Invited Review

Reconstruction Support for the Greenhouse Strawberry Production Area in Miyagi Prefecture Damaged by the Great East Japan Earthquake

Yasunaga Iwasaki1, Wataru Sugeno2, Naoko Goto2, Yukiko Honnma2, Manami Yusa2, Hiroaki Yamane2, Mizuho Ito2, Chisato Goto2, Shiori Takayama3, Iwao Takano3 and Masuyuki Takaichi1

1Institute of Vegetable and Floriculture Science, NARO, Tsukuba 305-8519, Japan
2GRA Inc, Yamamoto, Miyagi 989-2201, Japan
3Miyagi Prefectural Institute of Agriculture and Horticulture, Natori 981-1234, Japan

The Great East Japan Earthquake heavily damaged horticultural production in the Tohoku Pacific Ocean coastal region of Japan. In this paper, we will describe the reconstruction support for strawberry production in Miyagi Prefecture that was damaged by the disaster. We have been involved in supporting horticultural reconstruction efforts in this region since the earthquake struck in 2011. In 2012, the Japanese Government began a research project to support reconstruction of the affected agricultural area (“A Scheme to Revitalize Agriculture and Fisheries in Disaster Area through Deploying Highly Advanced Technology”). The horticultural research station for the project, located in Yamamoto-town (Miyagi Prefecture), is a Venlo-type greenhouse 0.72 ha in area. Yamamoto-town and nearby Watari-town, together represent a major strawberry production region in Tohoku. Therefore, technical support to reconstruct the strawberry greenhouse facilities was a high priority of the research project. Since inception of the project, we have provided technical information to growers and the local extension service, and we have cooperated with them to solve technical problems. Due to the amount of salt accumulated in the soil after being flooded by the earthquake-related tsunami, we determined that an elevated growing-bed system was the best option to resume strawberry production. Therefore, we designed and proposed an elevated growing-bed system consisting of individual growing containers and a crown-temperature control system; this system should prevent the spread of soil-borne diseases from occurring frequently in connecting long beds. Separate containers also provide the drainage needed to keep the root zone (air and water contents) amenable for growing strawberries. The crown-temperature control system, established by the National Agriculture Research Organization (NARO), was added to increase yield and reduce fuel consumption. Large-scale, multi-span greenhouses were constructed by the local government (total 152 growers, 41 ha) and the first strawberry cultivation restarted in September 2013. In the research station greenhouse, we have continuously demonstrated or developed new technologies and provided information to the growers.

Key Words: crown-temperature control, elevated bed, semi-closed environmental control.

Introduction

Watari-town (38°02'16.0" N, 140°51'09.3" E) and Yamamoto-town (37°57'44.5" N, 140°52'39.0" E) in Miyagi Prefecture were once a part of the greatest strawberry (*Fragaria × ananassa* Duch.) production area in the Tohoku district of Japan. However, the area suffered devastating damage from the Great East Japan Earthquake and associated tsunami (Norio et al., 2011). As a member of a support team (Fig. 1) organized by the local extension service, the authors have been offer-
ing technical support, starting immediately after the earthquake, to the local research organization and private companies involved with reconstructing strawberry production facilities (Tabuchi and Iwasaki, 2014). Greenhouses were newly constructed for the growers by local governments and strawberry production was restarted in September 2013. The support team has, on a regular basis, held seminars and offered technical advice to growers and visited their greenhouses to help solve technical problems. This paper describes research efforts to provide support for reconstruction of the strawberry growing areas in southern Miyagi.

Technical Support to Reconstruct the Strawberry Production Area Damaged by The Great East Japan Earthquake

Construction of large-scale strawberry greenhouses and resumption of strawberry production

