Crops

Information contained in this presentation came from the National Engineering Handbook Irrigation Guide

Crops

- The purpose of irrigation is to supplement natural precipitation so that the moisture requirements of crops are met.
- Crop stress caused by moisture is mitigated by proper irrigation.
- Understanding crop water needs is essential to establish proper growth and yields.

Crops

- Good soil condition is key for optimum:
  - Aeration
  - Water infiltration
  - Permeability
  - Uniform root development
- Good soil condition can be maintained by:
  - Eliminating excess tillage
  - Avoiding field operations when soils are moist
  - Using organic material or crop residue
  - Using grass or legumes in rotation
  - Excluding livestock while soils are moist

Crops

- Healthy plants use water more efficiently
- Total water use is by a healthy plant is greater than that of a plant deprived of nutrients
- Yield per unit of water is much greater for healthy plants

Crops

- Proper nutrient levels are managed by maintaining proper soil pH, and by using an appropriate cropping system.
  - Liming may be needed in acidic soils
  - Leaching excess salts on saline soils
  - Amendments and leaching on sodic soils
- To determine proper nutrient needs one can:
  - Perform soil tests
  - Field observations
  - Planned yield and quality require certain fertilizers

Crops

- Optimum production requires:
  - Weed control
  - Insect control
  - High quality seeds
  - Applications of fertilizers according to plant needs
  - Good soil management
  - Good water management
  - Crop should fit the soil, water, climate, irrigation system,farm equipment, and market availability

Crops

- Water is one component needed to achieve a desired crop yield and quality
- A definition of water use efficiency is the amount of yield per unit of area per unit of water.
  - 6 bushels of wheat per acre per acre inch of applied water
- With these comparisons, improvements can be made

Crops

- Maintaining soil water within 5 bars tension usually provides the expected yield and quality
- Excessive irrigation can leach out essential plant nutrients, especially nitrates which are mobile in water
- Excessive irrigation can contaminate ground water

Crops

- Crops must have sufficient moisture throughout the growing season for optimum production.
- Most importantly water must be available to crops at critical periods of growth and development.
- Moisture stress during critical periods can cause irreversible loss of yield or quality.
- Some crops require mild moisture stress to set and develop fruit for optimum harvest timing.

Crops

- Irrigation timing should be determined by set methods to maintain crop continuity.
- Visual observations won’t always be accurate and can lead to misrepresentations because:
  - Moisture stress conditions may already have occurred
  - Some plants temporarily wilt to conserve water
  - Dry appearances may be due to lack of nutrients or pest damage
- Critical water periods will be shown in the following slides

Crops

Crop	Critical period	Comments
Alfalfa hay	At seedling stage for new seedlings, just after cutting for hay, and at start of flowering stage for seed production.	Any moisture stress during growth period reduces yield. Soil moisture is generally reduced immediately before and during cutting, drying, and hay collecting.
Beans, dry	Flowering through pod formation.	Sensitive to over-irrigation.
Beans, green	Blossom through harvest.	
Broccoli	During head formation and enlargement.	
Cabbage	During head formation and enlargement.	
Cauliflower	During entire growing season.	
Cane berries	Blossom through harvest.	
Citrus	During entire growing season.	Blossom and next season fruit set occurs during harvest of the previous crop.

Crops

Crop	Critical period	Comments
Corn, grain	From tasseling through silk stage and until kernels become firm.	Needs adequate moisture from germination to dent stage for maximum production. Depletion of 80% or more of AWC may be allowed during final ripening period.
Corn, silage	From tasseling through silk stage and until kernels become firm.	Needs adequate moisture from germination to dent stage for maximum production.
Corn, sweet	From tasseling through silk stage until kernels become firm.	
Cotton	First blossom through boll maturing stage.	Any moisture stress, even temporary, ceases blossom formation and boll set for at least 15 days after moisture again becomes available.
Cranberries	Blossom through fruit sizing.	
Fruit trees	During the initiation and early development period of flower buds, the flowering and fruit setting period (maybe the previous year), the fruit growing and enlarging period, and the pre-harvest period.	Stone fruits are especially sensitive to moisture stress during last 2 weeks before harvest.

