


Transpiration & Water Loss




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Water Loss

- Typically, 90 to 95% of a commodity is water
- Besides resulting in direct loss of salable weight, it is also an **important source of quality loss**
 - Appearance quality** - wilting, shriveling, accelerated development of injuries
 - Textural quality** - loss of crispness, juiciness, etc.
 - Nutritional quality** - e.g. vitamins A & C
- Thus, managing water content of commodities is critically important



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% Water Loss	Potential Effects
0.5	Increased activity of some cell wall enzyme.
1	Increased carbon dioxide & ethylene production. Faster ripening, yellowing & abscission. Reduce wound healing (periderm formation).
2	Reduced turgor. Increased ABA content, reduced susceptibility to chilling injury. Accelerated loss of volatiles.
3	Reduced severity of certain physiological disorders. Loss of membrane integrity.
4	Faster loss of vitamins A & C. Loss of flavor. Discoloration of mechanical injuries.
5	Loss of color intensity & gloss. Accentuation of pitting associated with chilling injury. Wilting & shriveling.
6	Loss of textural quality, e.g., softening, limpness, flaccidity, & loss of crispness & juiciness.

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Percent water loss that results in unmarketability

Commodity	% Loss
Asparagus	8
Brussels sprouts	8
Cabbage	7
Celery	5
Lettuce	3
Spinach	3

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Effects of Water Loss

- Physical Effects
- Economic Effects
- Physiological Effects

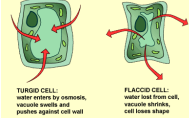



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Effects of Water Loss


- Physical Effects
 - Reduced turgor pressure from as little as 2% water loss =>
 - Wilting & flaccidity of vegetables
 - Shriveling and wrinkling of fruit
 - Shrinking produce within a package allows it to move/vibrate during transport = damage

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Effects of Water Loss


- Economic Effects
 - Commodities are often sold on a weight basis
 - Less weight = lower price
 - Reduced quality/grade of a commodity reduces its value



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Effects of Water Loss

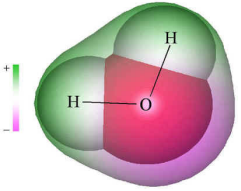
- Physiological Effects (% water loss)
 - Detrimental
 - Increased respiration & ethylene production (1%)
 - Reduced periderm formation in some roots and tubers (1%)
 - Faster ripening, yellowing & senescence (1%)
 - Accelerated reduction in volatiles (2%)
 - Faster loss of vitamins A & C (4%)
 - Stem end rind breakdown (unknown%)



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Water - The Molecule

- O atom covalently bonded by 2H
 - 105° bond angle

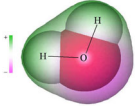


http://xnet.rrc.mb.ca/rcharney/The%20water%20molecule_files/molecul2.jpg

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Water - The Molecule

- Polar molecule
 - O atom - partially negative
 - 2H atoms - partially positive
 - Overall - neutral molecule
 - Water's polarity is responsible for many of its unique properties
- Water has one of the highest Dielectric Constants (a measure of a molecule's polarity)

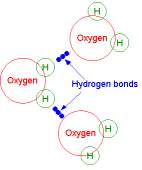


http://xnet.rrc.mb.ca/rcharney/The%20water%20molecule_files/molecul2.jpg

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Hydrogen Bonding

- Polarity gives rise to Hydrogen Bonds
- H-bonding = the weak electrostatic attraction between partially (+) charged "H" and partially (-) charged "O"
 - Besides water, H-bonds can also form between other molecules with other electronegative atoms (O or N)




<http://www.mse.cornell.edu/courses/engr111/images/hydrogn.gif>

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Properties of Water


- High Specific Heat (S.H.) (1 kcal/kg/°C)
 - Lots of energy required to raise the temperature of water 1 °C
- High Thermal Conductivity (T.C.) (5.2 kcal/kg/h/°C)
 - Water rapidly conducts heat away from the point of application
 - Disperses heat quickly (reason for effectiveness for hydrocooling)