The climate of Watari- and Yamamoto-town area is suitable for the production of strawberries because it has better solar radiation and warmer temperatures than other horticultural areas in the Tohoku district (Fig. 2). Strawberries have been cultivated in this area from the beginning of the Showa Era, about 90 years ago. The total strawberry production area was about 100 ha before the Great East Japan Earthquake struck in 2011. This area suffered serious damage; 98% of the strawberry production area was lost to saltwater intrusion and continued cultivation became impossible. Utilizing a subsidy from the Japanese Government, construction of large-scale strawberry greenhouses was completed, and since autumn 2013, 52 growers in Yamamoto-town (covering 17.4 ha) and 99 growers in Watari-town (covering 23 ha) have restarted strawberry cultivation (Fig. 3). However, the new cultivation system is drastically different from the former, pre-disaster system. Traditionally, growing facilities were small, annualhills were formed in walk-in tunnels, and water curtain systems were used for cultivation (Yamasaki, 2013; Yoshida, 2013). Growing facilities are now large, multi-span greenhouses with elevated growing beds. Technical support is needed to improve growers’ understanding on how to successfully grow strawberries on these new, elevated growing beds and how to control or manage the larger greenhouse environment. As members of a support team organized by the local extension service, the authors have been offering technical support, on a regular basis, held seminars and offered technical advice to growers and visited their greenhouses to help solve technical problems (Fig. 1). To promote the involvement of researchers from across the country, the Japanese Government started a research project focused on reconstructing industries destroyed by the earthquake in 2012, named “A Scheme to Revitalize Agriculture and Fisheries in Disaster Area through Deploying Highly Advanced Technology” (Agriculture, Forestry and Fisheries Research Council, http://www.affrc.maff.go.jp/docs/sentan_gijyutu/sentan_gijyutu.htm). As a result, a greenhouse of 0.72 ha in size was built for empirical research in Yamamoto town, a part of the project area. In Watari- and
Yamamoto-towns, not only were greenhouses destroyed, but the tsunami associated with the earthquake deposited saline water on the soil, which also increased the NaCl concentration in groundwater. As a result, growers could not use the soil or groundwater in the area, both of which are essential for growing strawberries. To remedy this situation, the local governments of both towns decided to build several greenhouse parks for strawberry production. A reconstruction subsidy provided by the Japanese Government was used to construct the greenhouse parks, each of which houses 10 to 50 multi-span greenhouses (0.24 ha in average size). Each greenhouse had an elevated growing bed installed to avoid soil salinity stress (Yamamoto et al., 2014).

**Design and introduction of a standardized, elevated-bed system for strawberry production**

Over the past couple of decades, private companies and local research stations have built many different types of elevated growing bed systems (Mochizuki et al., 2009). However, although there are advantages to growers having many design options to choose from, each design requires a different management approach and this could prevent rapid accumulation of technical knowledge relative to useful cultivation approaches or reduce group problem-solving capabilities among growers. In this area, most of the growers were not initially familiar with cultivating strawberries on elevated growing beds. Therefore, in order to rapidly promote the acquisition of the growers’ skills, it was desirable to construct identical elevated growing beds in all greenhouses. Therefore, we proposed design specifications that could be used for all elevated growing beds constructed in the area.

In the first step, we sent questionnaires to strawberry researchers and engineers throughout Japan in order to obtain technical input and examine various specifications required for growing strawberries on elevated growing beds. We also obtained manuals for each elevated growing-bed system. Based on these data and through repeated discussions among our support team, we established standard-design specifications for an elevated, growing-bed system, which growers in Watari-town accepted. The standardized design is summarized as follows:

1. Each growing bed consists of individual, 0.75-m long, styrofoam containers placed in a linear series (Fig. 4(a)). The risk of diffusion of soil-borne diseases is reduced by physically separating individual containers. Furthermore, the height of the growing bed can be more easily adjusted, which maintains a uniform height and this is expected to reduce the risk of root rot caused by the lack of oxygen due to poor drainage.

2. Each growing bed is equipped with a crown-temperature heating system to provide supplemental heating (Fig. 4(b)). By heating the crown of strawberries in the cold season, growth is promoted and heating fuel consumption is reduced (Dan et al., 2014). In Miyagi Prefecture, low temperature in the root zone during the cold season sometimes causes a reduction in nutrient uptake; therefore, root zone heating was thought to be required. However, by using separate planters as growing beds, a heat exchange pipe could not be placed properly in the growing bed. Therefore, the crown-temperature heating system was chosen because the heat-exchange pipe can be laid on the surface of the containers.

   In the crown-temperature control system, developed by NARO (National Agriculture Research Organization), heat exchange pipes are placed on the surface of the growing media, in contact with strawberry crowns. The system circulates water at about 20°C. This system would normally use a heat-pump chiller, which would provide both cool and hot water; the cool water cools...
the plant during the high temperature season (just after planting or in spring) to promote differentiation of the flower bud, while the hot water heats the plant and also soil during the cold season to promote vegetative growth. However, the system designed for Watari-town only employs the heating function, which uses a boiler fueled by kerosene.