Crops

Crop	Critical period	Comments
Grain (small)	During boot, bloom, milk stage, early head development and early ripening stages.	Critical period for malting barley is at soft dough stage to maintain a quality kernel.
Grapes	All growth periods especially during fruit filling.	See vine crops.
Peanuts	Full season.	
Lettuce	Head enlargement to harvest.	Water shortage results in a sour and strong lettuce. Crop quality at harvest is controlled by water availability to the plant, MAD 15 – 20% is recommended.
Melons	Blossom through harvest.	
Milo	Secondary rooting and tillering to boot stage, heading, flowering, and grain formation through filling.	

Crops

Crop	Critical period	Comments
Onions, dry	During bulb formation.	Maintain MAD 30 – 35% of AWC. Let soil dry near harvest.
Onions, green	Blossom through harvest.	Strong and hot onions can result from moisture stress.
Nut trees	During flower initiation period, fruit set, and midseason growth.	Pre-harvest period is not key because nuts form during midseason period.
Pasture	During establishment and boot stage to head formation.	Maintain MAD less than 50%. Moisture stress immediately after grazing encourages fast regrowth.
Peas, dry	At start of flowering and when pods are swelling.	
Peas, green	Blossom through harvest.	
Peppers	At flowering stage and when peppers are in fast enlarging stage.	

Crops

Crop	Critical period	Comments
Potato	Flowering and tuber formation to harvest.	Sensitive to irrigation scheduling. Restrict MAD to 30 – 35% of AWC. Low quality tubers result if allowed to go into moisture stress during tuber development and growth.
Radish	During period of root enlargement.	Hot radishes can be the result of moisture stress.
Sunflower	Flowering to seed development.	
Sorghum grain	Secondary rooting and tilling to boot stage, heading, flowering, and grain formation through filling.	
Soybeans	Flowering and fruiting stage.	
Strawberries	Fruit development through harvest.	

Crops

Crop	Critical period	Comments
Sugar beets	At time of plant emergence, following thinning, and about 1 month after emergence.	Frequent light applications during early growth period. Temporary leaf wilt on hot days is common even with adequate soil water content. Excessive fall irrigation lowers sugar content, but soil moisture needs to be adequate for easy beet lifting.
Sugarcane	During period of maximum vegetative growth.	
Tobacco	Knee high to blossoming.	
Tomatoes	When flowers are forming, fruit is setting, and fruits are rapidly enlarging.	
Turnips	When size of edible root increases rapidly up to harvest.	Strong tasting turnips can be the result of moisture stress.
Vine crops	Blossom through harvest.	
Watermelon	Blossom to harvest.	

Crops and adapted irrigation r

Crop	Management depth (ft)	Surface – level border	Surface – level furrow	Surface – graded border	Surface – graded furrow	Surface – graded corrug.	Sprinkler	Micro-	Subirr.
Alfalfa	5	x	x	x	x	x	x		
Beans, dry	3	x	x	x	x		x		
Beans, green	3				x		x	x	
Cane berries	3	x	x	x	x		x	x	
Citrus	3	x		x			x	x	
Corn, grain	4		x		x		x		x
Corn, silage	4		x		x		x		x
Corn, sweet	3		x		x		x		x
Cotton	3		x		x		x	x	

Crops and adapted irrigation r

Crop	Management depth (ft)	Adapted irrigation methods: Surface, level border	Surface, level furrow	Surface, graded border	Surface, graded furrow	Surface, graded corrug.	Sprinkler	Micro-	Subirr.
Grain, small	4	x	x	x	x	x	x		x
Cranberries	2	x					x		
Grass, seed	3	x	x	x	x	x	x		
Grass, silage	3	x	x	x	x	x	x		
Milo (sorghum)	3	x			x		x		x
Nursery stock	0-3	x	x	x	x		x	x	x
Orchard	5	x	x	x	x		x	x	x
Pasture	3	x		x		x	x		x
Peanuts	3		x		x		x		x
Peas	3	x	x	x	x		x		
Potatoes	3		x		x		x	x	

Crops and adapted irrigation r

Crop	Management depth (ft)	Surface: level border	Surface: level furrow	Surface: graded border	Surface: graded furrow	Surface: graded corrug.	Sprinkler	Micro-	Subirr.
Safflower	5	x	x	x	x		x		
Sugar beets	5		x		x		x		
Sunflower	5	x	x	x	x		x		
Tobacco	3						x	x	
Tomatoes	2		x		x		x	x	x
Turf, sod	2	x		x			x		
Turf	2	x		x			x	x	
Vegetables	1/	x	x	x	x		x	x	
Vegetables	2/	x	x	x	x		x	x	x
Vegetables	3/	x	x	x	x		x	x	x
Vegetables	4/	x	x	x	x		x	x	x