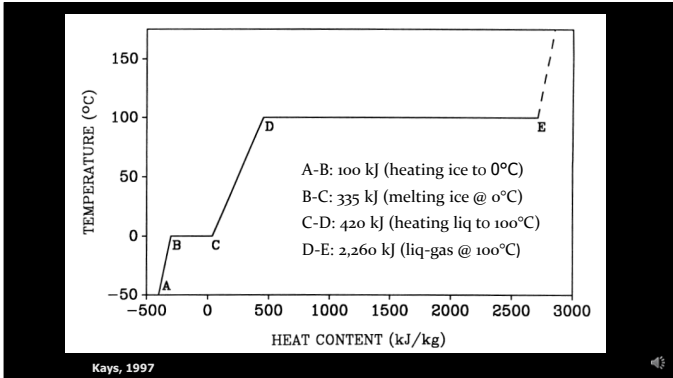
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Properties of Water

- **High heat of vaporization** (540 kcal/kg)
 - Water that evaporates (transpiration) absorbs a great deal of heat => cools the plant tissue
- **High heat of fusion** (80 kcal/kg)
 - When water goes from a liquid to a solid, it releases heat energy. Principal behind freeze protection
 - From solid to liquid, water absorbs energy. Added benefit for top-icing




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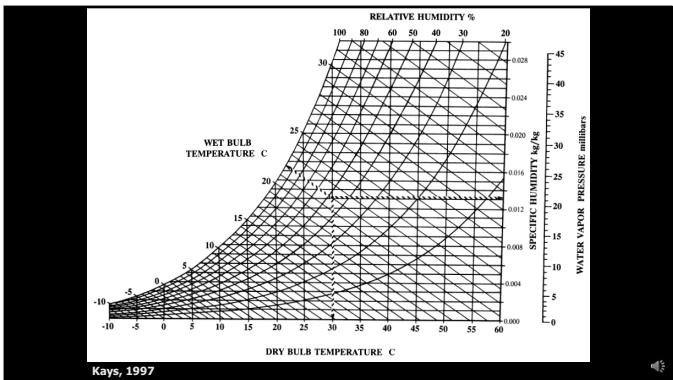


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The Psychrometric Chart




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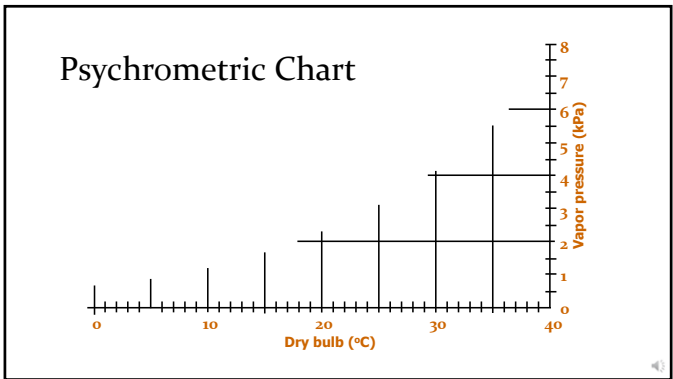
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Liquid – Gas Equilibrium

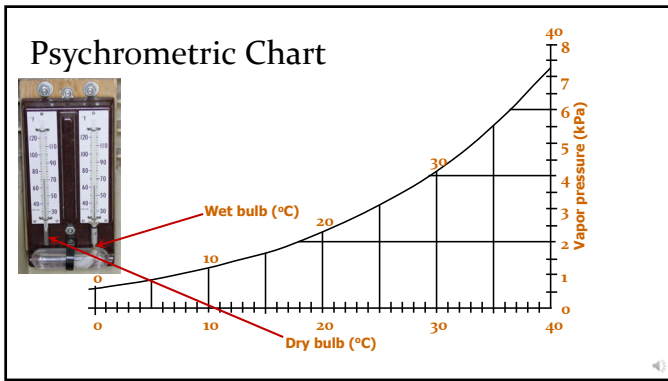
- **Humidity Ratio (HR):**
 - Also called the mixing ratio, specific humidity, or absolute humidity
 - Shows the moisture content of the air (= water content mass of water per mass of air)
 - Water vapor is often only = 0.4 to 1.5% of the weight of air
- **Vapor pressure:**
 - Directly proportional to humidity ratio
 - Shows the partial pressure of water vapor in the air



