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“The Challenge”

“Welcome to the new normal, the world as we know it is being disrupted; new business rules are being written. The economic downturn is shaking up business models. Our industry is being challenged to grow with less, while feeding more. Globalization is shifting our markets. Meanwhile, “new” consumers are fundamentally changing their shopping behavior. These disruptions offer opportunity – for innovation, for growth, for a chance to make our business stronger in the long term. The companies that understand and adapt to the new realities are the ones that will succeed.”

Brian Silverman, President, Produce Marketing Association, August 2009

The Retractable Roof Production System can help growers meet “The Challenge”

The retractable roof production system allows growers in warm climates to uniquely utilize the benefits of the natural outdoor environment and the protection of a controlled greenhouse environment to **lower input costs** while:

- **Extending harvest seasons** in order to realize the higher prices of the shoulder seasons and extend supply season to distributors
- **Increasing yields** which reduces the fixed costs per case
- **Eliminating the supply disruptions** due to erratic weather... so that growers never lose a customer
- **Growing organically or chemical free** in order to achieve higher revenues and lower production costs
- **Increasing the shelf life**

The retractable roof production system can **increase profit per kg or pound 200%-500%** and generate a **return on investment in 2 to 5 years** depending on the crop and growing environment.

<p>Grow with less...</p> <ul style="list-style-type: none"> • area (smaller footprint) • water, labor, energy, agrichemicals • losses due to excessive cold, heat, wind, rain in the open field • losses due to limitations of conventional greenhouse production systems 	<p>Feeding more due to...</p> <ul style="list-style-type: none"> • higher yields per plant • longer harvest seasons • longer shelf life
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Overview of Retractable Roof Production System for Fruit and Vegetable Production in Warm Winter Climates

Retractable Roof Greenhouses/ Shadehouses are a hybrid production system that utilizes the benefits of the open field, a conventional greenhouse and a shadehouse.

Farmers growing in the open field have to live with the losses due to excessive cold, heat, wind, rain and insects since they have no ability to control the weather. They have the lowest cost production system available, however their quality, yield and timing depends on the weather. They tend to have to plant many hectares of produce in order to have sufficient quantity of harvest due to the losses caused by excessive cold, heat, wind, rain and insects.

Growers who have built low tech conventional net houses and greenhouses to protect plants from the weather extremes face challenges totally different of those of the open field farmer: insufficient light and CO₂ levels during the early morning and late afternoon, excessive humidity levels and insufficient wind which causes plants to stretch and grow more leaves and less fruit, insect populations which can quickly grow out of control, foliar diseases, nutritional deficiencies, pollination problems and salt build up in the soils over the years.

Retractable roofs are a tool which can help growers take advantage of both outdoor and greenhouse conditions while preventing the disadvantages of each. Most conventional greenhouses are designed to excel in cold dark locations like Holland and Canada where temperatures are too cold to retract the roof.

Consequently, conventional greenhouses have been designed to try to create the best possible environment inside a greenhouse but that tends to increase the capital and operating cost and increases the level of education and experience required of the greenhouse manager. Growing vegetables in conventional closed greenhouses creates a totally foreign environment for the plants and results many new problems that farmers have never been exposed to when growing outside. These problems become more significant in warm climates with higher humidity levels. The result is that many new greenhouse ventures are not profitable when farmers try to transition from a field into a conventional closed greenhouse.

The Cravo retractable roof production system however, is designed to excel in sunny warm climates. The primary concept of the retractable roof is that a retractable roof is being installed over an outdoor field and that many of the field practices and protocols will still be applicable. The best case scenario is that the same farm equipment can be used in the retractable roof as is used in the field. Simple drip irrigation systems have proven to be economical, efficient, effective and easy to use. The retractable roof growing system implies that the preferred growing environment is the natural outdoor environment and that the retractable roof is going to be closed to protect the outdoor plants only when extreme cold, heat, wind, rain is present. Farmers who have experience growing in fields find the transition into the retractable roof must easier than into a conventional closed greenhouse since they are still growing outside when outdoor conditions are suitable, but



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they now have the ability to close the roof to protect plants from excessive rain, heat, wind or cold. Farmers find it easy to understand that they will be able to take advantage of the best of the natural outdoor conditions and the best of a greenhouse by being able to open and close the roof as conditions change.

The retractable roof is fundamentally different from conventional greenhouses since it uses reinforced polyethylene roof coverings which can have a usable life of 7 to 12 years which is double to triple the life of conventional greenhouse plastic roofs. The retractable roof allows the roof to retract 90% ensuring the ventilation is never insufficient and light reduction during early morning and late afternoons is not excessive. When the retractable roof is installed in a hot climate, the roof covering is typically white which helps reduce soil temperatures from 70C (158F) in the full sun down to 40C (104F) under the white plastic roof. This dramatic reduction in the infra red radiation exposure helps ensure that plants stay active and healthy during hot summer conditions. The excellent cooling properties of the roof covering allow for production in warmer climates where heating systems are not required.