Crops and root systems

- Root systems are predetermined genetically:
  - Some have tap roots which penetrate deeply
  - Some have shallow lateral roots
- The distribution of the plant roots determines its moisture extraction pattern
- Annual crop root systems depend upon stage of growth
- All plants have very shallow root systems which only require light frequent watering in the beginning
- Roots will not grow into dry soil

Crops and root systems

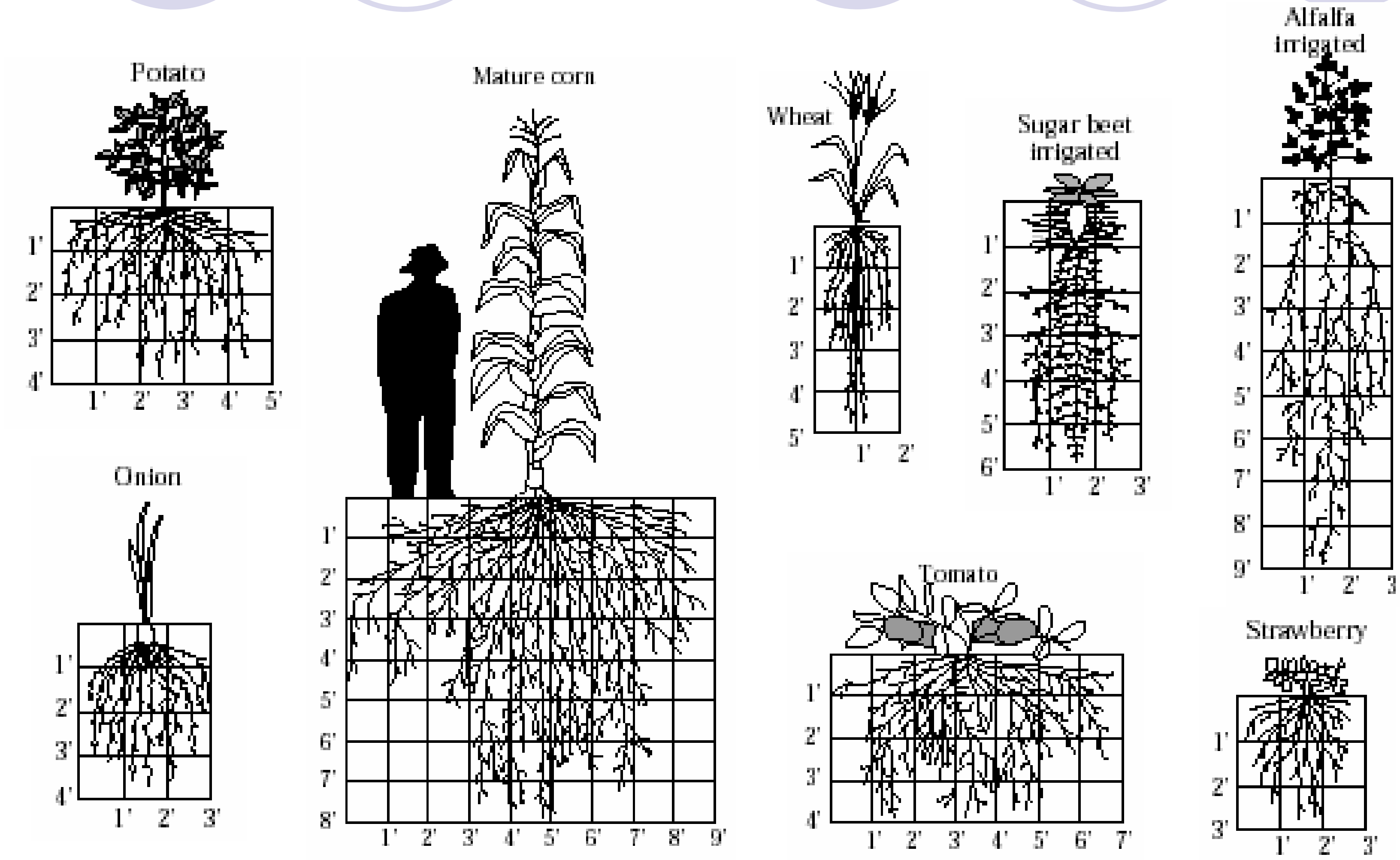
- Moisture absorbing roots are greatest in the upper part of the root zone.
- Extraction is most rapid in the zone of greatest root concentration and where occur favorable conditions of:
  - Aeration
  - Biological activity
  - Temperature
  - Nutrient availability