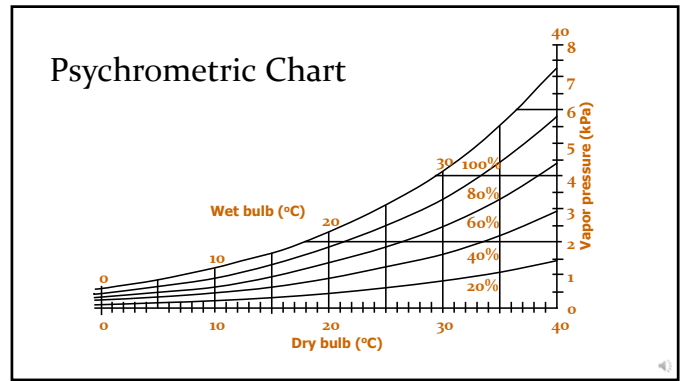
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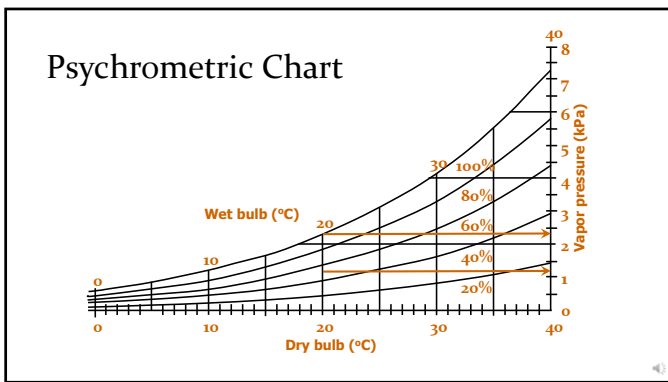
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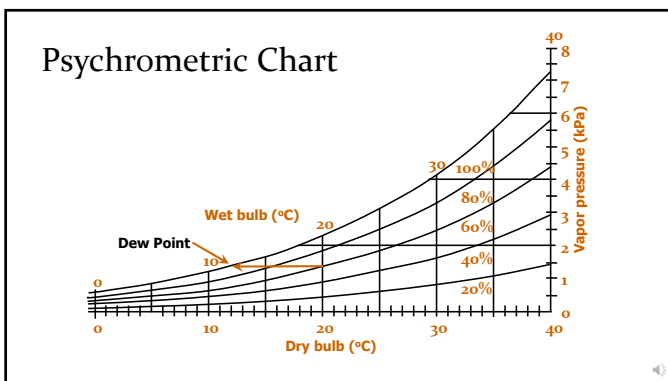
Relative Humidity

- Relative humidity (RH):
 - Corresponds to the ratio of actual water content of the air to the maximum water content at a given temperature

$$RH = \frac{VP}{SVP} \times 100$$

- RH = Relative humidity
- VP = Vapor pressure
- SVP = Saturated vapor pressure (100% relative humidity)

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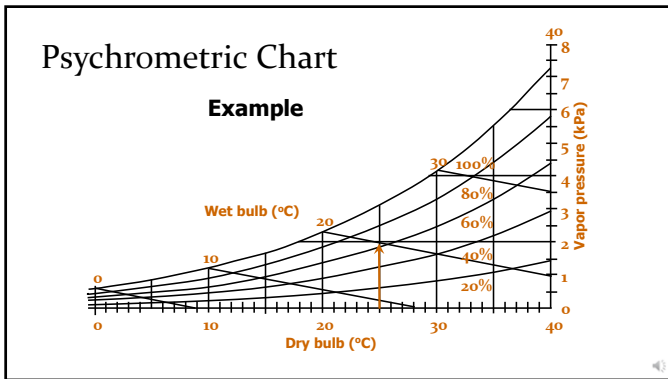


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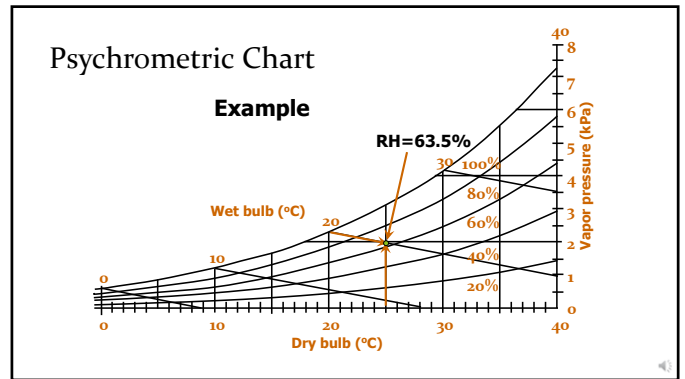
Dew-Point

