

Sustainable Horticultural Crop Production in Japan

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Introduction

Japan is a unique country in which a majority of the land is unsuitable for plant production because of the very rocky and mountainous terrain. Consequently, Japan only has 11.64% arable land (US. CIA, 2010). This requires the Japanese people to be very efficient with every hectare of land that they have to use. However, this does lead to the overuse of chemicals in order to make crops grow at a faster rate. I chose Japan because of the beauty of the Zen gardens inspired by Buddhism.

Japan is an island country off of the East Coast of Asia, located at 36.00°N, 138.00°E. This chain of islands stretches approximately 15,000 miles through the Pacific Ocean. This makes Japan comparable to the size of California. Almost all of Japan's land area is contained in four major islands: Kyushu, Honshu, Shikoku, and Hokkaido. Tokyo, one of the most densely populated cities in the world, is located on Honshu (Japan 2010).

Japan has a very mountainous terrain that covers almost all of the land area. Landforms are steep and rugged, indicating that Japan is still a young area. Japan is also host to

many volcanoes that aid in giving the soil very unique minerals. Long wet seasons and the mild temperatures throughout Japan have allowed for a lush vegetation cover. However, despite the rough mountainous terrain and generally poor soils, the Japanese have still managed to be successful in growing crops (Japan 2010).

Japan has also been burdened with virtually no energy natural resources. This is a major disadvantage because Japan has the tenth largest population in the world with 27,078,679 people (July 2009 est.). Due to this lack of resources and large population, Japan is the world's largest importer of coal and liquefied natural gas as well as the second largest importer of oil. Making power for this many people by using fossil fuels results in air pollution from power plant emissions which cause acid rain. This acidification of lakes and water tables lowers the water quality and also threatens delicate aquatic life (US. CIA, 2010).

Japan's tiny agricultural sector is highly subsidized and protected, with crop yields among the highest in the world due to terrace farming. Japan is usually self sufficient in rice but imports about 60% of the food that is consumed (US. CIA, 2010).

The main horticultural crops that are produced in Japan are used for food because of the small amount of arable land that they have available. These crops include *Oryza sativa* rice, *Malus domestica* apples, *Vitis vinefera* grape, *Prunus cerasus* cherries, *Allium cepa* onions, *Zea mays* sweet corn, *Daucus carota* carrots, *Solanum lycopersicum* tomatoes, *Raphanus sativus* Japanese radish, *Dioscorea oppositifolia* Chinese yams. Various types of floricultural crops are also produced and exported (Araki, 2002).

Definition of Sustainability:

“It is important that agriculture be considered not only from a financial standpoint, with health and national survival as priorities over economic concerns. This perspective requires that we not only hold out hope and expectations in the face of extreme difficulty, but also address the urgency of confronting some extreme underlying problems in current Japanese agriculture” (Kenkyukai 1971).

Japan’s traditional farming techniques are being replaced with technological advancements and a developing industry. These changes can be seen with decreased amounts of labor and greater yields in the fields. This modernization is being fueled mostly because of capitalistic views and isn’t showing promise for the future of Japanese agriculture (Kenkyukai, N. 1971).

Japan is constantly trying to improve the modernization of agriculture because of the many negative consequences when applying harmful chemicals to the producers and consumers. Also, the overuse of chemicals, synthetic fertilizers and dumping of livestock waste are contributing factors that are constantly threatening many species of wildlife and their habitats (Kenkyukai 1971).

The current farming techniques in Japan seem to be on the one hand reasonable and effective. On the other hand, they may be problematic in terms of safety, taste, threat to workers, and consumers; or if the animal waste or crop management hinder or hurt the environment or soil fertility, these practices must be phased out. Japan needs to develop new technologies to become more sustainable (Kenkyukai 1971).

To convert to these new practices, farmers need to invest capital and truly strive to

become more sustainable. However, if the Japanese people underestimate the difficulty of this process, the change will become even more complicated. While eating habits and general views about sustainable agriculture do not currently coincide with the current trend of sustainable agriculture, farmers need to innovate now for the future (Kenkyukai, 1971).

For Japanese farmers to succeed in this changeover, there must be a sense of urgency and commitment. This isn't about how much they're able to produce, but what the environmental impacts of their actions will be on future generations. They must also prove this concepts worth to everyday citizens by becoming an industry that isn't solely motivated by financial obligations or an economic viewpoint (Kenkyukai, 1971).