Depth to which crops will extract water

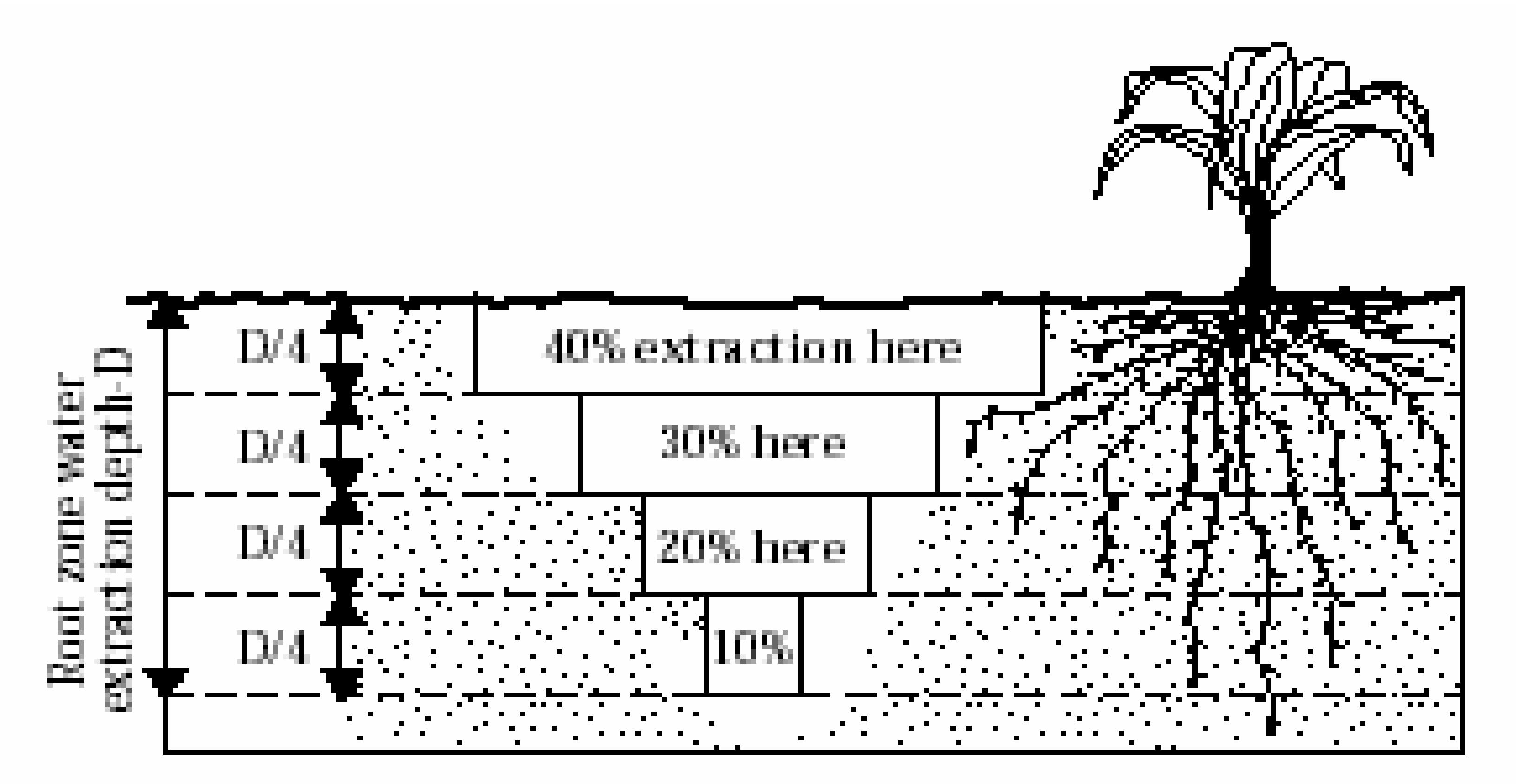
Crop	Depth (ft)	Crop	Depth (ft)
Alfalfa	5	Corn, sweet	2 - 3
Asparagus	5	Corn, grain	3 - 4
Bananas	5	Corn seed	3 - 4
Beans, dry	2 - 3	Corn, silage	3 - 4
Beans, green	2 - 3	Cotton	4 - 5
Beets, table	2 - 3	Cucumber	1 - 2
Broccoli	2	Eggplant	2
Berries, blue	4 - 5	Garlic	1 - 2
Berries, cane	4 - 5	Grains & flax	3 - 4
Brussel sprouts	2	Grapes	5
Cabbage	2	Grass pasture/hay	2 - 4
Cantaloupes	3	Grass seed	3 - 4
Carrots	2	Lettuce	1 - 2
Cauliflower	2	Melons	2 - 3
Celery	1 - 2	Milo	2 - 4
Chard	1 - 2	Mustard	2
Clover, Ladino	2 - 3	Onions	1 - 2
Cranberries	1	Parsnips	2 - 3
		Peanuts	2 - 3

