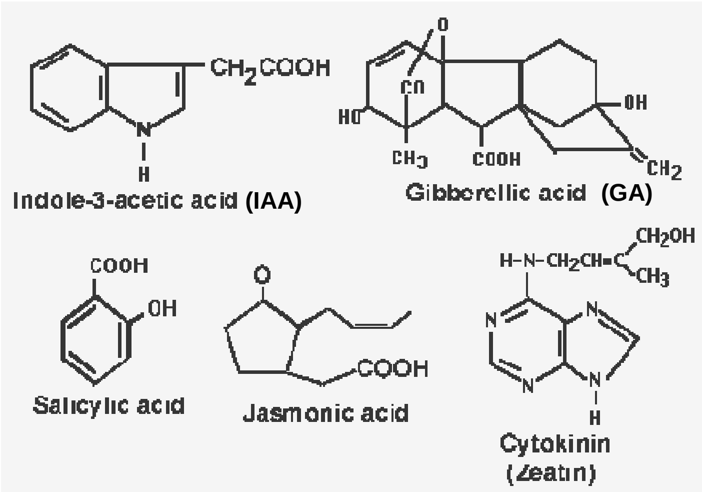
Specific components may vary

SOURCE - SINK RELATIONSHIP

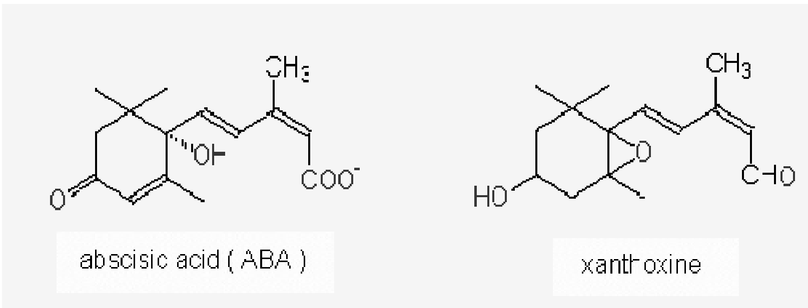


Sink will Change With maturity

PHYTOHORMONES



PHYTOHORMONES



GROWTH RATE & NUTRIENT SUPPLY

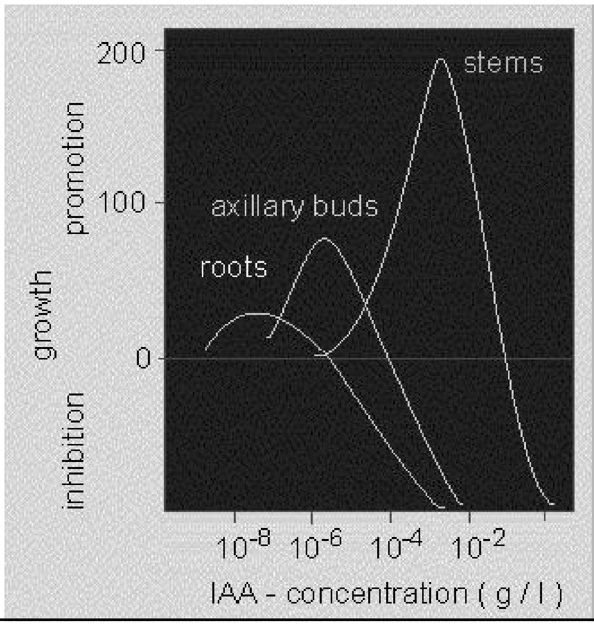
- **Biological Yield**
  - total production of plant material
- **Economic Yield**
  - plant organs which are harvested
- **Which plant types have:**
  - biological = economic yield
- **Which plant types have:**
  - biological ?²economic yield

GROWTH RATE & NUTRIENT SUPPLY

- **Vegetative growth stage:**
  - formation of new leaves, stems, roots
  - very active protein metabolism
  - most photosynthates used for synthesis of nucleic acids and proteins
  - N nutrition largely controls growth rate
  - carbohydrate accumul. gen later
  - amount of N must be in balance with other parameters
  - nutrient balance very important