Benefits of the Retractable Roof Production System

Retractable Roofs can be the most profitable fruit and vegetable production system in warm climates since they allow growers to increase revenues by improving the **quantity, quality and timing** of production while lowering fixed production costs.

Analyzing the linkage between the growing environment, the retractable roof and the profitability of the production

1. Examine the advantages and disadvantages of the outside growing environment where crops are grown
2. How Retractable Roofs can modify the environment to create the best possible growing environment
3. How plants respond to changes in the environment due to the retractable roof
4. How the yield, quality and timing of the harvested is impacted by the plant response to the retractable roof environment
5. How the profitability of the production is affected by the changes in yield, quality and timing and production costs



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The way one looks at the benefits of the retractable roof depends whether the grower is more of an open field grower or a greenhouse grower.

Compared to farmers growing in the open field, retractable roofs can:

1. Help harvest earlier and later
2. Produce fruit that meets the quality standards of both food service and supermarkets
3. Improve yields 200% to 300% per sq m allowing for a 50% to 75% reduction in area planted
4. Reduce water usage 50% per hectare and up to 75% per kg of tomato
5. Increase the natural disease and insect resistance by protecting plants from excessive transpiration
6. Reduce the insect reproduction rate
7. Reduce and/or eliminate the use of agrichemicals for insect and disease control
8. Allow growers to use soap and garlic for control
9. Increase the shelf life of fruits and vegetables

For growers producing in the open field, producing tomatoes in the retractable roof can **increase the profit per hectare from US\$ 15,500 in the open field to \$135,000 retractable roof. Profit per kg can increase from \$0.19 to 0.45/kg.** This increase in profitability is accomplished by targeting high priced market windows and using the higher yields to reduce the fixed operating costs by growing on a smaller footprint. For climates like the arid locations of Mexico, the **return on investment can be 2-5 years.** The savings in fixed production costs from growing on a smaller footprint in a retractable roof are frequently sufficient to make the yearly bank loan payments on a 5 year loan for the purchase of a retractable roof greenhouse making the purchase of the retractable roof essentially cash flow neutral for the first 5 years.

For growers using nethouses or low tech greenhouses, retractable roofs can:

1. Help harvest earlier and later
2. Improve yields 60% to 150%
 - a. Eliminate the yield losses due to dust/ dirt build up on the roof since the roof is retractable most mornings and later in the afternoon
 - b. Prevent the excessive vegetative growth by increasing the transpiration rate
 - c. Increase plant densities due to higher light and lower humidity levels
3. Double the yield of large and extra large fruit
4. Produce fruit that meets the quality standards of both food service and supermarkets
5. Reduce the size of the area to be planted
6. Prevent the pollination problems typical in greenhouses by lowering humidity levels
7. Increase the natural disease and insect resistance by increasing the cuticle thickness of the plants
8. Reduce the insect reproduction rate by reducing temperature and humidity levels



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9. Reduce or eliminate the use of agrichemicals and allow growers to use soap and garlic for control
10. Reduce labor costs to prune and manage plant since plants naturally grow more balanced
11. Reduce water usage by using the rain to irrigate and to clean the soil
12. Prevent the salt build up in soils by allowing rain to help clean or leach the soil
13. Allow for larger greenhouses to be build helping to reduce capital costs and improve labor efficiency
14. Reduce or eliminate the need for fossil fuels for heating by locating in warmer climates and using the retractable roof to exploit the heating effect of the sun.
15. Eliminate the need for expensive sophisticated irrigation/ fertigation systems since the plants tend to lose optimal amounts of water and the higher transpiration rate makes it easier for plants to absorb synthetic or organic fertilizer

For growers currently growing tomatoes in conventional nethouses or low tech greenhouses, depending on the location, the **profit per hectare can be around \$40,000 per hectare for a nethouse, \$75,000 for a conventional low tech polyhouse and \$135,000 for a retractable flat roof. The profit per kg can be \$.26 for the nethouse, \$0.31 for the poly covered greenhouse and \$0.45 for the retractable flat roof.** The return on investment can be around 1.5 years for the nethouse, 3-5 years for the poly covered greenhouse and 2-5 years for the retractable roof.



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Retractable Roofs help make food production sustainable and environmentally friendly

1. Up to a **85% reduction in water** usage per kg of fruit compared to open field production.
2. **Fossil fuel** for heating is reduced or eliminated
 - a. Enhanced cooling capabilities allow for production in warmer climates.
 - b. Retracting the roof allows for enhanced heating of soil allowing the earth to act as a heat sink during the night.
3. **Minimal electricity** is required since motors run intermittently and one 2hp motor can close up to 9,000 sq m of roof in 7 minutes.
4. **Reduced agrichemical usage** is beneficial for workers, food and ground water.
5. **Reduced landfill** since retractable roof coverings last 2 to 3 times longer than conventional greenhouse plastic and since plastic mulch may not be necessary thereby eliminating the purchase, installation, removal and disposal of the plastic mulch.