Crop	Depth (ft)	Crop	Depth (ft)
Peas	2 - 3	**Trees**	
Peppers	1 - 2	Fruit	4 - 5
Potatoes, Irish	2 - 3	Citrus	3 - 4
Potatoes, sweet	2 - 3	Nut	4 - 5
Pumpkins	3 - 4		
Radishes	1		
Safflower	4	**Shrubs & misc. trees**	
Sorghum	4	**for windbreaks**	
Spinach	1 - 2	< 10 ft tall	2 – 3+
Squash	3 - 4	10 – 25 ft tall	3 – 4+
Strawberries	1 - 2	> 25 ft tall	5+
Sudan grass	3 - 4		
Sugar beets	4 - 5		
Sugarcane	4 - 5	**Other**	
Sunflower	4 - 5	Turf (sod & lawn)	1 - 2
Tobacco	3 - 4	Nursery stock	1 - 3
Tomato	3	Nursery stock	pots
Turnips	2 - 3		
Watermelon	3 - 4		
Wheat	4		

Root Distribution Systems



Typical water extraction pattern



Soil factors limiting root development

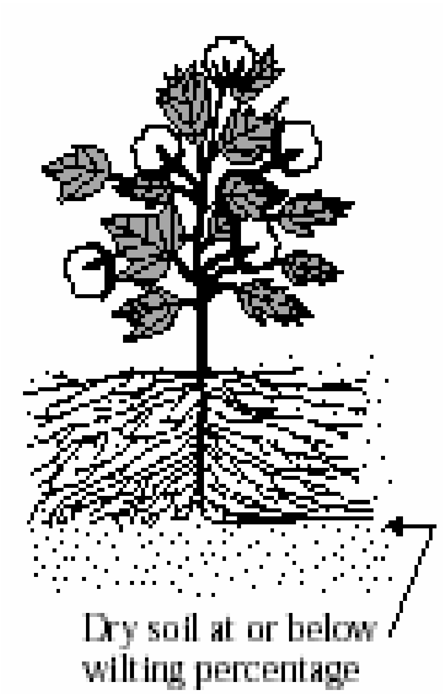
- soil density and pore size or configuration,
- depth to restrictive layers and tillage pans,
- soil-water status,
- soil condition,
- soil aeration,
- organic matter,
- nutrient availability,
- textural or structural stratification,
- water table,
- salt concentrations, and
- soil-borne organisms that damage or destroy plant roots.

