Sustainable Horticultural Crop Production in South Africa

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I. Introduction

Located in the southern hemisphere at 24,00 east latitude and 29,00 south longitude, South Africa and is the southernmost country on the African continent. South Africa is bordered by Namibia to the northwest, Botswana to the north, Zimbabwe to the north northeast, Mozambique to the northeast. South Africa nearly surrounds Swaziland in the northeast where it does not share a border with Mozambique, and completely surrounds the small country of Lesotho located in the east central region of the country. To the east, south and west South Africa is bordered by the South Atlantic and Indian Oceans with a total of 2,798km of coastline (Fig. 1, CIA, 2010).

Fig. 1 Map of South Africa and neighboring countries (United States Central Intelligence Agency, 2008)
http://www.lib.utexas.edu/maps/cia08/south_africa_sm_2008.gif

South Africa's topography is varied, with low lying coasts on the east, south and west edges of the country. Moving inland, these coasts become rugged hills and in the center

of the country, these hills become a vast plateau. The highest point in South Africa is Njesuthi Mountain which lies 3,408 meters above sea level. This mountain is located at the northeast border of Lesotho, in the Drakensberg mountain range. South Africa's lowest elevation is 0m, or equal to sea level. South Africa is primarily an arid region, with a subtropical climate on the east coast (CIA, 2010). Because South Africa does not have internal sources of water, irrigation is essential for any production in the plateau and arid regions (Mather, 1996). Of South Africa's total 1,219,090 sq km (CIA, 2010), only 12% of South Africa's land can be used for crop production and of this small portion only 22% is arable land. Because water is so scarce an estimated 1.3 million hectares (ha) are irrigated. Heavy rainfall ranges from winter to summer in certain areas of South Africa and many areas are at risk for drought (Department of Agriculture and Land Affairs (DALA), 2010).

These variations in climate and topography allows for a great amount of genetic diversity amongst the native plant species. This is why I chose South Africa for my research. South Africa has made great contributions to horticulture as one of the most biologically diverse sources of new plant varieties. Many popular plants are native to South Africa including flowering plants like Gerbera Daisies (*Gerbera spp.*) or Bird of Paradise (*Strelitzia spp.*) and succulent plants like Living Stones (*Lithops spp.*) and Aloe (*Aloe spp.*) (South Africa National Biodiversity Institute, 2010).

South Africa has a population of 49,052,489 people who belong to 4 dominant ethnic groups: Black African (79%), White (9.6%), Colored/Mixed Race (8.9%), and Indian/Asian (2.5%) (CIA, 2010). There are many languages spoken in South Africa, including IsiZulu (23.8%), IsiXhosa (17.6%), Afrikaans (13.3%), Sepedi (9.4%), English (8.2%), Setswnwana (8.2%), Sesotho (7.9%), Xitsonga (4.4%) and other (7.2%) (CIA, 2010). The people of

South Africa are deeply affected by HIV/AIDS. Based on 2007 estimates, South Africa has the second highest number of adults and children living with HIV/AIDS at 5.7 million, and has the most AIDS related deaths (350,000) than any other country in the world (CIA, 2010).

II. Sustainability

In South Africa, there are various definitions of sustainability given by separate agencies. The two most commonly recurring definitions are found through The South African Education & Environment Project (SAEP), Brundtland Commission & South African Constitution, Section 24(b)(ii) which all define sustainability as "a process that meets the needs of the present without compromising the ability of future generations to meet their own needs" (SAEP, 2010; Department of Environmental Affairs and Tourism (DEAT), Republic of South Africa, 2008). The National Environmental Management Act (NEMA), (Act No. 107 of 1998) defines sustainability as "the integration of social, economic, and environmental factors into planning, implementation and decision making so as to ensure that development serves present and future generations" (DEAT, 2008). The general theme of these definitions is the hope that responsible environmental practices now will benefit the current generation while ensuring available natural resources for the future.