GROWTH RATE & NUTRIENT SUPPLY

EFFECT OF AUXINS



GROWTH RATE & NUTRIENT SUPPLY

- **Vegetative growth stage:**
  - **mineral nutrient requirement primarily determined by rate of CO_2 assimilation**
  - **temperature is very important; affects growth rate more than light**

ROOT CROP NUTRITION MANAGEMENT

- Tuber initiation produced by hormones
  - ABA promotes; GA inhibits
  - ABA/GA ratio controls tuber setting
- Continuous supply of N $\Rightarrow$ low ABA/GA
  - regrowth of tubers (text, Plate 5.7)
- Decline in N supply $\Rightarrow$ increases ABA
  - normal tuber production
- Tuber filling also related to CHO supply
- N management:
  - vegetative stage - high N
  - tuber stage - declining N; maintain P, K

FRUIT CROP NUTRITION MANAGEMENT

- Prior to fruit setting, need rich vegetative growth to build up food reserves
- Fruit setting related to phytohormones (ABA/IAA) and probably nutrition
- Fruit ripening $\Rightarrow$ food, nutrition (Ca)
- Temperature & light effects - less control
- Alternance - perennial fruit crops that tend to bear fruit only every 2nd season; especially noted in apples

GROWTH REGULATORS

- Synthetic plant hormones ("bioregulators")

  TIBA - 2, 3, 5-triiodobenzoic acid
  - inhibits auxins

  CCC - chlorocholine chloride
  - inhibits gibberellins

- Objectives:
  decrease stem elongation (why?)
  increase (extend) reproductive growth
  decrease senescence & abscission

NET ASSIMILATION RATE (NAR)

- Net assimilation =

  (Photosynthetic Prod'n - Respiration)

- Difference between C3 & C4 plants:

  - no photorespiration in C4 plants

  - C4 plants show positive NAR at very low CO_2 levels around leaf (5x < C3)

NET ASSIMILATION RATE (NAR)

• **High plant density:**

  - more mutual competition for H_2O, nutrients, light

  - increased fungal diseases, lodging, shading (<NAR)

• **Light may often be limiting factor**

  - decreased photosynthesis

  - increased respiration

NET ASSIMILATION RATE (NAR)

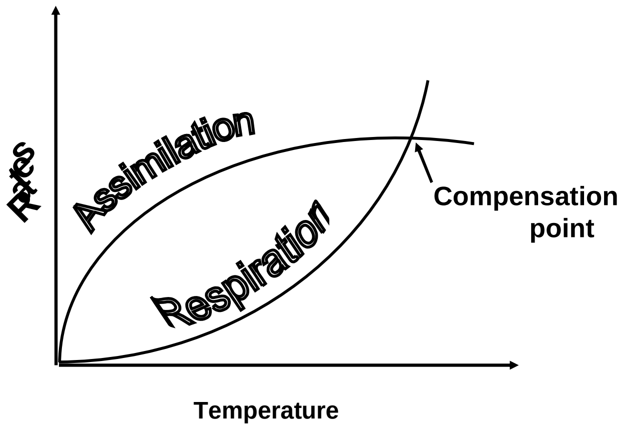


Fig 5.19 Rates of CO_2 assimilation & respiration in relation to temperature

LEAF AREA INDEX (LAI)

- LAI describes density of plant population
  - leaf area of crop per unit area of soil
  - m^2 per m^2
- Crop specific but general range of 3 -6
  - depends upon species, leaf shape, leaf angle, light intensity
- At high LAI, mutual shading
  - reduces NAR
  - high N increases LAI and reduces yield, even at optimum LAI

CO_2 ASSIMILATION & CONCENTRATION AND LIGHT INTENSITY

- Atmospheric CO_2 is increasing
- Most plants increase production with increased CO_2
- Could do for greenhouse prod’n but ??
- Interaction of CO_2 & light with respect to assimilation (see Text, Fig 5.23)
- Increased CO_2 would not increase yield if light is limiting