Historical Production Practices

More recently the use of greenhouses and high tunnels are increasing in Hokkaido and these growing structures covered an area of 2,900 ha in 2005. The average area of greenhouses and high tunnels per farm is about 20 a. Tomato, cucumber, welsh onion, strawberry, watermelon and spinach are mainly produced in greenhouses and high tunnels. Strawberries are now grown on high beds for comfortable work and lower labor costs. Tomatoes are produced in glasshouses and high tunnels in order to prevent crop damage by rain (Araki, 2002).

Hokkaido now has the policy to promote 'Clean Agriculture', which is friendly to environment. The objective is to reduce the use of chemicals and fertilizers, so as to produce safe agricultural products. In vegetable production, plastic mulch or plant residue mulch is used for effective weed control, and net covering is used for pest

control. Farmers who do not use chemicals and fertilizers can label their products as 'Yes Clean' (Nishio, 2002).

Shortly after World War II, the Japanese government adopted a price support policy to overcome shortages in food and encourage rice production. The price support policy caused farmers to cultivate high-yielding cultivars along with intense fertilizer applications to increase production. The average amount of nitrogen applied to rice paddies increased from 69 kg/ha in 1952 to 108 kg/ha in 1986 (Nishio, 2002).

In general, the suitable level of nitrogen for rice varieties was 80-110 kg/ha. However, because of the high price of rice, farmers applied far too much.

Unnecessary fertilizer use in Japan caused the eutrophication of surface water, when phosphate and nitrate escaped from fields in lakes and rivers via drainage canals. This problem occurred when water used for irrigation was released, even though the paddy soil in Japan has the capacity to remove many of the nitrates in the soil by absorbing them for later use (Nishio, 2002).

This new Japanese price support policy was a great success increase the rice yields from 3.4 mt/ha in 1952 to 5.2 mt/ha in 1986. However the consumption of rice began to decline after the standard for living started to rise. There became a rice surplus in the late 1960's and because of this the Japanese government limited the amount of land that was to be planted in rice. After 1987, the government cut the price support policy and only used it under necessary circumstances. This caused a steep fall in price of rice which in turn lowered the amount of nitrogen applied to rice, from 108 kg/ha in 1987 to 76 kg/ha in 1999 (Nishio, 2002).

With a rice surplus, consumers became more selective of the rice and began to choose rice based on flavor. Luckily, "Koshihikari", a new rice variety with a desired flavor, reaches its maximum yield at a lower level of nitrogen than high-yielding varieties. The common Nitrogen application for "Koshihikari" is 60 - 70 kg N/ha. The area planted in "Koshihikari" increased from 5.9% in 1970 to 35.5% in 2000 (Nishio, 2002).

Today there isn't much overuse of Nitrogen for rice, however the main crops in upland fields are vegetables, fruits, and flowers that require more nitrogen than the cereals and legumes that were grown in the past. Consequently, nitrogen has remained an issue for the future of farming that needs to be addressed. Currently little is being done to curb this heightened use of Nitrogen (Nishio, M. 2002).

Current Production Statistics

Japan has a large number of small farms in a relatively small area. In 2008 census, Japan had 1.8 million commercial farms. Commercial farms averaged a land area of only 1.9 hectares. Over 8 million farmers live on these farms, and among them, 2.2 million have jobs besides farming. Of the 2.2 million people one-third of them are over the age of 70 and the other two-thirds are over the age of 60 (Dyck, 2009).

Japan is a country whose agricultural needs lie mostly on the shoulders of cereals. From 1999-2001 Japan produced 12.45 million metric tons of cereal with 6,147 kg per ha crop yield. However, Japan's production went down 13% from 1979-1981. Their crop yield went up 17% these years due to terrace farming and use of better cultivars to increase production. This displays that while Japan is getting a higher crop yield per ha, the amount of land that is now available to farming is lower. The percent of GDP

generated from agricultural activities in 2000 was a low 5%. Not very many of the nation's resources are geared toward crop production as of today, and the country relies heavily on importing the majority of their food (Agriculture and Food-Japan, 2003).

Another problem seen with Japan's current production statistics is that the average annual fertilizer use in 1999 was 1.437 million tons at intensity of 295 kg per hectare of cropland. This is significantly higher than most of the other countries compared. The world average for the intensity of fertilizer used is only 94 kg per hectare of cropland. This displays one of the main problems that Japan has with its agricultural practices today. Even though they have been trying to curb their use of fertilizer as explained in their production practices, they still have a major problem with trying to overproduce on the little amount of arable land that is available to them (Agriculture and Food-Japan, 2003).