**Research project developed to restore the strawberry production area**

To promote the reconstruction research project, a dedicated research team (staff 10 members) was organized. They are working at the research station (greenhouse) located in Yamamoto-town and provide technical support to growers and demonstrate new technologies (such as a movable benches (Hayashi et al., 2011), supplemental lighting using LED (Goto et al., in press, Fig. 5), UV-B fluorescent bulbs to suppress powdery mildew (Sugeno et al., in press, Fig. 6), and a crown-temperature control system. In addition, they solve problems related to strawberry production in the newly constructed greenhouses. We describe some of the results of the experiments conducted by the research team in the station greenhouse below.

**Effects of LED supplementary lighting to improve photosynthesis on growth and yield of strawberry forcing culture**

Strawberry plants are transplanted in a heated greenhouse in autumn and the normal harvest period is from late November to June. Insufficient solar radiation for fruit loading during the winter sometimes causes a decline in growth and yield. Recently, supplemental lighting was reported to be useful to increase yield of strawberries (Hidaka et al., 2013). Therefore, we investigated the effects of supplemental lighting with artificial lights using light emitting diodes (LEDs). Strawberry plants were transplanted in an elevated bed. We ran two experiments: Experiment 1 was on light quality (ratio of red-to-blue light), while Experiment 2 examined various lamp positions relative to the plants. In Experiment 1, strawberry plants were exposed to three different qualities of light (red-to-blue ratios = 2:1, 3:1, and 4:1, on photosynthetic photon flux density (PPFD) basis) with LED lamps (peak blue wavelength = 450 nm, peak red wavelength = 660 nm, SPL = 120 BR-ERx). In Experiment 2, LED lamps of two light qualities (red-to-blue ratios = 3:1 and 4:1) were installed in three different positions (above, in the middle, and at the bottom of the plant canopy). Yield increased in almost all supplementary-light treatments compared to controls in both experiments. In Experiment 1, the yield was higher when the red-to-blue ratio was 3:1 and 4:1 than when it was 2:1. In Experiment 2, strawberry yield increased by about 10% relative to the control, but no significant difference was observed among light positions or light quality. In addition, no increase in total dry weight was observed due to supplemental lighting, but the fruit distribution ratio (fruit dry matter/total dry matter) increased (Table 1). The most noteworthy aspect of this experiment is that the total yield
increased despite the fact that plant height and leaf area were reduced and total dry matter did not increase when lighting was supplemented with LED lights. That is, there was a large change in the distribution ratio related to using LED lights. We considered this change to be due to an adaptation of the strawberries to environmental changes caused by adding supplementary light. We suggested that the amount of photosynthetic products needed to be distributed to the leaves was reduced and that the yield increased as a result of an increase in translocation to the fruits.

**Irradiation with UV-B fluorescent bulbs suppresses powdery mildew**

Powdery mildew (*Sphaerotheca aphanis* (Wallr.) U. Braun) is a serious disease in strawberries. It is difficult to control this mildew with chemical fungicides only, because *S. aphanis* is adept at developing fungicide resistance. However, UV-B lights have been reported to induce resistance in strawberry plants against powdery mildew (Kanto et al., 2014). We investigated the ability of a new type of UV-B fluorescent bulb (Fig. 6, recently developed by Panasonic Lighting Devices Co., Ltd., Japan) to suppress powdery mildew under greenhouse conditions. In Experiment 1, strawberry plants were radiated with the UV-B (light intensity on the surface of the plant canopy was 4.0 to 13.4 μW·cm⁻²) for 3 h daily from the time of transplant to the end of cultivation. We found that the number of fruits infected with the powdery mildew declined by 84.3% relative to the control treatment (no irradiation). UV-B radiation (light intensity 4.3 to 15.3 μW·cm⁻²) for 4 days per week for 3 h per day lowered infection rates by 54.8% relative to the controls (Table 2). In Experiment 2, we investigated whether the frequency of fungicide spraying could also be reduced by incorporating a daily UV-B radiation re-

