PROJECT REPORT – Isabel Technologies, Inc.

Incorporation of NVAC Technology to Existing Greenhouse Designs

Prepared for Isabel Technologies, Inc.
By Lucas McCartney, B.Eng., Ph.D.

May 2018

McCartney AgSolutions inc.
50, 5e Avenue, St-Gabriel-de-Valcartier
Quebec, G0A4S0, Canada
Email Address: mccartney.agsolutions@gmail.com
Telephone Number: +1-581-309-0234

For:
Isabel Technologies, Inc.
600 California Ave
San Francisco, CA 94130
Email Address: eric@isabel.io Website: isabel.io
Telephone Number: +1-646-531-6182

1. Relevant Industry and Literature Review

Tropical Environment Protected Agriculture

Many tropical nations rely heavily on agriculture for economic, social and food security motives. However, many have deforested land with poor soils that cover large areas which makes much of the land unusable for agriculture. These regions face climate change challenges such as sea level rise and decreased soil moisture. Shorter and more intense rainfall events and longer and more pronounced dry seasons are impacting agriculture in the tropics. Sub-Saharan Africa and parts of Latin America, the Caribbean, and Central Asia are tropical regions suffering the worst from this decline in available local agriculture. Constraints impacting the current use of protected agriculture technology in tropical regions such as the Caribbean are largely rooted in the designs of the structures being used. The development of adequate protected agriculture solutions will allow some tropical nations to counter some of these changes.

A tropical climate is defined to have an absolute minimum temperature of 18 °C, but is typically hot at midday year-round, nearing or surpassing 30 °C, with heavy precipitation. High relative humidity is therefore common in many tropical locations. In such environments, protected agriculture offers protection from high daytime temperatures, intense rain and winds, vast amounts of pests and diseases, and strong solar radiation. A tropical climate can also be dry for varying lengths of time. In very hot and dry tropical environments, the conditions can resemble that of an arid climate, and protected agriculture is used to limit plant evapotranspiration to reduce plant water stress. High relative humidity levels and ambient temperatures in tropical greenhouses create a complicated dynamic system that is influenced by varying external conditions, making it a challenging environment to control.

Considering the changing quality of the soils in tropical regions, protected agriculture offers improved growing substrates that are soilless. Worldwide, most of the hydroponic industry uses inorganic growing media such as rockwool, sand, perlite, vermiculite and others, while only about 12% use organic growing media such as peat, bark, sawdust and others. Although rockwool dominates, due to its widespread use in temperate climates, the specific substrate to be used is entirely based on production type, cost, on-site performance and local availability. In fact, substrates such as rice husk biochar and coconut coir gave similar or better yield in tomato production than rockwool under high temperature stress conditions (30 °C and 35 °C, when compared to 25 °C). This coincides with the availability and surplus of these materials in tropical and sub-tropical locations. The variety of growing systems that exist, namely hydroponic systems, such as nutrient film technique (NFT) systems, deep well or deep flow systems or ebb and flow systems can be used with soilless plant substrates successfully in tropical regions.

Greenhouse ventilation, air movement and temperature control are critical in tropical climates. In many developing countries, however, it is critical for greenhouse designs to remain low-cost and to consist of locally available materials. Passive ventilation and cooling measures are recommended over active ones as they are simple and economically viable. The inaccessibility to technology, rising cost of energy and the unreliability of power grids renders forced ventilation unfeasible in most tropical nations. If economically available, evaporative cooling solutions are useful during the very driest and hottest periods, which can be infrequent in many tropical locations. However, cooling methods in tropical climates must be used with caution to avoid the sanitary repercussions of increased relative humidity and airborne water droplets. One of the key challenges remains providing effective greenhouse cooling in high relative humidity environments.

