ORGANIC AGRICULTURE IN JAPAN AND PERSPECTIVES ON ORGANIC VEGETABLE PRODUCTION IN GREENHOUSES

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ABSTRACT

The area taken up by organic agriculture in Japan has not increased over recent years, unlike that in other Asian nations, such as Korea and China, and this also differs from worldwide trends. Even though there are adverse factors affecting organic agriculture in Japan, organic production should be promoted to establish a more sustainable society that can adapt to shortages in fertilizer resources and requires fewer chemical pesticides.

Efficient vegetable production in greenhouses could be used to promote organic production in Japan. Many advanced techniques can be introduced into greenhouses. For example fertigation systems could be installed to improve fertilizer management, and it would be relatively easy to introduce IPM (Integrated Pest Management) into greenhouses. Physical controls, such as soil solarization, screen, and UV irradiation; and agronomic controls, such as choice of varieties and grafting to disease-resistant stock, could also be used. Biological control methods based on natural enemies and microbial pesticides could be introduced, and if these techniques were integrated into the greenhouse cultivation regime, then it should be possible to produce crops without any harmful chemicals.

Finally, Integrated Greenhouse Management (IGM) using advanced fertilizer and pest management techniques would achieve almost the same results as organic farming. Management should essentially follow the concept of Good Agricultural Practices (GAPs), which uses sustainable physical, chemical, and biological techniques, and promotes the adoption of constant hygienic and pest-free management practices. Furthermore, the international and complex production systems used today mean that practical standards for food reliability, and food safety and security need to be established immediately. A more efficient organic agriculture production system centered on greenhouse production could be a promising way of promoting organic agriculture in developed and socially mature countries like Japan.

Keywords: environmental control, IGM (Integrated Greenhouse Management), organic fertigation, sustainable vegetable production, system integration

FEATURES OF JAPANESE ORGANIC AGRICULTURE

The area taken up by organic agriculture in Japan has not increased over recent years compared to other Asian nations, such as Korea and China, etc. That differs from worldwide trends because European countries and the USA have increased their production of organically certified products (Table 1; Nakano and Zhao, 2017). This unique situation in Japan may have been caused by farmers, distributors, and consumers. Organic production without chemical fertilizers and pesticides, is often perceived to be difficult for farmers, even though technical guidelines for organic farming have been established in every prefecture in Japan. Agricultural production in Japan has been in steady decline over the years and is supported by older farmers (average age of a farmer is 65 years old and it is increasing). It is also hard to change the conventional production system to labor-intensive and complex organic farming systems. Distributors are wary of organic products because the amount of supply is not as stable as conventional products. Finally, consumers often do not accept the premium quality of organic products, their higher price, or their potential inconvenience. In addition, other categories of specially cultivated products by the agriculture of environmental conservation type have been authorized since 2001 and are becoming popular competitors to organic products.
PERSPECTIVES ON ORGANIC VEGETABLE PRODUCTION IN GREENHOUSES

1. Features of Japanese protected cultivation

Generally speaking, land suitable for agriculture has been restricted in Japan, which means that intensive vegetable production has been developed using innovative techniques (Fig. 1). For example, covering plants with plastic material have been put to practical use and in the 1960s, were considered as popular practice in stabilizing yields in the open field. Plastic house cultivation systems are an innovative technology that can be used to increase production efficiency because the systems are closed, which improves pest management, energy, and resource use efficiency (Kozai et al., 2017).

The protected cultivation area in Japan is almost 50,000 ha. Greenhouses covered with plastic film and production using soil are the dominant systems in Japan. Advanced Venlo-type greenhouses with hydroponics, which are popular elsewhere in the world, account for less than 3% of the total protected cultivation area in Japan. Almost half of vegetable output has been from protected cultivation. However, organic production attempts to create and use efficient production systems are also considered sustainable (Table 1 and Fig. 1).

Table 1. Actual area and percentage of land under organic agriculture (×10³ ha)

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2011</th>
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<tbody>
<tr>
<td>Asia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>0.50%</td>
<td>1%</td>
</tr>
<tr>
<td>China</td>
<td>1553</td>
<td>1900</td>
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<tr>
<td></td>
<td>0.30%</td>
<td>0.40%</td>
</tr>
<tr>
<td>Japan(^a)</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>0.10%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Europe and America</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>865</td>
<td>1016</td>
</tr>
<tr>
<td></td>
<td>5.10%</td>
<td>6.10%</td>
</tr>
<tr>
<td>Italy</td>
<td>1150</td>
<td>1097</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>8.6</td>
</tr>
<tr>
<td>France</td>
<td>557</td>
<td>975</td>
</tr>
<tr>
<td></td>
<td>1.90%</td>
<td>3.60%</td>
</tr>
<tr>
<td>USA</td>
<td>1640(^b)</td>
<td>1949</td>
</tr>
<tr>
<td></td>
<td>0.50%</td>
<td>0.60%</td>
</tr>
</tbody>
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\(^a\) Only includes organic JAS (Japanese Agricultural Standard) certified land
\(^b\) 2005
2. Organic fertilizer management in greenhouses