Current Production Practices

In many ways Japan's current production practices are far behind the rest of the world. Japan's current greenhouse production is especially obsolete at the moment. There is an estimated 52,000 ha of greenhouses in Japan, and 14,000 ha of rain shelters. Only five percent of the greenhouses are covered in plastic film while the rest are covered in different sorts of plastics. Japan uses sixty-nine percent of the total greenhouse area for vegetable production, only seventeen percent for flowers, and fourteen percent for fruit tree production. With Japan being a leader in technology throughout the world, it is surprising to find that the vast majority of the

greenhouse systems are obsolete. Only three percent (1,500 ha) of Japanese greenhouses use a state of the art hydroponics system in their greenhouses (Nichols, M. 2008).

Hydroponics is currently an up and coming technology that is largely used for the production of vegetables. This system is capable of being sustainable with low amount of water loss and soilless media that is required. Japan is slowly investing to work into this market however the main focus in Japan is still rice production.

The glazing materials used in Japanese greenhouses are also behind on the current trend to achieve sustainability in greenhouses. Only five percent of the greenhouses in Japan are covered in double pane float glass. The rest are covered in different forms of plastics that have a lower light transmittance and require fossil fuels to make. Also, by using a glazing material that doesn't allow for as high of a high light transmittance, there is a need for artificial lighting which consumes large amounts of electricity further diminishing the sustainable aspects in the greenhouses (Nichols, M. 2008).

The use of greenhouse space is also far behind in terms of vegetable production. A professor at Massey University visited a greenhouse tomato producer in Japan and described it as being, " very disappointing because of the tremendous advancements that have been made in greenhouse tomato production throughout the past twenty years. Visiting this Japanese production facility felt like being in a time warp." Today high wires and layering are the new ways to develop an efficient and usable greenhouse. This house still had low wires and layering so the tomatoes

essentially rested on the floor. This misuse of usable greenhouse space isn't a sustainable practice because it requires more greenhouse hectares to be built in order to satisfy the needs of the consumer (Nichols, 2008).

Evidence of rice farming in Japan has been found as late as 7,000 B.C and has stayed as one of the major crops grown ever since. The high demand for rice has Japan constantly looking for newer cultivars and better growing and harvesting techniques. Farmers now use small diesel-powered rototiller tractors to plow the rice paddies. Mechanized planters are also a new trend coming into the slowly evolving rice paddies. The process of transplanting plugs into the rice paddies used to take 20-30 people to plant one rice paddy in a day. This new mechanization allows for one planter to transplant at least a dozen paddies in one day. While the current mechanization doesn't make rice farming more sustainable, it allows for efficient farming and greater turnover of paddies (Hays, 2009).

The reduction of fertilizer is also a new trend found in Japanese agriculture that will have great effects on the environment due to improved water quality. New cultivars and mechanization in rice farming are allowing Japan to cut down on their nitrogen use. The cultivars require less nitrogen and the mechanization allows for a greater turnover on paddies allowing farmers to produce more rice than they ever have in the past without promoting growth solely with fertilizer (Hays, J. 2009).

Historical Practices vs. Current

Progress in agricultural advances have been slim in Japan other than drastic problems that would change the environment forever without making a change. Nitrogen use and mechanization have been the two major problems that Japan has

been working on since it's past.

To curb Japan's usage of nitrogen in rice paddies, new cultivars and regulations have been developed. In the past Japan had a great demand for rice so the farmers would put as much nitrogen as they could to push rice production to it's limit. While this worked in the short term, researchers soon found the detrimental problems that this was having on the water supply in Japan. Through table 1 it can be seen the steps that Japan has made to make rice production more sustainable.

Mechanization was also a major factor in reducing Japan's reliance on nitrogen to promote growth in crops. In the past it required 20-30 individuals an entire day to transplant plugs into just one rice paddy. Today Japan can use one transplanting machine to transplant plugs in at least a twelve paddies each day. This allowed Japan to greatly increase the amount of rice produced by having a quicker turnover on the paddies.

Greenhouse production has also changed throughout Japan's history. Japan is slowly moving into more sustainable horticulture practices in their greenhouses by using hydroponics that has little water drain off and usually a higher yield. In terms of glazing materials Japan first started with mostly glass greenhouses and then moved to using more plastic glazing materials. Only five percent of Japan's greenhouses are currently covered with glass which requires consuming more natural resources because of the oil needed for the glazing materials and the supplementary light needed because of the lower light transmission.