Because of South Africa's racially divided history, the political motivation behind these definitions is to restore unity amongst the people of South Africa. During apartheid, conservation and sustainability had a very different and racially biased impact. White farmers were encouraged to implement sustainable practices, like less chemical inputs and soil erosion prevention, but they were optional and there was no punishment for non-compliance. Any non-white farmers were forced to comply. They were relocated to

"bantusans" where native Africans were forced to live in crowded conditions. Because of the crowding, those that farmed in the bantusan settlements inevitably dealt with overgrazing and over cropping as a result of the small space they were allowed to work with. Now that apartheid has ended, the South African government has made great efforts to enforce responsible production standards in a non-biased way. This is advantageous because there is a defined expectation for all agricultural and horticultural producers, regardless of race. The government has gone as far as implementing a law making previous landowners financially responsible for any necessary land restoration after leaving their property. By creating this kind of accountability, there is additional incentive to follow sustainable practices rather than risk any expensive fines later on. Another way that sustainability is developing is through government and agricultural extension programs designed to educate and enable rural low income farmers. By doing this, these farmers are able to become self-sustaining, and can make fair wages for their work. By creating opportunities through sustainable practices, South Africa is ensuring that even low income farmers will have incentive to follow responsible production guidelines. By making sustainability a priority across all socioeconomic classes and by implementing real consequences for any abuse of the land, the South African government has sent a message that sustainability is important and should not be taken lightly.

One major disadvantage facing the sustainable movement in South Africa is the residual effects of apartheid. Because the people of South Africa lived for so long with separate rules, it is estimated that those who were allowed leniency with sustainable policies will be slow to adapt to reform, while it is hoped that low income farmers will quickly adopt sustainable practices because they do not have long established practices or substantial monetary

investment (Mather, 1996). While the South African government is taking steps to mitigate the potential reversion to social divide, there are attitudes and practices that are very ingrained in South African culture that will take time to overcome.

III. Historical Production Practices

In 1647, the Dutch ship Haarlem was wrecked near the Cape. Before they were rescued, the crew planted vegetable seeds they had saved from the wreck with hope of having a plentiful food source available until help arrived. They discovered that vegetables grew so well in the climate of the Cape, that in 1649 the Dutch East India Company established a port at the Cape. It was to serve as a half way resting point for Dutch merchantmen on their way to India and Asia. This rest stop provided fresh water, meat and fresh produce for the merchant to have on the second leg of their journeys (van Rensburg, 1976).

As early as 1910, manuals were published on how to rotate crops, use green manures to regenerate soil organic matter, and how to control invasive weeds using composted manure applications. These manuals also warned farmers against intensively cropping the same plot, and encouraged crop and pasture rotation as well as planting crops that create humus to rejuvenate the soils (Department of Agriculture-Pretoria, 1910). This shows that sustainable agricultural practices were encouraged at an early date. By maintaining soil health, erosion is prevented and crop yield improved. The modern chemical inputs used in intensive farming do nothing to help the health of the soil and speed erosion, which is a major issue in South Africa.

South African agriculture was primarily self-sufficient for many years. The main focus of producers was to provide the necessary amount for South African use, and the government

offered producers a set price for their produce no matter what the yield (Mather, 1996). Because of this policy, producers faced more financial risk by exporting their small crops independently as they were not guaranteed the set price that was available domestically. Exporting agricultural and horticultural good was not common practice until the 1960s when more intensive farming practices began to be implemented across the country and more produce was available. With higher production and a larger surplus, export became a small portion of the South African economy. Because of this, large scale commercial production of covered vegetable or flower crops was not necessary until recently.

South Africa's floriculture industry began as a locally produced and locally consumed product in the 1950s. Floriculture products were not exported until the mid 1960s, and at the same time, floriculture began to be included in national reports on the South African economy (Olivier, 1974b). An estimated 90% of floriculture production is centralized around Johannesburg, where cooler winter weather necessitates crop protection from the elements (Olivier, 1974b). In 2008, floriculture exports from South Africa had a trade value of $214,046,930 or $1,647,653,832.60 South African Rand (R) which is nearly quadruple the 2007 export value of $59,813,564 or $460,422,618.40 R (United Nations, 2010).

Because of South Africa's ideal growing climate, controlled environment growing structures were not used by vegetable producers until the 1970s and early 1980s. One of the first controlled environment growing structures in South Africa was built by Don and Mark Bilton at their farm in Bonterivier in 1972. They were growing tomatoes in the soil and erected a "plastic covered structure" to protect them. Eventually they moved to a fully enclosed greenhouse and began to grow hydroponic lettuce (Intensive Agriculture South Africa, 2010). In 1974, it was noted that "in South Africa there is not a single vegetable

grower who has any commercial acreage under protection" (Olivier, 1974a). The reason protected structures were introduced later than other places in the world is because there was no need to regulate the climate in South Africa, but protective structures were eventually adopted to help prevent crop damage from excessive rains and hail (Olivier, 1974a).