(1) Key factors are Nitrogen (N) and Calcium (Ca)

According to the research master plan produced by the Ministry of Agriculture, Forestry, and Fisheries (MAFF), the numerical target for cost reduction in tomato production has been a 30% reduction to the level of FY 2011 by the third research term (FY 2011–2015). A reduction in fertilizer N is an important theme. However, the fertilizer cost only represents about 10% of the total cost. Therefore, even if the fertilizer cost were reduced by half, the goal could not be achieved. In other words, any strategy needs to include an increase in yield if this goal is to be achieved (Nakano et al., 2012). Thus, research into high-yielding strategies is an important area of study in Japan.

There is a close linear relationship between production levels and nutrient absorption by tomatoes (Sonneveld and Voogt 2009). For N, \( Y = 18.7X + 63.4 \) (\( Y: \) N uptake, kg ha\(^{-1}\); \( X: \) Yield, kg m\(^{-2}\); \( R = 0.90 \), Fig. 2). Continuous fertilization over a longer time period is essential in order to achieve higher yields. Tomato yield in Japan has been somewhat lower than the Dutch levels because all data comes from a conventional fertilization system (greenhouses covered with plastic film and production using soil). This indicates that this system has low N use efficiency. One exception, however, is Sun Farm Ohyama (http://tochigi-aca.jp/member/035.html), which has achieved a high yield (32 kg m\(^{-2}\)). While this farm does not employ a hydroponic system, its higher yields have been attributed to soil fertigation and the preparation of appropriate soil conditions with a control of air conditions.

There are many different aspects of plant nutrition to take into account when attempting to achieve high quality and productivity levels in tomato production. However, N and Ca are the two most important components. There is little information about N usage, especially on what causes excessive vegetative growth in Japanese cultivars. This uncontrollable characteristic must be improved genetically. Currently, quantitative management systems have been developed to enable Japanese varieties to be cultivated hydroponically. The mechanisms by which N nutrition affects vegetative and reproductive growth, especially during the early growth stage, have yet to be demonstrated. However, the Ca concentration in the leaves and fruits of Dutch cultivars was higher than in the Japanese cultivars (Nakano et al., 2015). Nitrogen nutrition switching from the vegetative to reproductive stage, and Ca nutrient use that is related to the ripening phytohormones should be the main targets for establishing high-yielding systems that use high-quality Japanese cultivars (Fig 2).
Fig. 2. Relationships between tomato yield and N uptake.

▲: Ohyama Farm (high yielding Japanese tomato farm with soil fertigation).

(2) Organic fertigation as part of sustainable soil management
We have established an organic fertigation system (Nakao et al., 2000, 2002). The concept has two features. One feature is to continuously top dress the plants with small amounts of organic liquid fertilizer so that the application matches the decomposition ability of soil microbes (Fig. 3). The second feature is the addition of a deficit element, e.g. Ca, in advance as a Ca material or manure.

Fig. 3. Concept behind an organic fertigation system (Nakao et al. 2000 and 2002).
We attempted to establish an organic fertigation system using corn steep liquor (CSL) as liquid fertilizer instead of the usual inorganic fertilizer. The combination of CSL (some products are certified as being a fertilizer suitable for organic farming) and manure led to stable production levels by the organic fertigation system, even in the first year of production (Nakano and Uehara 2007, Fig. 4). Recently, liquid corn and fish fertilizers have been shown to be good options for the organic production of blackberry using fertigation (Fernandez-Salvador et al. 2015).

![Fig. 4. Effect of top dressing soil containing manure with organic liquid fertilizer (CSL). Organic fertigation is an IFM (Integrated Fertilizer Management) technique.]

3. Organic pest management in greenhouses

The integration of different technologies is the basic approach to pest suppression in Integrated Pest Management (IPM) systems. IPM consists of four main aspects. These are physical control, chemical control, biological control, and agronomic control. The systematic integration of these techniques in the greenhouse is successful because they can be easily controlled (Fig. 5).
(1) **Screening**

Screening is one of the basic physical control mechanisms in greenhouses. Insect invasion is restricted by a mesh screen. Therefore, the effect on greenhouse ventilation rate should be considered when introducing this technique in high temperature regions (Harmanto *et al.*, 2006). The use of insect-proof screens with at least 40-mesh (hole size: length 0.44 mm and width 0.39 mm) screens have been introduced as a physical barrier to silver leaf whitefly (*Bemisia tabaci* Perring) and tomato yellow leaf curl virus (TYLCV) disease for which this insect is a vector.