- Dew-point temperature:
 - Where the horizontal lines intersect the wet-bulb temperature line
 - Represents the point where condensation begins to form as the air is cooled
 - As the air cools, its water-holding capacity decreases until it is no longer able to hold even the water vapor it initially held

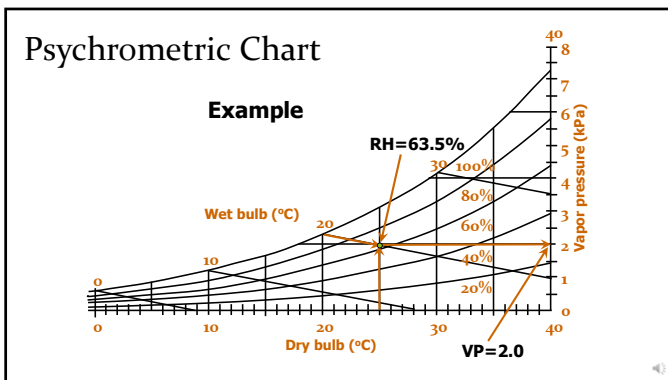
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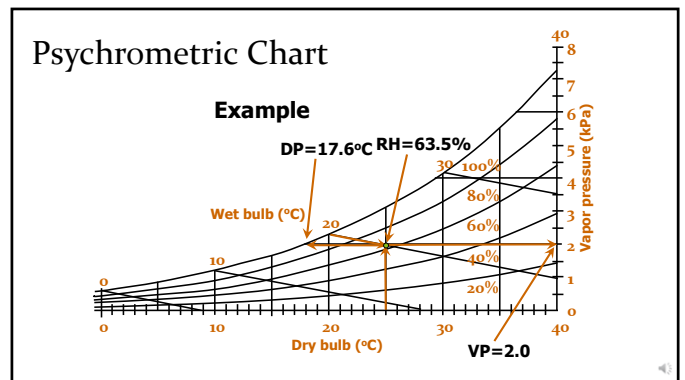
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Liquid – Gas Equilibrium

Key concepts

- Maximum air water content (vapor pressure or humidity ratio) increases rapidly with increasing temperature
- Warm air can hold more water than cold air

Kays, 1997

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Liquid – Gas Equilibrium

Key concepts

- When warm, moist air is cooled, RH increases until it reaches its dew-point
- Air cooled below its dew-point begins to lose water as condensation

Kays, 1997

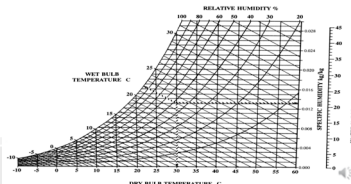
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Liquid – Gas Equilibrium

Key concepts

- Placing a cold commodity in a warm room with moist air, cools the air that contacts the commodity to below the dew-point

– Condensation will form on the commodity surface (AKA “sweating”)



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Liquid – Gas Equilibrium

Key concepts

- Placing a warm commodity in room with cold, moist air will warm the air contacting the commodity
 - The RH will drop as the air warms because warmer air can hold more water
 - Increased water loss until the commodity is cooled
- Delayed cooling results in greater water loss



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Water Loss

- The rate of water diffusion between two points is related to the concentration gradient
 - Greater concentration (or vapor pressure) difference = faster diffusion rate (stronger driving force)
 - VPD (vapor pressure difference) is the driving force of water movement
 - The vertical bars represent VPD between 80% and 100% RH at 0°C & 40°C



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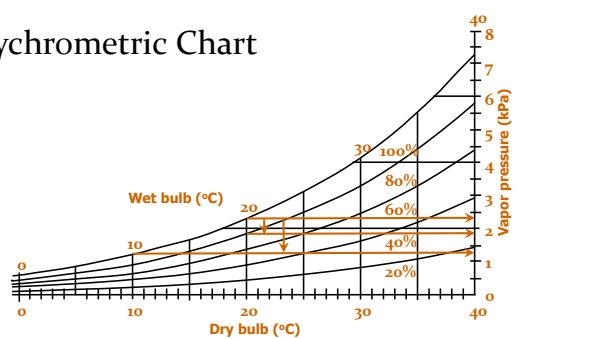
Water Loss