Table 1

	<u>Sustainable Past</u>	<u>Current</u>	<u>Unsustainable Past</u>	<u>Current</u>
Greenhouse Production	Low Use of fossil fuels	Hydroponics, small use of glass New Cultivars,	Inefficient use of greenhouse space	Use of Plastics, Artificial Lighting, Use of Greenhouse space
Rice Padies	Terrace Farming	Less use of N New Cultivars	Nitrogen Use, Mechanization	Lower Nitrogen Use, new cultivars
Fruit Production Glazing Materials	Little Mechanization Mostly Glass	Some glass	Nitrogen Use	New Cultivars Use of plastics
Flower Production	Little Mechanization	More Efficient Greenhouses	Inefficient use of Greenhouse Space	Mostly Grown in Greenhouses

Ranking Japan’s horticultural practices from most sustainable to least is not an easy feat because of the relatively low priority that sustainability has in Japan. Points are illustrated in Table 1. The most sustainable practice in Japan is the rice farming. This is because of the large steps that have been taken to greatly reduce the amount of nitrogen used in its practices. Flower production in Japan would rank second with a high yield with little mechanization and low use of nitrogen. Vegetable production in Japan has made little improvements to become more sustainable. The only advancements that have been made have been with the limited use of hydroponics. Lastly, greenhouse production in general has taken actual steps backward by becoming much less sustainable with the use of plastic glazing materials and the increased use of artificial lighting.

The two crops that Japan really needs to focus on and promote research and development is rice and vegetable production. Rice production could be done much more efficiently by using larger planting and harvesting machines instead of the small hand driven machines that are used as of now. With this increased production it could suffice the needs of the Japanese people and decrease the amount of rice that is imported from other countries. Secondly, tomato production could make great leaps in Japan by improving greenhouse usage. As explained by a professor that visited Japan from the US, entering a Japanese greenhouse is like being in a time warp. The greenhouse space is very inefficiently used and newer techniques for growing are not being implemented. Also by using glass glazing materials Japan could greatly reduce it's need for artificial lighting.

Sustainable Development Strategy

There has been very little movement in the horticultural industry to move to more sustainable practices in Japan. The Japanese government needs to subsidize yet enforce the movement into more sustainable crop production practices in Japan or else the farmer has no incentive become more sustainable. The Japanese government can make the changeover from current unsustainable practices to more efficient sustainable practices with rules and regulations as well as a monetary incentive.

The largest problem with Japanese agriculture is the very inefficient use of nitrogen, which in turn is destroying many of Japan's fresh water sources. Lack of regulation is the main reason for the high nitrogen usage in Japan. Many countries such as the United States have limits on the amount of nitrogen farmers are allowed to put

on each acre and streams and rivers are also tested for high nitrogen content.

Curbing the use of nitrogen use in Japan seems like an easy fix with government intervention but there are many problems that are beneath the surface that need to be addressed and changed. The Japanese government wants farmers to produce as much they can on the very limited amount of land that is available for farming. This is to reduce the amount of agricultural product that needs to be imported from other countries which also keeps most of the money going to the Japanese farmers instead of foreigners.

Research must be done to create new cultivars that create high yields without a high input of nitrogen fertilizer. Research must be encouraged by the Japanese government to ensure the success of the creation of these new cultivars. Researchers have started creating new cultivars over the past twenty years, but it still isn't enough because Japan is still one of the greatest users of nitrogen fertilizer in the world.

Mechanization has also been an area that has been slowly developing in the agricultural sector in Japan. This change would make it possible for farmers to use less fertilizer while still being able to plant and harvest their crops more quickly in turn increasing the amount of product produced. There are still farmers in Japan who rely heavily on hand labor to plant the plugs of rice into the paddies.

To mechanize Japan, companies in Tokyo need to develop affordable and effective machines that are able to accomplish most of the farmers needs. These machines need to be affordable because many of the farmers in Japan are small family owned farms with very few assets available to purchase new farm equipment. With the help of the

Japanese government it may be possible to lower the amount of product that must be imported while keeping more money in Japan. While the broad mechanization of Japanese agriculture may not seem like a sustainable practice, it will lower the amount of imported foods which have traveled thousands of miles and lower the amount of nitrogen used by farmers.

Newer technology in general has been one of the largest problems that has plagued Japanese agriculture through recent years. There seems to be no explanation to why this is because of Japan's relatively great technology sector. It seems that agriculture has simply been left in the wake of electronic research that has been done on cameras, televisions, and other electronic devices. The small amount of arable land and historical Japanese farming may be the reason why Japan has deemed agriculture as a "lost cause." Very small steps have been made to improve these known problems in sustainability and production because of the general lack of interest in Japan. Japanese farming is far enough away from most of the major cities and seems to have been forgotten in the great push for technology in the electronics sector.