IV. Current Production Statistics

In 2008, it was estimated that there were 46,027 self employed commercial farmers, and 473,000 self employed communal farmers throughout South Africa (Vink, 2008). The East Cape sub-tropic region of South Africa is the most productive region overall. In the 2002 Report on the survey of large and small scale agriculture, the East Cape district was responsible for 49% of South Africa's crop production (Statistics South Africa, 2002). The report also listed 27 crops produced in South Africa – the top 10 of which are included in Fig 2. Other crops not included in the graph are peaches, naartjies, plums/prunes, bananas, green beans, sweet potatoes, cauliflower, beetroot, table grapes, avocados, macadamia nuts, pecans, carrots, grapefruit, onions and pumpkins. The 44 regions included in the report produced a total of 1,178,088 metric tons of vegetables, citrus, deciduous fruit, tea and nuts (Statistics South Africa, 2002). All of these horticultural crops combined comprise about 2.5% of South Africa's total Gross Domestic Product (GDP) of $277 billion

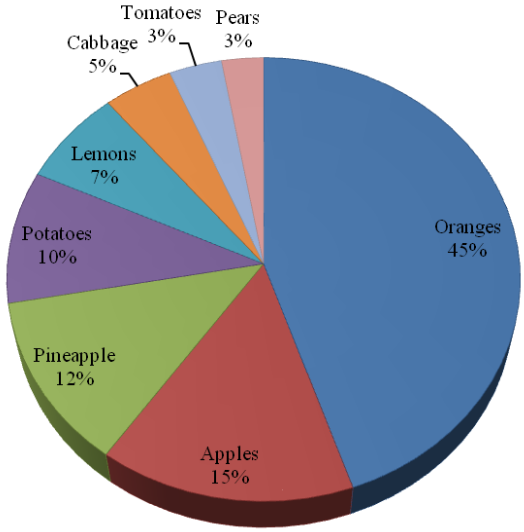

Fig. 2 - Top 10 Crops Produced in South Africa (Ranked by metric tons produced)

US Dollars (or $2,132,243,203,088.60 R) and provide jobs for 8% of the total employed population (DALA, 2010). The most profitable vegetable crops that are grown in protected structures today are tomatoes and cucumbers because of their high price point during the winter (Rennie, 2007).

V. Current Production Practices and Technology

Today, one of the biggest issues facing commercial producers in South Africa is water use and irrigation. There are a large number of growers who currently use hydroponic growing systems as a way to reduce crop loss from soil disease and to eliminate some of the labor involved in watering crops. According to the South African Agriculture Research Council, the advantages to implementing hydroponic systems include high quality harvests that do not need washing, preparation of soil for planting is not necessary, weeds do not interfere with the crop, higher yields can be produced in smaller spaces, "good" growing soil is not needed as crops can be grown anywhere, water is efficiently used, and the nutrients the plant needs for growth are constantly available. Also, the risk of soil pollution through over fertilization is eliminated (Joubert, 2010).

Growing crops under protective structures helps growers with water issues specific to their region. For example, in the semi-arid areas protection is necessary to regulate water use and prevent excessive evapotranspiration, while in the semi tropical region to the east protection is used to prevent crop damage from excessive rain, and soil erosion from water runoff (DALA, 2010).

In 1972, when growers began producing vegetables in tunnels, the plants were grown directly in the soil. In the late 1970's growers began to have issues with soil borne diseases,

and as a result had to grow their vegetables in containers (Maree, 1994). Since the 1970's South African growers have used soilless media to grow their crops, and extensive research continues today. By using renewable and easily available materials like pine bark and wood shavings, growers can avoid soil diseases, yet be able to replace their media with each crop without major expense (Maree, 1994).

Crop cover can also help prevent soil loss by blocking wind erosion and limiting soil runoff due to rains. The most common type of crop cover used is high tunnels as they allow for passive ventilation, heat and light which utilizes the natural advantage of the South African climate and makes these structures more sustainable with fewer inputs. Basic greenhouses are also used, primarily in floriculture where the crop needs more protection and controlled conditions to avoid crop loss or failure. Because of the heat, light and mechanization required for these greenhouses, these structures are not as sustainable as the high tunnels.

Greenhouse components in South Africa have quickly evolved with available technology. One of the first greenhouse glazing manufacturers in South Africa was Gundles plastic, and in 1968 they were producing Uvidek 602 at widths for tunnels (6.5 meters) and for greenhouses (11.5 meters). It was a critical step towards greenhouse growing once these materials were available in the appropriate sizes (Rennie, 2007).