Facts about Cravo Retractable Roofs

1. Cravo Retractable Roofs have been in operation for over 25 years on 4 continents.
2. Cravo retractable roof buildings have survived every hurricane that they have been exposed to in Florida, Texas and Mexico.
3. The woven roof coverings have been used in California and Arizona for 10 years without being changed.
4. A frame roofs are used for rain sensitive crops, flat roofs are used for rain tolerant crops.
5. The white roof coverings are designed to excel in hot climates.
6. The clear roof coverings are designed to excel in warm to cooler climates.
7. Minimal electrical requirements since one motor can close approximately 9,000 sq m of flat roof in 7 minutes, and 4,000 sq m of A frame roof in 2.5 minutes
8. Retracted roof curtains should be oriented in a north/ south direction in order to ensure movement of direct sun and shadows across the plants as the sun moves from east to west throughout the day.



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Why Insect pressures are less in retractable roofs than in the open field **or a conventional greenhouse**

There are 4 basic principles which help to minimize crop losses due to insects:

1. **Reduce the entry of insects** into the growing area to minimize pressure
2. Ensure that the plants are exposed to environmental conditions which create **optimal stresses** to allow plants to **fully develop their natural defense mechanisms**
3. Prevent the plants from being exposed to **excessive stresses**
4. **Slow down the insect reproduction cycle**

A retractable roof with insect screening on the walls helps achieve all 4 principals.

1. Reduce Entry of Insects

- Insect net on the perimeter walls reduces entry of insects through the walls
- The majority of insect pressure is 2m from the ground so there is minimal insect pressure from insects coming in through the openings in the roof

2. Ensure that the plants develop their natural defense mechanisms

- When the roof is retracted, plants develop thick wax cuticles on the leaves, stems and fruit since they are exposed to the full spectrum and intensity of UV and infra red radiation. In addition, the wind and lower humidity causes an increase in transpiration which further increases cuticle development, reduces leaf size and increases root development to ensure that the roofs have a large capacity to absorb water to cope with the higher transpiration rates
- A high brix or sugar content in the plant makes the plant less desirable to sucking insects. Plants grown in the retractable roof have the same brix as those grown in the open field. For example, the leaves from a roma tomato plant grown in the retractable roof had a brix of 11 which was the same as the plant grown in the open field. However, the same variety grown in a nethouse had a brix of only 8, which means the plant in the nethouse had less sugar and a higher water content making it easier for insects to attack.

3. Prevent plants from being exposed to excessive stresses

- If a plant has insufficient water either due to excessive water loss or insufficient water take up, leave will start to flag or droop. Since insects can sense which plants are in excessive



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stress and they prefer to feed on sick or stressed plants, it is important to prevent excessive stress.

- The retractable roof can help prevent excessive water stress both help helping to increase water uptake and reduce water loss. When the roof is retracted, the higher transpiration rates cause the plants to develop larger, deeper root systems which then allows the plants to increase the water uptake when required. When outdoor temperatures and transpiration is excess, the roof is closed 90% which reduces transpiration by blocking the infrared radiation and wind, and increases the relative humidity by creating a micro climate around the plant. In addition, when young plants are being transplanted during hot conditions, closing the roof will help prevent excessive soil temperatures which ensure that the root system stay active to supply water to the plant. This strategy of closing the roof 90% for several days after transplanting is key to helping reduce the chance of virus transmission to the young plants.
- Agrichemicals for disease and insect control can also cause excessive stresses to plants. The reduced incidence of foliar diseases and insect damage in the retractable roof helps reduce or eliminate the need for agrichemicals which in turn prevents negative stresses or side effects.

4. Slow down the insect reproduction cycle

- The insect reproduction rate increases as temperatures and humidity increase and as the food supply increases.
- Empirically, the reproduction cycle of insects appears to be lower in the retractable roof than either the open field or conventional houses.
 - The rapid increase in insects in **the open field** during hot conditions is prevented in the retractable roof since the roof closed 90% during hot conditions to reduce temperatures and plant stress.
 - The rapid growth in insects in **conventional houses** is prevented since the roof is retracted during when outdoor conditions are optimal. This lowers the humidity levels slowing insect reproduction and increases the development of the plants self defense mechanisms



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Critical But Frequently Ignored Principals for Optimizing Plant Growth and Quality

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.
 - **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.
 - **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.
 - **Excessive transpiration** rates cause excessive water stress which causes plants to lose their defence mechanisms against insects and develop dwarf characteristics.
 - 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.
 - 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.
5. 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.
6. 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.
7. 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.
8. A black surface outside is a better measure of plant temperature than air temperature since it incorporates the heating affect of infra red radiation.