Designing a Future Sustainable Production Facility

When designing a test production facility in Japan it was important to look at what crops and facilities needed to be upgraded in the future to be competitive worldwide in terms of sustainability and use. Tomato production in Japan is an up and coming market that needs to be looked at much more closely. The tomato production facilities found in Japan were very outdated hydroponics systems that inefficiently used its greenhouse space with plastic glazing materials and unsustainable heat sources. With all of the

great resources found in Japan such as rivers, the ocean, and relatively temperate weather, there really isn't a reason to not make these greenhouses much more sustainable.

The place for the test production facility will be in Nakagawa at 035°N38, 137°E14. The reason that Nakagawa was chosen is because it is in Southern Japan that has a fairly temperate climate that would be very suitable for growing tomatoes in a sustainable greenhouse. Fukuoka, the sixth largest city in Japan, is only an hour to north which has a large harbor and railway to ship the tomatoes.

Hydroponic techniques are used for a variety of crop plants; tomatoes have received the most attention for business applications. You can grow other crops using hydroponic methods, but you must think about how well the crop will sell. If a crop doesn't have a strong market for a certain area then sales will be poor. However, tomato production in Japan has seen a significant boom in late years to make these new production facilities viable in the Nakagawa area.

Through the use of wind, solar and geothermal these new greenhouses in Nakagawa will be marvels of modern sustainable greenhouses. The proposed greenhouses will be contiguous even span with dimensions of 1000' x 500'. Plants need sunlight for photosynthesis so typical greenhouse glazing materials are designed for maximum light transmission. Double paned float glass glazing will be used on all exterior surfaces of the hydroponics greenhouses with a 3' curtain wall on all sides. This glazing material has a high transmission rate of light while also having a high r-value for keeping heat in during cold seasons. Shade curtains will also be used to shield plants from

receiving too much sun throughout the day while also keeping heat out of the eaves throughout the night.

Recent advancements in solar technology have created outstanding 17% conversion efficiencies in the solar panels. These free-standing towers will be on the south end of the greenhouses on an automatic swivel that will rotate with the movement of the sun to ensure optimal light intensity at all times of the day. This solar energy collected during the day is used to heat water tanks under the greenhouse that is stored until it is needed during the night to heat the greenhouses.

Nakagawa is also blessed with coastal winds due to its relative proximity to the Pacific Ocean. Wind energy has been used for rural electrification since 1936. A small 100kW wind generator will be placed on a small hill adjacent to the greenhouses. This generator will be used to operate much of the greenhouse equipment except for the supplemental lighting array because of its rather significant power consumption.

Through the generation of electricity through wind and solar power, heating and electricity needs beyond these systems will be minimal, which will greatly reduce the greenhouses electricity needs through less sustainable approaches.

Conventional hydroponic techniques use soil less cultivation with bare root systems that do not use media. Soil less cultivation is a very sustainable practice because many of the components in modern media contain many products from fossil fuels such as perlite and vermiculite which take many years to decay and go back into the environment. These tomatoes grown hydroponically are nutritious, healthy and clean produce. The improved and consistent vegetable quality is second to none

because of the elimination of pesticides and herbicides. This keeps the toxic chemicals that will help keep Japan's groundwater and oceans free from contamination.

Commercial hydroponics systems have proved more productive than conventional systems of agriculture. Hydroponics have averaged around 20 to 25% higher yields than conventional soil cultivation. This could really benefit Japan's current GDP in agriculture while feeding more people with sustainable and fresh Japanese tomatoes.

The experiments to be tested in these greenhouses would be focused on how to keep control of light and heat in the relatively hot Southern Japan coastline. Another important test that must be done is finding or creating new tomato cultivars that thrive in the Japanese climates. Tomatoes are typically grown in somewhat cooler temperatures but with a controlled environment like a greenhouse year round production would be possible if the heat in the greenhouse could be controlled during the summer months.

The production schedule for growing tomatoes in Japan would be started from rootstock. In the first 2.5-3 weeks of production seeds would be sown and then grafted onto rootstock after 3 weeks on a heat mat. After the tomatoes are grafted they are placed into the hydroponics system for four to five weeks. The tomato plants then need to be pinched and shipped to Fukuoka to be put onto a rail car or ship. The production of tomatoes can be repeated throughout the entire year but more artificial lighting will have to be used throughout the winter months to achieve the 12-hour photoperiod that tomatoes wish to have for optimum growth.

The real obstacle when approaching a great undertaking like the sustainable

hydroponics greenhouse stated above is simply the amount of initial investment. If the Japanese government doesn't step in to subsidize sustainable farming in the future then nothing will happen. As of right now these facilities are far too expensive for the average farmer in Japan to invest in.

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