(2) **Solar sterilization**

Heating of soil by solar radiation to control soilborne pests (solarization, Katan 1981) is a traditional method and is effective and practical in organic open fields as well as in the greenhouse. Furthermore in the greenhouse, isolated beds (with a root-proof sheet, Uehara 1990) subjected to solarization can control tomato bacterial wilt disease caused by *Pseudomonas solanacearum* because the root area is restricted.

(3) **Environmental controls**

Powdery mildew is probably one of the most common and widely distributed diseases of plants in greenhouses (Douglas 2001). Infections can significantly reduce tomato fruit production. In the greenhouse, powdery mildew tends to be more problematic in the spring and fall when day-night temperatures favor high relative humidity, but it can develop at any time during the production cycle. However, environmental control can successfully manage this disease.

Powdery mildew caused by *Podosphaera pannosa* is a major disease of greenhouse roses (Kobayashi *et al.*, 2013) and chemical fungicides are absolutely necessary for disease control. However, ultraviolet (UV) supplementary radiation suppresses the development of powdery mildew disease in the greenhouse through systemically acquired resistance.
(4) Microbial pesticides and safer materials for disease control

Some strains of *Bacillus subtilis* have antagonistic activity against the pathogen, *Botrytis cinerea* (Honda et al., 1977). Some bacteria have appeared on the market as microbial agents. Recently, microbial pesticides have become more popular as an environmentally sound control technique. A novel repellent, acetylated glyceride, has been developed against the sweet potato whitefly, *B. tabaci* (Kashima et al., 2014). It is a food additive that is considered a safer alternative to synthetic agricultural chemicals. The exogenous application of l-histidine, but not d-histidine, inhibited wilt disease in tomato (Seo et al., 2016). These results suggest that l-histidine could be a plant activator increasing the resistance to *Ralstonia solanacearum*.

(5) Natural enemies

The stinkbug (*Tupiocoris cucurbitaceus*) could be a predator of the greenhouse whitefly (*Trialeurodes vaporariorum*) in tomato crops (López et al., 2012). Under well-controlled greenhouse conditions, natural enemies are easy to propagate to effectively suppress population levels of the pest. The introduction of natural enemies could reduce the labor cost involved in spraying and lead to the production of safer agricultural products.

(6) Nutrient management for chemical pesticide reduction and human health

Balanced fertilizer application is a basic concept that can be applied to reduce soil borne disease because there is a causal relationship between excess phosphorus (P) in the soil and clubroot disease incidence (Murakami et al., 2004). Some other elements also improve resistance to disease. Higher silicon concentrations increase cucumber yields (Voogt et al., 2001) and an additional benefit of applying this element is an increase in productivity and quality. In humans, silicon increases bone density and reduces blood pressure. People living in certain regions of the world suffer from selenium and/or iodine deficiency, which means there is a need for plant supplemental products (Bruulsema et al., 2012). Iodine would also be a good potential biofumigation agent (Kiferle et al., 2013). These elements would serve the twin purposes of achieving higher vegetable crop yields and supporting human health.

4. Authenticating the geographical origin of agricultural products and their production methods

Multi-element analysis, including stable isotopes, can be used as a possible indicator of food safety and security, including organic product security (Nakano and Zhao 2017). Analytical methods can be used in two ways when certifying geographical origin: one is where multivariate analysis is used to determine the concentrations of omnipresent elements, such as Al, Ca, Cl, Mg, Mn, Fe, and Zn; the other focuses on special elements, such as the stable Sr, O, and H isotope ratio. When certifying production methods, especially for organic products, $\delta^{15}$N values could be used as a potential indicator, particularly in protected cultivation systems such as plant factories (an advanced type of greenhouse horticulture, Nakano et al., 2003). The accuracy of these values is affected by production conditions. Therefore, the accurate prediction of the $\delta^{15}$N values of products is improved under controlled conditions, e.g., in a plant factory, by using $\delta^{15}$N-evaluated fertilizer, media, and water.

CONCLUSION

Organic production should be promoted in order to establish a more sustainable society that can adapt to fertilizer shortages and requires fewer chemical pesticides, even in Japan.

More efficient vegetable production in greenhouses could promote organic production in Japan because many advanced techniques could be introduced into greenhouses. Integrated Fertilizer Management (IFM) can reduce fertilizer use, and integrated pest management (IPM) could limit harmful pesticide use. Both these practices can be introduced into advanced organic farming systems in the greenhouse. Finally, integrated greenhouse management (IGM) using advanced fertilizer and pest management techniques would achieve almost the same goals as organic farming. Management should essentially follow the concept of Good Agricultural Practices (GAPs), which uses sustainable physical, chemical, and biological techniques, and promotes the adoption of constant hygienic and pest-free management techniques. Furthermore, the international and complex production systems used today mean that practical standards for food reliability, and food safety and security need to be established immediately. A more efficient organic agriculture production system centered on greenhouse production could be a promising way of promoting organic agriculture in developed and socially mature countries like Japan.
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