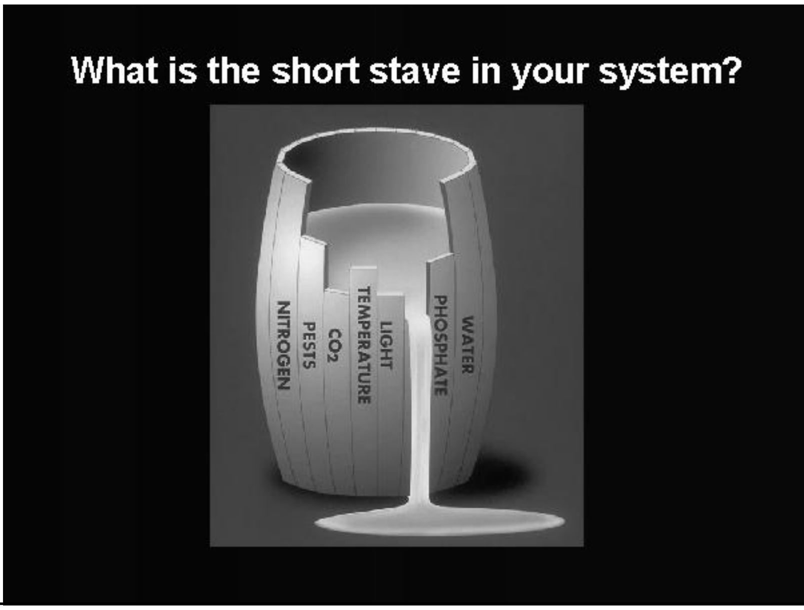
CO_2 ASSIMILATION & CONCENTRATION AND LIGHT INTENSITY

- Degree of utilization of radiation energy by plants is low (~5%) ; less for annual crops
- C3 plants utilize ~2.7% of available E
- C4 plants utilize ~4% of available E
- Selectively bred plants have increased efficiency

YIELD CURVES

- Sprengel discovered ‘Law of Minimum’
- Liebig was greatest proponent of significance for crop plants
- Sometimes called “Law of Limiting Factors”
- Mitscherlich developed mathematical relationship between yield and “unit growth factors” (see Text)

LIMITING FACTORS



YIELD CURVES

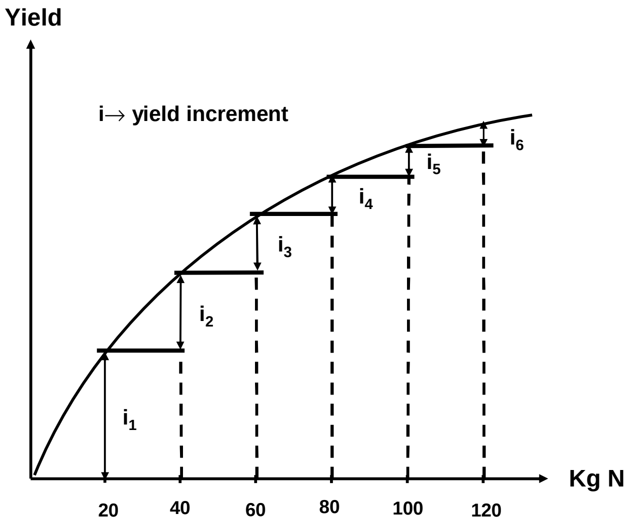


Fig. 5.25 Response curve showing diminishing increments

YIELD CURVES

Mitscherlich - equation

$$y = A(1 - 10^{-cx})$$

y = yield
A = max yield
c = integration constant
x = growth factor

- **Relationship not simple**
- **Cannot precisely determine growth factor**
- **Can obtain relative information**

YIELD CURVES

- **Universal application of M-equation depends on obtaining asymptotic growth curves (N - Fig 5.26)**
- **Due to complexity of factors, many yield curves are unlike Fig. 5.26**

  - Fig 5.29 for N for rice;
  - Fig 5.31 for grain and currency yield

YIELD CURVES

- Main conclusion from Mitscherlich's work:
  - as growth factor is increased, the yield increments become smaller
- This "law of diminishing yield increments" has also been applied to industrial and economic problems

NURITION & PLANT QUALITY

- Major factors controlling crop quality are fixed genetically
- Exogenous factors can influence levels of some organic compounds in plants

ROOT CROPS

- K^+ promotes CO_2 assimil & transl of CHO to potato tubers (high starch content)
- K_2SO_4 better effect than KCl (Cl^- decreases CHO translocation

NURITION & PLANT QUALITY

• Influence on tuber
  - starch content $\Rightarrow$ K^+
  - starch quality $\Rightarrow$ P
  - tuber blackening $\Rightarrow$ Fe-chlorogenic acid
    sufficient K^+ $\Rightarrow$ citric acid production
    $\Rightarrow$ reduced blackening (WHY?)