- $VPD = SVP_{tissue} - VP_{air}$
- SVP_{tissue} = Saturation vapor pressure of the air at a given temperature
 - Air within a commodity is nearly saturated (no less than 95%, usually estimated at 100%)
- VP_{air} = Vapor pressure of the air at a given temperature, pressure & RH



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Psychrometric Chart



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Water Loss

- For each commodity:



$$J = VPD * k$$
 - J = rate of water loss
 - e.g., %/day, gm/h, lb/week, etc.
 - k = proportionality constant
 - Depends on different features of the commodity



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Sample Questions



- Calculating RH, dew-point, vapor pressure (humidity ratio) based on wet-bulb & dry-bulb measurements
- How do these change when air is warmed and cooled. When does air lose water or dry commodities out?
- What happens when air moves over refrigeration coils?
- Boundary air layer – effects of wraps, packaging, and air speed

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Factors Affecting Water Loss

- Commodity factors
 - Surface to volume ratio
 - Routes of water loss
 - Epidermal cells vs. periderm & other cells
 - Structure of the surface
 - Stomates – Cuticular waxes
 - Lenticels – Trichomes
 - Surface imperfections – Architecture

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Radish Weight Loss






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Factors Affecting Water Loss

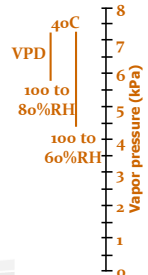

- Commodity factors (continued)
 - Physiological state of the commodity
 - Stage of maturity or stage of ripeness – more mature commodities generally lose less water
 - Cultivar
 - Cultural conditions
 - Weather or growing practices

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Factors Affecting Water Loss

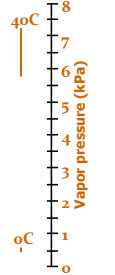

- Environmental factors
 - Humidity
 - Lower humidity => greater VPD => greater water loss
 - Diffusion shells and air velocity
 - Outside the epidermis, there is a thin layer of air that maintains high humidity ("diffusion shell"). Surface features (e.g. hairs) strongly influence the thickness of this shell
 - Faster air flow => decreases thickness of the diffusion shell => increases water loss

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Factors Affecting Water Loss

- Environmental factors (continued)
 - Temperature
 - Higher temperatures => generally greater VPD => greater water loss
 - Atmospheric pressure
 - Lower pressures (high altitudes) increases water loss






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Reducing Water Loss

Commodity Treatment

- Addition of water to some commodities (incl. cut flowers, potted plants)

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Reducing Water Loss

Commodity Treatment

- Careful handling
 - Injury and punctured surfaces greatly increase water loss
 - Proper temperature, R.H., packaging, etc.




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Reducing Water Loss

Commodity Treatment

- Rapid cooling & keeping cold





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Reducing Water Loss

Commodity Treatment

- Curing of certain root, bulb, and tuber vegetables

<https://uapbnews.wordpress.com/2015/10/13/sweet-potatoes-proper-curing-improves-quality-shelf-life/>




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Reducing Water Loss

Commodity Treatment

- Waxing and other surface coatings




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Reducing Water Loss

Commodity Treatment

- Use of plastic films (wraps) that act as moisture barriers




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Reducing Water Loss

Commodity Treatment

- **Packaging**
 - Polyethylene or plastic liners
 - Wood or plain fibreboard boxes can absorb water




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Reducing Water Loss

Manipulating the Environment

- Maintaining temperature of refrigeration coils within 1°C of the air temperature
 - Larger evaporator coils
- Minimizing air movement around the commodity & reducing room air exchanges
- Addition of moisture to the air (**humidifiers**)




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Reducing Water Loss

Manipulating the Environment

- **Moisture barriers**, e.g.
 - In the walls of storage rooms and transport vehicles
 - Polyethylene liners or curtains within shipping containers
- **Wet the floor** in storage rooms



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Reducing Water Loss

Manipulating the Environment

- Use **crushed ice** in shipping containers and in retail display of commodities that tolerate direct contact with ice




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Reducing Water Loss

Manipulating the Environment

- **Sprinkle produce with water** during retail marketing
 - Can be used on leafy vegetables, cool-season root vegetables, and immature fruit-vegetables (e.g., snap beans, peas, sweet corn, and summer squash)

<http://www.gocornheadquarters.com/October-2011/UltraMist-Guarantees-Leak-Free-Spray/>



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