Simple split roof designs with large roof vents, single layer film cladding, tall screened sidewalls and natural ventilation are ideal for tropical environments. Polyethylene film is widely used across the globe in greenhouse construction for its accessibility and ease of use, but many other cladding materials are available to growers. The lifespan of greenhouse films varies between 6 to 45 months, depending on the photostabilizers used, the geographic location, the climate and the use of pesticides and other chemical products. Polyethylene film used for greenhouses ranges in thicknesses from 3 to 8 mil (0.08 mm to 0.22 mm) and is the preferred cladding material for tropical climate protected agriculture. It is a question of location, durability and economy whether a greenhouse is covered every year with a new thinner film (4 mil or 0.1 mm) or every other year with a thicker film (6 mil or 0.15 mm). Many tropical locations have high solar radiation which makes even thicker films brittle within months; in which case, yearly replacement is necessary regardless of the choice of film. Harsh weather conditions negatively impact cladding and other plastics in the greenhouse systems and rapidly degrade their optical and mechanical properties. During dry seasons, dust accumulates on the film and can cause important reduction in light transmission. Washing the film can prevent this. Some woven plastic films varying from 0.2 mm to 0.25 mm (8 mil and 10 mil) are available to some growers. Such films are durable and may last a few years even in strong solar radiation. However, these resistant films have poor light transmission and can therefore only be used with a crop that does not require high levels of light. More advanced but costly greenhouse film materials can contribute to the cooling of the greenhouse with proper material and additive choice. Added benefits can include certain reflective, absorptive and interference properties, as well as condensation and drip control. However, these materials must remain resistant and economically available.

The height of the greenhouse up to the gutter should be in the range of 2.5 to 4.5 m instead of the traditional range of 1.5 to 2 m to allow for better airflow within, and air influx from the wind. The current trend in passive greenhouse technology is towards taller to reduce the peak greenhouse air temperatures at crop level. A screening mesh size of mesh 70 (0.21 mm) is able to thwart most insect pests. More specifically, for control of greenhouse whitefly (*Trialeurodes vaporariorum*), a very common pest, the pore size should be a maximum of mesh 58 (0.29 mm) screen. This size screen would also exclude aphids (Hemiptera: Aphididae) and leaf miners and it is sometimes called an “anti-virus” screen. Although effective in preventing the entry of insects, sidewall and roof vent screening will cause a restriction in airflow. Larger mesh sizes can be used or sections of mesh can be entirely removed from vents to enhance air movement, ventilation and cooling, at the expense of increased pest stress.

Shade cloth is used to reduce the solar radiation load reaching the crop. The density is expressed as the percentage of light excluded. For example, 30% shade cloth has 30% light exclusion and allows 70% light to pass through. Shade cloth is also commonly used in greenhouses for hardening tissue culture planting material or for hardening of budded and grafted plants. In certain situations, it is used as an alternative to insect mesh or as thermal screens. A more expensive solution, reflective aluminized netting, is used as an effective ceiling above the crop to reduce solar radiation and aid in reducing greenhouse and plant leaf temperatures. Finally, some growers may rely on the application of whitewash on the greenhouse cladding to reduce the solar radiation reaching the plants and reduce the heat entering the greenhouse. All these methods reduce the photosynthetically active radiation (PAR) reaching the crop and can cause a reduction of quality and yield.

Many locations, tropical or not, do not have sufficient groundwater supply for a greenhouse operation. Gutter systems with water reservoirs provide irrigation water through rainwater harvesting. Oversized gutters provide rapid harvesting of rainwater for later use in irrigation during drier periods. The plumbing from the gutters to the reservoirs should include netting to remove debris, and the reservoirs should be light-blocking (black in colour), fully closed or covered with a roof system.

2. Proposed Design Projects Description
    a. NVAC technology retrofit for Greenhouse 1
        i. Greenhouse as seen in Figure 1
        ii. AutoCAD drawings of custom NVAC system for greenhouse as seen in Figure 1 are in appendix.
        iii. Materials and hardware choice for NVAC system

6 mil polyethylene film. The NVAC roof is not subject to any significant wind or rain load therefore the polyethylene film does not need to be of substantial thickness.