| Light quality (R/B) and set position | Leaf area (cm²) | Leaf dry matter/ Area of leaf (mg·cm⁻²) | Total dry matter (g) | Dry matter (g/partitioning) |
|-------------------------------------|----------------|----------------------------------------|---------------------|-----------------------------|
| 3:1 above                           | 2167.4         | 11.6                                   | 87.3                | 45.6 (52%)                  |
| 3:1 middle                          | 2136           | 11.6                                   | 88.9                | 48.5 (55%)                  |
| 3:1 bottom                          | 1959.1         | 10.6                                   | 89                   | 45.9 (52%)                  |
| 3:1 middle                          | 2077.7         | 12.2                                   | 89.4                | 47.6 (53%)                  |
| 3:1 bottom                          | 1566.7         | 11.4                                   | 83                   | 46.5 (56%)                  |
| control above                       | 2640           | 11                                     | 91.7                | 42.3 (46%)                  |
| control middle                      | 2562.6         | 12.2                                   | 83.2                | 39.5 (48%)                  |
| control bottom                      | 2293.8         | 11                                     | 84.3                | 42.0 (50%)                  |

**Table 2.** Suppression of strawberry powdery mildew by UV-B radiation.

| Treatment               | Surveyed plants | Total fruits harvested | Infected fruits | Infection ratio | Infected rate relative to control |
|-------------------------|-----------------|------------------------|-----------------|-----------------|-----------------------------------|
| No radiation (Control)  | 60              | 2281                   | 298             | 13.1 a          | —                                 |
| UV-B daily              | 30              | 1073                   | 22              | 2.1 b           | 84.3                              |
| UV-B 4 d·week⁻¹         | 30              | 1066                   | 63              | 5.9 c           | 54.8                              |

* Number of fruits infected/total number of fruits harvested.

† Different letters within a column indicate statistically significant differences by chi-square test (Bonferroni correction at *P* = 0.05).
gime. Under a daily, 3 h, UV-B radiation regime (intensity 8.0 to 18.8 μW·cm−2), the infection ratio of powdery mildew on strawberry fruits was 0.1%, even when fungicide spraying frequency was reduced to four times (about 16 times is the usual spraying frequency). Our results indicate that using a UV-B lighting system to inhibit powdery mildew fungus in strawberry plants could substantially reduce fruit loss and the cost of fungicide spraying. Our total yield of strawberries was about 6 kg·m−2. Because the infected ratio was about 13% when plants were not irradiated, loss of fruit biomass due to powdery mildew was estimated to be about 0.8·kg·m−2. This represents a monetary loss of about 880 yen (= 7.33 US$)·m−2 due to powdery mildew (based on the 2016 wholesale price of strawberries in Japan of about 1,100 yen (= 9.16 US$)·kg−1). If UV-B fluorescent bulbs were installed in a typical greenhouse, the loss of yield from this disease would be expected to decline 84% (Table 1). This represents an estimated increase in annual profits (over normal profits) of 740 yen (= 6.16 US$)·m−2. In addition, the cost of spraying fungicide is estimated to decline by about 50 yen·m−2 by using UV-B irradiation (spraying 16 times per year costs 58.8 yen (= 0.49 US$)·m−2, while spraying four times per year costs 10.4 yen (= 0.086 US$)·m−2). The cost of the UV-B lighting system was about 600 yen (= 5.00 US$)·m−2 (for 60 bulbs per 1,000 m2 and about 10,000 (= 83.0 US$) yen per bulb). The bulb has a lifetime of 4500 h (which provides 5 years of use when used 10 months per year for 3-h of irradiation daily). With an annual depreciation of about 120 yen·m−2 and an annual operating cost of 30 yen (= 0.25 US$)·m−2, the annual profit gained by using a UV-B lighting system in a greenhouse is estimated to be 640 yen (= 5.33 US$)·m−2.

Promotion of communication among growers assisted by ICT to share and accumulate technical information and know-how about strawberry cultivation

We now focus our efforts on introducing and establishing new technologies at production sites. In order for growers to understand and accept the new introduced technologies, it is important that the knowledge and know-how is transferred to members of the region’s leadership. Many growers in Watari- and Yamamoto-towns have had plenty of experience cultivating strawberries, but few have much experience growing them on elevated beds. In addition, environmental control techniques have improved greatly in recent years. To standardize greenhouse management approaches, it is necessary to establish newly introduced techniques at all production sites. To do that, we thought that it would be important to promote communication among the growers and provide a means for them to exchange and share information on cultivation techniques (for example, on controlling environmental conditions, growth, yield, workload), which is expected to improve collective knowledge over time. In the 20 greenhouse system, we installed (on a trial basis) UECS (Ubiquitous Environment Control System) environment monitoring systems (Hoshi et al., 2016, 2018), which collect environmental data (temperature, humidity, carbon dioxide concentration) and stores the data on a web server. By using this system in all greenhouses, growers can share information on environmental conditions with each other. Exchanging information is useful to promote communication among growers and expanding the accumulation of technical knowledge. We (researchers) also visit each greenhouse weekly to obtain growth data, gain insight into management, check status of pests, etc. summarize and analyze those data, and provide technical advice to growers. These data are utilized in seminars organized and conducted by the extension service. We are now working on expanding these greenhouse systems to all growers and are building a “support network” (using ICT) to further advance this trial.