Currently, there are multiple types of greenhouse glazing material being used in South Africa. Plastic films are the dominant material with variations like UV resistant poly, thermic effect poly that contains additives to absorb infrared radiation, light diffusion film for even light distribution, UV blocking films, anti-drip films, photo selective pigmented films to filter specific light wavelengths, and anti-drip film (Green Zone, 2010; Vegtec, 2010). It is

rare in South Africa for a greenhouse to be constructed from glass because the sunlight would be too intense for any crop underneath. Although South African companies manufacture and sell glass glazing material, they are only recommended for cooler climates like Johannesburg where many flower producers grow crops under glass (Olivier, 1974b).

Most growing structures are built using steel that has been galvanized either before the pieces are formed and bent or after the pieces are formed by dipping in hot zinc (Green Zone, 2010). Steel is he preferred structural component for greenhouses, tunnels and shade houses because it is durable and strong enough to endure the strong weather in South Africa (Green Zone, 2010; Vegtec, 2010).

Once produced crops are ready for sale, South Africa has the advantage of an advanced transportation infrastructure. South Africa has 3 merchant marine ports, 5 sea ports, 362,099km of roadways, 20,872km of railways, and 10 large airports. For producers in the plateau region of South Africa, the airports, rail and roadways are the most sensible means of distributing crops while producers closer to the shore will used the ocean ports for distribution. The biggest importers of horticultural crops from South African crops are Western Europe and the United States (Statistics South Africa, 2002).

VI. Integration of Historical and Current Production Practices: Ranked Strategies

When the United States was experiencing the Dust Bowl in the 1930s as a result of over cropping and lack of soil management, the people of South Africa took notice. They saw the crisis in the United States as a glimpse of what could happen if they neglected their soil maintenance and conservation. South Africa was slow to adopt the Green Revolution after

World War II, because of the importance placed on environmental stewardship in production as early as 1910. Because of this, use of pesticides, nitrogen based fertilizers and intensive cropping did not begin until the 1960s, but was quickly replaced with alternative and more sustainable methods of production once the technology and equipment was made available.

In the past forty years, South African growers and scientists have been very proactive in making plant production sustainable. An important factor guiding their desire for sustainability is the abundance of native plant material with commercial potential within South Africa. Numerous domesticated plant varieties that we use today originated in South Africa, and there is no way to tell how many more varieties will come from the South African biome. The people of South Africa understand that by taking measures to protect soils, conserve water and reduce inputs, they are conserving an immensely valuable resource that no other country has.

The climate in South Africa is ideal for many crops, and plants can be grown year round in most areas of the country. Because of the favorable climate, and ample natural sunlight, supplemental lighting is very seldom if ever used in production facilities. This is a distinct advantage, as most countries have no option but to artificially light crops which becomes a mammoth production expense, and uses non-renewable power sources.

Because of their value, I will be focusing on tomato and cucumber production. When soil diseases became rampant in tomato and cucumber crops in the late 1970s, the growers did not attempt to fight them with fungicides or through other chemical means. Rather, producers looked for a sustainable alternative before sustainability was a priority in the industry. When the soil became unusable for crop production, growers took their plants out of the soil and began to grow them in soilless substrates like coir, wood shaving, pine bark

and rock wool. All of these materials are capable of being recycled or can be composted after their use. Another advantage is that growers can afford to replace these medias with each crop planting which minimizes disease, and as a result, chemical inputs.

To conserve water, growers began to install hydroponic systems as early as 1979. With water being a very limited resource, the hydroponic growing systems allowed growers to conserve water by recirculating it through their crops and allowing the plants to take what they need. This eliminated overwatering and water waste, while reducing man hours needed to irrigate crops. This also improved production sustainability by protecting the soil from over fertilization. By capitalizing on their abundance of natural light, adopting soilless growing media, and using hydroponics as a means of water conservation, the growers of South Africa have eliminated many elements of greenhouse production that negatively impact the environment (Fig 3). Of these elements, the most beneficial and sustainable practices, especially from a cost perspective, is the use of passive solar rather than high intensity artificial lighting. The second most beneficial sustainable practice is the use of soilless media. Implementing growing medias that are renewable and eliminate the risk of crop loss from soil borne diseases are also financially beneficial to grower although more research needs to be conducted on feasible renewable materials that can be used. The third best sustainable practice