• P - sufficient levels $\Rightarrow$ reduced sensitivity to mechanical damage

• May be applicable to other tuber crops ??

NURITION & PLANT QUALITY

Section 5.4.3 Grain crops
Section 5.4.4 Oil crops
Section 5.4.5 Forage crops

Read; not on test

NURITION & PLANT QUALITY

VEGETABLES & FRUITS

- **Plant nutrients such as P, K, Mg, Cl, S, trace metals are also essential for animal species**
- **N is exception - not essential for animals**
- **NO_3^- could be problematic if high levels are consumed**

NURITION & PLANT QUALITY

- **$NO_3^- \Rightarrow NO_2^-$ during storage & processing of fruit & vegetables**
- **$NO_3^- \Rightarrow NO_2^-$ in stomach**
- **NO_2^- increases risk of formation of nitrosamines (carcinogenic)**
- **NO_3^-/ NO_2^- ingestion can cause NO_2^- to react with hemoglobin to form methemoglobin**
- **Blood cannot carry O_2 and infants will suffocate: “Blue Baby Syndrome”**

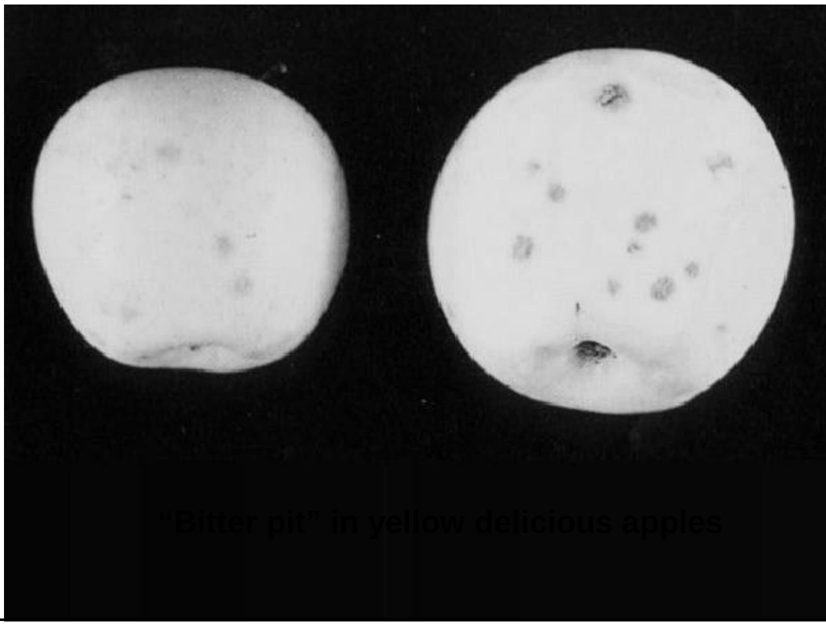
NURITION & PLANT QUALITY

- NO_3^- content: manage by application rate, timing & amount in soil
- NO_3^- sources: mineral fertilizers & O.M.
  - use care with slow-release fertilizers
- Light intensity is factor in NO_3^- reduction
- Vitamins, carotene - affected by N, K
- Fruit size, color, shape, flavor, taste affected by K, P, Ca

NURITION & PLANT QUALITY

- Ca especially important for many fruits & vegetables
- Low Ca:
  - apple - “bitter pit”
  - tomato - “blossom end rot”
  - may be due to too much vegetative growth during fruit filling & Ca $\Rightarrow$ growing shoots
- Weather conditions & climatic factors impt
  - proper climate for species of interest
  - T & light intensity important for flavor constituents

NURITION & PLANT QUALITY



"Bitter pit" in yellow delicious apples