Demonstration of greenhouse strawberry production using crown-temperature control under semi-closed environmental conditions

The crown-temperature control system (Hidaka et al., 2017) was introduced in 2014 and 2015 to demonstrate the effect of increasing the yield, dispersing transplant time, attained by expanding the harvest period, and thus reducing the concentrated workload. In a demonstration greenhouse (at the research station), we grow strawberries under a controlled environment (Yoshida and Morimoto, 1997; Yoshida et al., 1997) in which the CO2 concentration and relative humidity are maintained at higher than ambient (background) levels (so-called semi-closed environmental conditions [Heuvelink et al., 2008]). The results of these experiments are summarized below. Experiments on grower’s scales were conducted from September 2014 to June 2015 and from August 2015 to June 2016 in the station greenhouse, which contains 0.24 ha of growing space. The strawberry cultivar ‘Mouikko’ was being cultivated in both years of the demonstration. Heating was applied from mid-October to early March and cooling was applied from the middle of March; this caused yields to increase in both years. Therefore, the crown-temperature control system increased the yield (Fig. 7). In 2015, we designated an earlier transplant date than we had in 2014. For strawberries transplanted on 10 August 2015, no significant difference in crown-temperature control was observed in the flowering date of the second inflorescence or in the annual yield. In contrast, for strawberries transplanted on 30 August 2015, crown-temperature control significantly decreased the number of leaves produced between the first and the second inflorescences and increased the yield in January and December. The long day length in August may have canceled out the flower inductive effect of crown-temperature cooling for strawberries transplanted on
Transplanting Date (2014)

Marketable Yield (kg/m²)

Exp | Cnv
--- | ---
10-Sep | 5.0
20-Sep | 6.0

Transplanting Date (2015)

Marketable Yield (kg/m²)

Exp | Cnv
--- | ---
10-Aug | 4.0
30-Aug | 5.0
20-Sep | 6.0

Fig. 7. Effect of the crown-temperature control technique on the marketable yield at the station greenhouse in Yamamoto-town in 2014 (a) and 2015 (b). Strawberry seedlings were transplanted on 2 different days in 2014 (10-Sep and 20-Sep), and 3 different days in 2015 (10-Aug, 30-Aug, and 20-Sep). Exp stands for crown-temperature control applied cultivation and Cnv stands for conventional cultivation (without crown-temperature control).

August 10. This suggests that we should set the transplant date a little later than the end of August, even when a crown-temperature control system is installed. Under these conditions, fruit yields in both 2014 and 2015 were 6–7 kg·m⁻² (average fruit yield in a greenhouse constructed after the disaster in this area under conventional environmental conditions was about 4 kg·m⁻²). The electrical consumption amounted to 6.155 kWh·m⁻² (95.4 yen = 0.80 US$, 1 kWh = 15.5 yen, 0.13 US$) in 2014, and 6.071 kWh·m⁻² (94.1 yen = 0.78 US$) in 2015. The cost of introduction including a heatpump, water tank, pumps, pipes and control system was 1,280 yen·m⁻² (10.7 US$). From the results of our two-year empirical study under semi-closed environmental conditions, we found that using crown-temperature control increased the strawberry yield by more than 10%. This shows that operating profit can be increased by introducing a crown-temperature control system.

Conclusions
Six years after the devastating Great East Japan Earthquake, the afflicted areas are no longer a part of headline news. However, visitors can clearly see that the damaged area is still undergoing economic recovery. In the strawberry producing area of Watari-town and Yamamoto-town, the size of cultivated areas and the number of strawberry growers has declined relative to pre-disaster levels. Production and economic value of outputs are also lower than they were before the earthquake. To maintain the economic productivity of this area and help it expand in the future, it will be necessary to increase strawberry yield, increase the area cultivated, and increase the number of growers. Although researchers cannot do all this alone, we hope to help the expansion of the strawberry industry directly and support research on a continual basis.