1 3/8" or 1 7/8" galvanized fence top rail. This material is the top rail (pipe) that goes into 'frost fencing' or 'chain-link fencing'. It is easily sourced in most nations and comes in a variety of wall thicknesses, colors and finishes. Standard galvanized in 10ft or 20ft sections are great for the NVAC application. The top rail is cut into required lengths and bent if needed (see Greenhouse 2).

Plastic (usually white) gutter running the full length of the bottom of the NVAC roof to collect unused mist water. NOTE: it is normal that not all water evaporates and accumulation occurs.

Greenhouse snap clips for fastening the polyethylene sheeting along the edges of the NVAC roof:

http://www.greenhousemegastore.com/product/snap-clamps/pvc-fittings_1

Wiggle wire (also known as spring lock top) for fastening the polyethylene sheeting along the top and bottom of the NVAC roof:

http://www.greenhousemegastore.com/product/spring-lock-top-section/s

http://www.greenhousemegastore.com/product/spring-lock-deep-base/s

NVAC misting line can be one of 2 options:

Option 1:

Professional 12-ft Mist Cooling System by Orbit Irrigation Products, model # 20090

https://www.orbitonline.com/products/mist-cooling/kits/patio-cooling/professional/12-professional-38-mist-cooling-system-747

7 kits are required for Greenhouse 1. Tubing trimmed, and nozzles installed per spacing seen drawings in appendix.

This is the cheaper option, easily purchased online in North America and in some hardware stores. Risk of biofilm growth in mist tubing after a few months causing clogging.

Option 2:

Polyamide 12 nylon misting system tubing. It is heat stabilized, UV-stabilized, plasticized, and semi-flexible. It is also resistant to chemicals, friction, and abrasion. 120’ required for Greenhouse 1.

https://www.amfog.com/collections/m-tubing/products/m-tubing-nylon

MT 10/24 thread, 0.3 mm orifice stainless-steel nozzles. 34 required for Greenhouse 1.

https://www.amfog.com/collections/m-nozzles/products/m-nozzle-stainless-steel-20qty?variant=944162383

10/24 thread misting & cooling barbed T connector, brass. 34 required for Greenhouse 1.

https://www.amfog.com/collections/m-connectors/products/m-barbed-t?variant=985925991

This is the more expensive option, but the hardware is of higher quality, slows biofilm growth and is easily customizable.

Recommended:

Orbit 92100 Professional 160 PSI Misting Booster Pump. Model # 92100. This small pump provides ample pressure for the NVAC misting system for a full scale greenhouse 50-150’ in length and consumes only a small amount of electricity (1 Amp, 110V).

https://www.orbitonline.com/products/mist-cooling/maintenance-and-accessories/pumps/booster/38-in-booster-pump-1887

iv. Description of design

Figure 1. Greenhouse design 1.

The NVAC system was designed specifically for this existing greenhouse design. The NVAC roof is straight, not bent, but includes all features of the typical NVAC roof and system. The NVAC roof can be cladded in one uniform layer or the required polyethylene film. Structural cables or trellising cables can be detached and reattached to allow installation of the NVAC roof. The misting line might function at low water pressures from the raised water tank. A booster pump might be required to ensure proper operation of the mist system and proper cooling.

b. NVAC technology retrofit for Greenhouse 2
    i. Greenhouse as seen in Figure 2
    ii. AutoCAD drawings of custom NVAC system for greenhouse as seen in Figure 2 are in appendix.
    iii. Materials and hardware choice for NVAC system

6 mil polyethylene film. The NVAC roof is not subject to any significant wind or rain load therefore the polyethylene film does not need to be of substantial thickness.

1 3/8" or 1 7/8" galvanized fence top rail. This material is the top rail (pipe) that goes into 'frost fencing' or 'chain-link fencing'. It is easily sourced in most nations and comes in a variety of wall thicknesses, colors and finishes. Standard galvanized in 10ft or 20ft sections are great for the NVAC application. The top rail is cut into required lengths and bent if needed.

Plastic (usually white) gutter running the full length of the bottom of the NVAC roof to collect unused mist water. NOTE: it is normal that not all water evaporates and accumulation occurs.