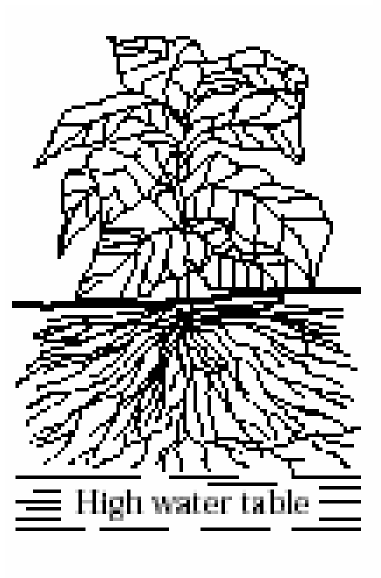
Crop root penetration

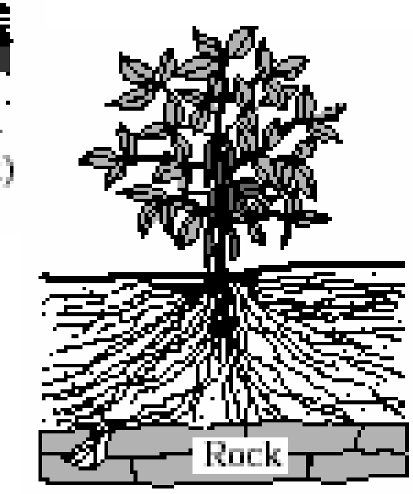
- Limitations
  - Dry soil
  - Water table
  - Bedrock
  - High salt concentrations
  - Tillage compaction layers
  - Dense fine textured soils
  - hardpans

- Every tillage operation causes some compaction which affects root penetration
- Compaction layers can be fractured by subsoiling when the soil is dry
- Only those field operations essential for successfully growing crops should be used
- Use a shovel or auger to determine actual root development patterns and limitations

Effects of root development on soils with depth limitations







Crop and irrigation requirements

- Crop evapotranspiration
  - Plants need water for growth and cooling
- Stomata
  - Small opening on the leaves allow the intake of CO_2
  - Water is lost to the atmosphere due to transpiration
- The total water used by the specific crop, which includes direct evaporation from plant leaves and the soil surface and transpiration, is called crop evapotranspiration (ETc).

Crop and irrigation requirements

- Irrigation frequency can be estimated by dividing the MAD by the estimated or measured evapotranspiration of the crop as follows:

$$\text{Irrigation frequency (days)} = \frac{\text{MAD}\left(\text{inches}\right)}{\text{Crop ET rate (in/day)}}$$

Crop and irrigation requirements

- Net irrigation requirement is the amount of water to be replaced at each irrigation, determined by the amount the soil can hold between field capacity and the moisture level selected when irrigation is needed

  (MAD)
- If the MAD level selected is 40 percent of AWC in the root zone (Soil-water Deficit = 40%), it is necessary to add that amount of water to bring the root zone up to field capacity. For example if the total soil AWC in the root zone is 8 inches and MAD = 40%:

$$\begin{aligned}\text{Net irrigation} &= 40\% \times 8 \text{ in} \\ &= 3.2 \text{ in}\end{aligned}$$

Crop and irrigation requirements

- Gross irrigation requirement is the amount of water to be applied to assure enough water enters the soil and is stored within the plant root zone to meet crop needs
- No system is 100% efficient
- Applying too much water too soon is the cause of greatest overuse of water

Crop and irrigation requirements

- Unavoidable water losses are caused by:
  - Unequal distribution of water being applied over the field.
  - Deep percolation below the plant root zone in parts of the field.
  - Translocation or surface runoff in parts of the field.
  - Evaporation from the soil surface; flowing and ponded water.
  - Evaporation of water intercepted by the plant canopy under sprinkler systems.
  - Evaporation and wind drift from sprinklers or spray heads.
  - Non-uniform soils.

Crop and irrigation requirements

- Irrigation system efficiency depends upon the skills used in:
  - Planning
  - Designing
  - Installing
  - Operating the system
- Local climatic and physical site conditions must be assessed:
  - Topography
  - Soils

Crop and irrigation requirements

- Gross irrigation amounts can be determined with this formula:

$$\text{Gross irrigation amount (in)} = \frac{\text{Net amount to be replaced (in)}}{\text{Overall irrigation efficiency of system including management (\%)}}$$

$$= \frac{\text{Management Allowable Depletion (MAD)}}{\text{Overall irrigation efficiency}}$$

Crop and irrigation requirements

- Opportunities for reduced irrigation water application
  - Maximizing effective rainfall.
  - Deficit or partial season irrigation.
  - Selection of crops with low water requirements during normal high water use periods; i.e., small grains, (or accept the risk of drought periods).
  - Selection of drought resistant crops and varieties that provide yields based on water availability, i.e., alfalfa hay, grass pasture (accept the reduced yields caused by drought periods).
  - Irrigate just before critical growth period(s) of the crop to minimize critical plant moisture stress during those periods.