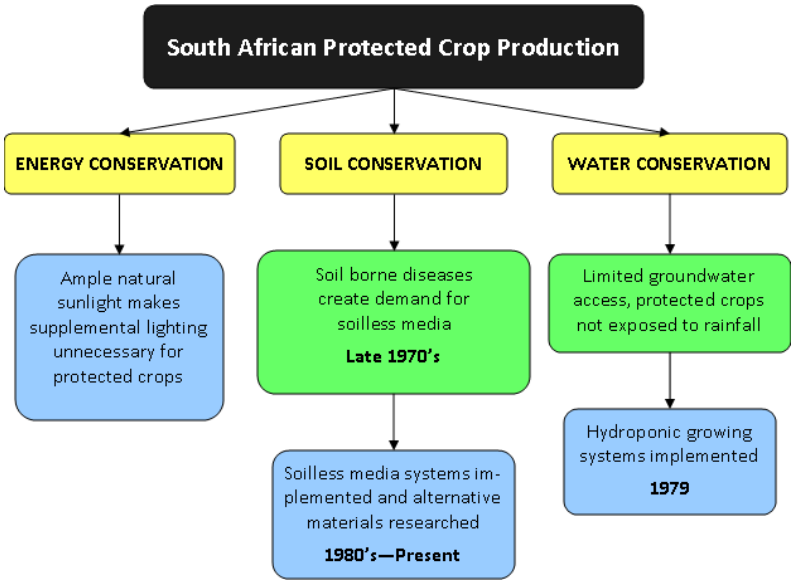

Fig. 3 - Progression of Sustainability in South African Production

is the use of hydroponics in greenhouse production. This allows growers to conserve water, which is very limited and expensive to access in South Africa. The downside of this system is its reliance on plastic materials for irrigation and storage (for example hoses and holding basins). A ranking of these three practices by the author (Fig 4) shows their current sustainability as well as the future potential for these practices in South African production. They have been scored on a scale of 1-5 with 5 being the most sustainable and having the highest future potential.

Rank	Production Practice	Current Sustainability	Future Potential	Total
1	Passive solar lighting	5	5	10
2	Soilless Media	5	4	9
3	Hydroponic Irrigation Systems	3	5	8

Fig. 4 – Ranking of current sustainable practices

VII. Finalized Sustainable Development Strategy

South Africa has a distinct advantage in maintaining these sustainable practices due to its ideal growing climate. By capitalizing on their climate, the producers within South Africa can grow greenhouse crops year round without relying on expensive inputs like supplemental lighting and heat.

Another advantage that South Africa has is that there is natural incentive for growers to adhere to sustainable practices without government intervention. Because of the lack of natural water sources, hydroponics is a way for growers to ensure the most efficient use in irrigation. By using hydroponics, growers are able to avoid crop failure or large expenses associated with lack of access to ground water. Also, because of the past issues with soil-borne diseases, it is again to the grower's advantage to implement a surface or soilless growing system whether it is raised beds, containers, soilless media or hydroponics. Because of the challenges faced by growers who attempt to exploit resources like water and soil, it is easier to take a more controlled approach like growing in soilless media or using hydroponics which in turn ensures a better crop and profit for the grower. These advantages to using

sustainable practices double as incentive for the growers, which means the South African government does not need to create additional incentive for growers to adopt sustainable practices, because they already exist.

The largest challenges that face South Africa in terms of sustainability are education and access. In the post-apartheid era, South Africa is still actively working to educate and empower rural communities by enabling low income growers to produce crops with hydroponic growing systems (SAEP, 2010). Through these efforts, knowledge of sustainable agricultural practices is spreading into the rural community, which allows growers to benefit from sustainable systems while remaining competitive with urban growers. Providing education and access to hydroponic equipment enables these rural communities and gives them an opportunity to become both financially and environmentally sustainable. By continuing these efforts, more sustainable practices can be implemented across South Africa, which in the end will have endless environmental and social benefits.

In order for the sustainable practices identified in Section VI to be implemented throughout the country, education efforts throughout South Africa would need to continue. By learning the benefits of this type of production, other growers will be encouraged to adopt sustainable practices too. Another challenge will be access. Because the rural areas tend to be lower income, it will be important to provide equal access to expensive elements of sustainability like high tunnels and greenhouses so that low income farmers can remain competitive with other growers in the industry. Without these protective structures, the crops may succumb to the intense South African sunlight or require more irrigation which would work against sustainable efforts.