NVAC misting line can be one of 2 options:

Option 1:

Professional 12-ft Mist Cooling System by Orbit Irrigation Products, model # 20090

https://www.orbitonline.com/products/mist-cooling/kits/patio-cooling/professional/12-professional-38-mist-cooling-system-747

6 kits are required for Greenhouse 1. Tubing trimmed, and nozzles installed per spacing seen drawings in appendix. 26 extra nozzles and 'slip-lok' fittings are required (model #10121W):

https://www.orbitonline.com/products/mist-cooling/maintenance-and-accessories/fittings/slip-lok/brass-slip-lok-tee-60

This is the cheaper option, easily purchased online in North America and in some hardware stores. Risk of biofilm growth in mist tubing after a few months, causing clogging.

Option 2:

Polyamide 12 nylon misting system tubing. It is heat stabilized, UV-stabilized, plasticized, and semi-flexible. It is also resistant to chemicals, friction, and abrasion. 100' required for Greenhouse 2.

https://www.amfog.com/collections/m-tubing/products/m-tubing-nylon

MT 10/24 thread, 0.3 mm orifice stainless-steel nozzles. 62 required for Greenhouse 2.

https://www.amfog.com/collections/m-nozzles/products/m-nozzle-stainless-steel-20qty?variant=944162383

10/24 thread misting & cooling barbed T connector, brass. 62 required for Greenhouse 2.

https://www.amfog.com/collections/m-connectors/products/m-barbed-t?variant=985925991

This is the more expensive option, but the hardware is of higher quality, slows biofilm growth and is easily customizable.

Recommended:

Orbit 92100 Professional 160 PSI Misting Booster Pump. Model # 92100. This small pump provides ample pressure for the NVAC misting system for a full scale greenhouse 50-150' in length and consumes only a small amount of electricity (1 Amp, 110V).

https://www.orbitonline.com/products/mist-cooling/maintenance-and-accessories/pumps/booster/38-in-booster-pump-1887

iv. Description of design

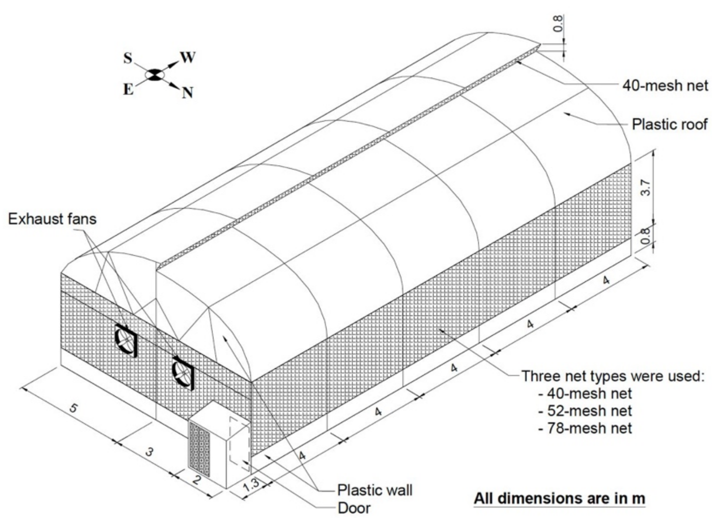

Figure 2. Greenhouse design 2.

The NVAC system was designed specifically for this greenhouse design. The NVAC roof is bent and includes all features of the typical NVAC roof and system. The NVAC roof must be cladded in separate polyethylene film sections in order to fit the structure within the existing structural features of the greenhouse. The misting line might function at low water pressures from the raised water tank. A booster pump might be required to ensure proper operation of the mist system and proper cooling.

3. Appendix
    a. Drawings Greenhouse 1
    b. Drawings Greenhouse 2
    c. Quote
    d. Confidentiality Agreement

______________________ Date May 27 2018

Dr. Lucas McCartney, PhD, B.Eng.

McCartney AgSolutions inc.
50, 5e Avenue
St-Gabriel-de-Valcartier, Quebec, Canada
G0A4S0
Phone +1-581-309-0234
mccartney.agsolutions@gmail.com