Crop and irrigation requirements

- Opportunities for reduced irrigation water application
  - Use state-of-art irrigation scheduling techniques that use local area climate and onsite rainfall data, and field-by-field soil moisture status monitoring.
  - Use tillage practices that allow maximum surface storage and infiltration of rainfall events, reducing runoff and soil surface evaporation.
  - Follow an intensive crop residue management and mulch program and minimize tillage to reduce soil surface evaporation.
  - Reduce irrigated acreage to that which can be adequately irrigated with the available water supply.

Crop and irrigation requirements

- Steps for improving water management:
  - Improve irrigation scheduling, and water measurement
  - Improve existing irrigation system, unless the system meets the needs of the crops grown

Crop and irrigation requirements

- Crops are placed in categories for irrigation purposes:
  - **Category 1. Row or bedded crops:** sugar beets, sugarcane, potatoes, pineapple, cotton, soybeans, corn, sorghum, milo, vegetables, vegetable and flower seed, melons, tomatoes, and strawberries.
  - **Category 2. Close-growing crops** (sown, drilled, or sodded): small grain, alfalfa, pasture, and turf.
  - **Category 3. Water flooded crops:** rice and taro.
  - **Category 4. Permanent crops:** orchards of fruit and nuts, citrus groves, grapes, cane berries, blueberries, cranberries, bananas and papaya plantations, hops, and trees and shrubs for windbreaks, wildlife, landscape, and ornamentals.

Crop and irrigation requirements

- All crops can be efficiently irrigated by more than one method
- A comparison of irrigation system versus crops that can reasonably grown with that system

Irrigation system	- - - Crop category - - -			
	1	2	3	4
Surface				
Basins, borders		x	x	x
Furrows, corrugations	x	x		x
Contour levee - rice		x	x	
Sprinkler				
Side (wheel) roll lateral	x	x		
Hand move lateral	x	x		x
Fixed (solid) set		x		x
Center pivot, linear move	x	x		
Big guns - traveling, stationary	x	x		
Micro				
Point source				x
Line source	x			x
Basin bubbler				x
Mini sprinklers & spray heads				x
Subirrigation	x	x	x	x

Crop and irrigation requirements

- Temperature effects and management
  - Water applied in a timely manner can provide protection
- Extremely high temperatures can
  - put plants into a temporary plant moisture stress,
  - hasten untimely fruit development and ripening,
  - cause moisture stress in ripening fruit,
  - sunburn berries and other fruit,
  - overheat bare soils during seed germination (i.e., lettuce),
  - overheat standing water in basin irrigation.

Crop and irrigation requirements

- Low temperatures can damage both annual and perennial plants
- If ambient air temperature and humidity are severely low permanent damage will occur to fruit, citrus, and nut trees
- Water can be applied to provide frost protection to about 25 °F.
- Frost protection occurs because of the heat caused by water changing to ice

Crop and irrigation requirements

- Salinity and sodicity effects:
  - When water is removed from the soil profile by plant transpiration and soil surface evaporation, salts remain in the soil profile and on the soil surface. If the soil-water solute is high in sodium, the soil becomes sodic. All other ionic concentrations in solution (i.e., calcium, magnesium, potassium) cause salinity.
- Can become serious if:
  - irrigation or natural precipitation is not sufficient to leach the accumulating salts,
  - water and soil management are less than adequate,
  - soil and water amendments are inadequate, or
  - the soil is poorly drained.

Crop and irrigation requirements

- Salinity and sodicity effects on AWC
  - Plants extract water from the soil by exerting an adsorptive force or tension greater than the attraction of the soil matrix for water.
  - As the soil dries, remaining water in the soil profile is held more tightly by soil particles.
  - Salts also attract water.
  - The combination of drying soils and elevated salt concentrations results in less water at a given tension being available for plant uptake.
  - If the salt content cannot be managed properly other crops should be considered

Crop and irrigation requirements

- Management practices for salinity and sodicity control
  - Improved irrigation water management
  - Improved crop residue management
  - Adding soil and water amendments
  - Selection of more salt-tolerant crops
  - Leaching with additional irrigation water
  - Pre-plant irrigations
  - Changing of seed placement on the furrow bed

Crop and irrigation requirements

- Toxic elements
  - Normally results when certain ions are found in the soil
  - Chloride
  - Sodium
  - Boron
  - Selenium
- The extent of damage (phytotoxicity) depends on
  - Concentration
  - Crop sensitivity
  - Crop growth stage
  - Crop water use rate