To date, South African growers have had great success producing cucumbers and tomatoes during the winter in greenhouses. Because these crops are out of season during the winter, South African growers can demand a higher price and in turn reap a higher profit for their goods (Rennie, 2007). There is also potential to export more of these crops to places like Europe or North America where tomatoes and cucumbers cannot be grown as easily during the winter. This would be in direct competition with South and Latin American growers, but if South African growers began producing specialty tomatoes, like heirloom varieties, they could capitalize on a growing demand for better tasting product and find their niche in the market.

VIII. A Future Sustainable, Controlled-Environment Production Facility.

Because of success that South African growers have experienced growing tomatoes during the winter, I would recommend expanding upon this success and experimenting with heirloom tomatoes to test feasibility of crop production and assess disease and insect risks with these non-hybrid cultivars. Heirloom tomatoes are increasing in popularity among consumers who are looking for a product that is grown for superior taste, rather than a tomato variety that is produced solely for high yields and less expense to the grower. South African growers could potentially expand on their past success with tomato production and find a niche in the market with a product that would demand a higher price point. By using current sustainable production methods like precision irrigation, passive solar energy and soilless media, additional sustainable practices like less pesticide or fungicide use can be evaluated to improve sustainability.

The proposed research site would be located near Cape Town (33,55° S latitude 18, 22° E longitude) on the Cape of Good Hope where the climate is favorable for plant growth

and the sunlight is less intense that in the central plateau. This location would be in close proximity to airports, roads and a huge seaport to ship goods. To save on cost, a high tunnel would be used, rather than a greenhouse structure. Passive solar energy would serve as the primary light and heat source, with supplemental lighting only when necessary. Ventilation would be manual, with the sides and ends of the tunnels being opened during the day to regulate temperature and humidity. At night, the tunnels would remain sealed to prevent pests and heat loss.

The high tunnel used would use a single poly glazing material, and standard metal framing components. It would measure 10 feet tall at the center and extend 40 feet – which would provide approximately 400 square feet of growing space. This experiment would measure the overall growth and crop yield from a variety of 10 different heirloom cultivars using 10 plants of each (100 plants total) with all plants grown within the high tunnel. Simultaneously, this experiment will evaluate the risk of disease and pest infestation as the crop grows to see if non-hybrid cultivars would require more chemical inputs to prevent crop loss. The range would be divided into 5 compartments with 20 plants in each so that spread of pests and disease can be monitored across cultivars, but also to maintain some control and prevent total crop loss.

The tomatoes would be planted in August in grow bags using a standard potting mix and all would be drip irrigated with a fertilizer solution. If needed, the plants can be leached using collected rainwater when salt accumulation symptoms are present in the growing media. Ideally harvest would occur before December 31st, but this would depend on the specific tomato cultivar and the temperature that can be maintained in the greenhouse using solar heat alone.

The first proposed experiment would monitor disease or pest occurrence without preventative chemical treatments, and overall crop yield to determine if heirloom tomato crops have potential for mass production in the South African climate with minimal energy and chemical inputs. Based on the results of this experiment future tests could evaluate the use of various fertilizers, growing medias and growing seasons. Because of past success growing tomatoes in South Africa during the winter, different production times (for example December to March or February to May) could also be evaluated in the future. This experiment would need to continue over at least two years to accurately determine any seasonal change in disease or pest susceptibility and also to monitor changes in crop yield at different planting times during the year. During the experiment, if a pest outbreak occurs, researchers could use the opportunity to experiment with integrated pest management practices to determine an effective means of control without chemical use.

At the end of the experiment, each crop would be harvested, and the yield recorded. The crops would be judged by a panel to test for flavor, texture and appeal of the crops produced. This feedback could be used as an indication of consumer response to the crops produced in high tunnels, and from this the potential market success could be determined. If these experiments prove to be successful, growers in South Africa could consider growing a specialty tomato for a higher price than they would receive for standard tomatoes. There is also potential for less energy inputs by using passive solar and manual ventilation, and less chemical use should these tomato varieties produce acceptable yields without infestation.

South Africa has been very proactive in implementing sustainable production practices as a response to the climate and available resources. South African growers benefit from these sustainable practices by having more control over expense and inputs used on their

crops. Because of its ideal climate and current sustainable production practices, South Africa has potential to be a world leader in sustainable production research. By expanding on current sustainable methods like hydroponics, soilless media and solar energy use, South African growers can experiment with other sustainable methods like pest control without needing additional and expensive inputs like heat or high intensity lighting. Because of this favorable research setting, South African sustainability studies will not only benefit South Africa but has potential to benefit growers worldwide.

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