Literature Cited

Dan, K., W. Sugeno, S. Nakahara, S. N. Goto, Y. Iwasaki, I. Takano, M. Okimura, K. Hidaka, S. Takayama and T. Imamura. 2014. Experiment on the crown-temperature control technique in forcing culture of strawberries in Miyagi. Bull. NARO Kyushu Okinawa Agric. Res. Cent. 64: 1–11 (In Japanese with English abstract).

Goto, N., Y. Honma, M. Yusa, W. Sugeno, Y. Iwasaki, H. Suzuki, T. Yoneda, S. Hikosaka, Y. Isigami and E. Goto. In press. Effects of led supplementary lighting to improve photosynthesis on growth and yield of strawberry forcing culture. Acta Hortic.

Hayashi, S., S. Saito, Y. Iwasaki, S. Yamamoto, T. Nagoya and K. Kano. 2011. Development of circulating-type movable bench system for strawberry cultivation. JARQ 45: 285–293.

Heuvelink, E., M. Bakker, L. F. M. Marcelis and M. Raaphorst. 2008. Climate and yield in a closed greenhouse. Acta Hortic. 801: 1083–1092.

Hidaka, K., K. Dan, H. Imamura, Y. Miyoshi, T. Takayama, K. Sameshima, M. Kitano and M. Okimura. 2013. Effect of supplemental lighting from different light sources on growth and yield of strawberry. Environ. Control Biol. 51: 41–47.

Hidaka, K., K. Dan, H. Imamura and T. Takayama. 2017. Crown-cooling treatment induces earlier flower bud differentiation of strawberry under high air temperatures. Environ. Cont. Biol. 55: 21–27.

Hoshi, T., K. Yasuba and H. Kurosaki. 2016. Present situation and prospects of japanese protected horticulture and ubiquitous environment control systems. Shokubutsu Kankyo Kogaku. 28: 163–171 (In Japanese with English abstract).

Hoshi, T., K. Yasuba, H. Kurosaki and T. Okayasu. 2018. Ubiquitous environment control system: An internet-of-things-based decentralized autonomous measurement and control system for a greenhouse environment. p. 107–123. In: H. Stephan (ed.). Automation in Agriculture, IntechOpen Ltd., London.

Kanto, T., K. Matsuura, T. Ogawa, M. Yamada, M. Ishiwata, T. Usami and Y. Amemiya. 2014. A new UV-B lighting system controls powdery mildew of strawberry. Acta Hortic. 1049: 655–660.

Mochizuki, T., Y. Yoshida, T. Yanagi, M. Okimura, A. Yamasaki...
and H. Takahashi. 2009. Forcing culture of strawberry in Japan—Production technology and cultivars. Acta Hortic. 842: 107–109.

Norio, O., T. Ye, Y. Kajitani, P. Shi and H. Tatano. 2011. The 2011 Eastern Japan Great Earthquake Disaster: Overview and comments. Int. J. Disaster Risk Sci. 2: 34–42.

Sugeno, W., Y. Iwasaki and Y. Hachiya. In press. Irradiation with UV-B fluorescent bulbs suppresses strawberry powdery mildew. Acta Hortic.

Tabuchi, T. and Y. Iwasaki. 2014. Reconstruction of the horticultural industry after the Eastern Japan Earthquake. Recommendations for the present and future. Hort. Res. (Japan) 13: 299–305 (In Japanese with English abstract).

Yamamoto, S., S. Hayashi, H. Yoshida and K. Kobayashi. 2014. Development of a stationary robotic strawberry harvester with a picking mechanism that approaches the target fruit from below. JARQ 48: 261–269.

Yamasaki, A. 2013. Recent progress of strawberry year-round production technology in Japan. JARQ 47: 37–42.

Yoshida, Y. 2013. Strawberry production in Japan: History and current progress in cultivation technology and cultivars. International Journal of Fruit Science 13: 103–113.

Yoshida, Y. and Y. Morimoto. 1997. Measurement, modeling and seasonal changes of canopy photosynthesis in ‘Nyoho’ strawberry. Acta Hortic. 439: 575–582.

Yoshida, Y., Y. Morimoto and K. Yokoyama. 1997. Soil organic substances positively affect carbon dioxide environment in greenhouse and yield in strawberry. J. Japan. Soc. Hort. Sci. 65: 791–799.