



CRAVO EQUIPMENT LTD.

Principals for Optimizing Plant Growth and Quality in Retractable Roofs

1. Inputs for photosynthesis (light, CO₂ and water) impact the **speed of plant growth**.
2. Plant stresses impact on **how the plant grows**, generally referred to as plant quality.
3. **How the plant develops** is primarily affected by transpiration, water stress, changes in leaf and soil temperature.
4. The **transpiration** rate is impacted by infra red radiation, wind, relative humidity and air temperature. We cannot easily measure transpiration, but by observing the plant, we can determine what level of transpiration the plants have been exposed to.
5. **Insufficient transpiration** rates cause plants to develop larger leaves, thin cuticles, longer internodes, smaller root to shoot ratio, vegetative growth. The thin cuticle makes plants more susceptible to insects, fungus. Low transpiration also reduces nutrient uptake and development.
6. **Optimal transpiration** rates cause plants to develop smaller leaves, thick cuticles, shorter internodes, larger root to shoot ratio, generative growth. The thick cuticle makes plants more resistant insects, fungus. Higher transpiration rates increase nutrient uptake and distribution.
7. **Excessive transpiration** rates cause excessive water stress which causes plants to lose their defence mechanisms against insects and develop dwarf characteristics.
8. Plants grown with low transpiration rates cannot tolerate rapid changes to high transpiration rates. Plants grown with high transpiration rates can tolerate rapid changes to low transpiration rates.
9. In the natural outdoor environment, **transpiration** is generally optimal when outdoor temperatures are optimal and excessive when outdoor temperatures are excessive. Transpiration is generally insufficient when plants are under a protective cover.
10. Direct **infrared radiation** causes soil and exposed fruit temperature to increase faster and reach higher temperatures than air temperatures. Outside soil temperatures of 60C have been measured when it was sunny and air temperatures were only 33C. If it was cloudy, then soil temperatures would be 33C. Transpiration will be higher when leaves are exposed to direct infrared radiation.
11. Greenhouse coverings intercept infrared radiation causing a reduction in fruit and soil temperatures but an increase in air temperatures. When the air temperature is warmer than the leaf temperature, transpiration is significantly reduced.
12. When outdoor air temperatures are greater than 28C and infrared radiation is high, it is best to reduce infrared radiation while minimizing reductions in visible light. A white plastic covering with a 40% shade will intercept more radiation and yet transmit more light than 50% black shade cloth.
13. A black surface outside is a better measure of plant temperature than air temperature since it incorporates the heating affect of infra red radiation.

Conventional growing environments

Open Field

Environmental challenges:

- excessive cold, excessive heat, excessive transpiration rates, rain, wind and insects

Typical Crop Management Strategy

- react to problems caused by negative weather conditions since there is no ability to protect crops proactively

Nethouse

Environmental challenges:

- insufficient transpiration
- excessive soil moisture excessive after rain
- insufficient soil temperatures in the winter

Typical Crop Management Strategy

- react to problems caused by negative weather conditions since there is no ability to protect crops proactively

Conventional Greenhouse

Environmental challenges:

- insufficient transpiration and water stress
- insufficient soil temperatures in the winter

Typical Crop Management Strategy

- try to create the best possible environment **inside** the greenhouse even when outdoor conditions are optimal

Retractable Roof Greenhouse

Environmental challenges:

- insufficient transpiration and water stress outside temperatures are cold and the roof is completely closed

Typical Crop Management Strategy

- use the roof to take advantage of the positives of the open field environment, a net house environment and a greenhouse environment while avoiding the negatives of each
- balance the plants need for optimal temperatures with the need to optimize transpiration

How retractable roofs can take advantage of all conventional growing environments while preventing the challenges with each

The strategy to optimize both speed of growth and plant quality using both the natural outdoor environment and a greenhouse environment follows. When the outside surface temperature is:

1. **below 16C**, the roof should be closed to maintain minimum desired plant temperatures
2. **above 17C**, the roof should be retracted to increase light, CO₂, transpiration, and water stress
3. **above 28C**, the roof should be closed 85% to reduce IR radiation, reduce leaf and fruit temperatures, transpiration and water stress
4. When wind is excessive, close the roof to protect plants
5. When rain is excessive, close the roof to protect plants

Why a white roof covering is used on the retractable roof when growing in warm climates:

- When outdoor conditions are optimal and the roof is retracted, plants receive full light spectrum so the white covering does not limit light levels to the plants
- When temperatures are excessive and the roof is closed 85%, the white roof covering blocks more infrared radiation and diffuses incoming light so that leaf temperatures are reduced. Surface soil temperatures of 71C were measured in Mexico in full sun. Closing the roof 85% dropped the soil temperature to 43C.
- When it is cold at night and the roof is closed, infrared radiation loss is reduced.

How to make communication about crop management more effective

1. Speak about the plant, not about the environment. For example:
 - a. say “transpiration is too low” instead of “ the humidity is too high” Transpiration is what you should really be managing, but humidity is only one factor affecting transpiration.
2. Do not ignore the effect of infrared radiation
3. Measure soil temperatures
4. Measure leaf temperatures