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Protected Cultivation of Peach and Nectarine in China – Industry Observations and Assessments

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Abstract

China is both the largest producer of outside-grown and inside-grown peaches and nectarines in the world. The latter are produced in more than 16,000 ha of protected cultivation greenhouses. These simple structures are solar-heated and most commonly exist in one of two forms: a single-slope, east-west oriented lean-to style or a north-south oriented high tunnel. Both systems can significantly advance ripening date and increase profitability to the grower. With proper management, the solar lean-to houses and high tunnels can advance harvest by as many as 90 and 30 days respectively, compared to the same cultivars grown outside. This crop advancement can lead to as much as a 5-fold increase in selling price in the market.

China, the native home for peach (and nectarine), has a 3000-year cultivation history (Huang et al., 2008) and it currently boasts over 50% of the world's production and acreage (FAO, 2010). Innovation in the 1980's led to the growing development of a new fruit production industry in rudimentary, energy-efficient, solar-heated greenhouses (Gao et al., 2004). The first success of protected peach cultivation was noted in 1995 at Shandong Agricultural University (Gao et al., 2004). This industry targets very early season markets (beginning in March) when fresh fruits grown outside are not yet available or are in very limited supply. As a result, demand is high and early market fruits command a very favorable price for the grower (Gao et al., 2004; Layne, 2009) (Figs. 1 and 2). Gao et al. (2004) noted that the wholesale price for early nectarines grown in Shandong province in late March could be as high as 60-80 RMB per kg. Although other fruits are grown using this technique [including strawberry, grape, cherry, apricot, and plum (Gao et al., 2004)], recent estimates for the peach and nectarine segment of the protected cultivation industry suggest that approximately 80% is nectarine while 20% is peach (Wang and Niu, 2012).

Current Situation and Practice

At present, there are nearly 16,000 hectares of protected peach and nectarine cultivation in seven Chinese provinces [Shandong – 5300 ha, Liaoning – 3400 ha, Hebei – 2800 ha, Shanxi – 1200 ha, Henan – 710 ha, Anhui – 680 ha, Shaanxi – 310 ha, other provinces – 1400 ha (Wang and Niu, 2012)]. In the case of nectarines, many are low-chill cultivars that ripen in the very early season (Gao et al., 2004). Yields of 15 – 23 tonnes per ha and income of $US27,000-54,000 per ha can be achieved (Wang et al., 1999a). Besides adding fruit supply to the market, extending the peach season and increasing income for farmers (Gao et al., 2004), other advantages to protected cultivation include elimination of rain-induced fruit cracking (especially

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Fig. 1. Typical "gift pack" of greenhouse grown nectarines on sale at the airport in Dalian, Liaoning province, P.R. China in April, 2010. White-flesh nectarines on left and yellow-fleshed nectarines on right. *(Photo by D.R. Layne).*

Fig. 2. Typical high-quality greenhouse grown white-fleshed peaches at street market in Beijing, P.R. China in April, 2010. Note styrofoam container containing peach shoots (to indicate freshness) and individually padded fruits attractively displayed. *(Photo by D.R. Layne).*

nectarines) and waterlogging, protection from hot winds and hail, reduced frost risk, expansion of the geographic growing range and production of fruit that can be marketed with reduced pesticide residues or as "pollution free" (Wang and Niu, 2012). If any insecticides are needed, it is typically a single application to control green peach aphid in the spring. Paper bags (Fig. 3) may or may not be used to protect the fruit and alter skin coloration but very attractive fruit can be produced in the greenhouse (Figs. 1, 2, 4 and 5).

There are two basic types of protected cultivation greenhouses for commercial peach and nectarine production in China. The first is the single-slope, energy-efficient, solar-

Fig. 3. Using paper bags to cover young developing fruit both to reduce potential for damage (insect, disease, abrasion, etc.) and also to alter skin coloration at harvest time in Changli, Hebei province, P.R. China in April, 2010. *(Photo by D.R. Layne).*

heated, lean-to greenhouse (Figs. 6-10 and 15-17). These simple, inexpensive houses occur primarily in northern China (32 – 47°N latitude) where the winters are cold but sunny (Gao et al., 2010; Jiang et al., 2004; Jiang and Yu, 2008). They are oriented east-west and they face south for maximum sunlight absorption during the winter. Essentially, they are half "Quonsets" where the back (north) and sidewalls absorb heat, provide support and protect against cold outside winds (Jiang and Yu, 2008). On top of the north wall, there is a short roof (Figs. 6 and 10). The roof is composed of water resistant materials that are load-bearing and that preserve heat. With an angle of elevation of 35-40 degrees for the back roof, winter sunlight can reach the back wall (Jiang et al., 2004). Often, these individual lean-to houses are 300 – 800 m^2 in area. Typically, they are 40-100 m long, 6-8 m wide and 3-4 m tall with a back wall that is 0.5-3.0 m thick depending on the material it is made from (Jiang and Yu, 2008). Back and sidewalls may be soil, brick, cinder block or stone (Figs. 6, 7, 8 and 10). In some cases, the walls may be constructed of two brick layers with perlite, coal cinders or other insulating material in between to reduce heat loss

Fig. 4. Beautiful white-fleshed peaches on two-year old trees in a greenhouse near harvest time in Changli. P.R. China in April, 2010. *(Photo by D.R. Layne).*

(Jiang et al., 2004). One farmer and his family typically have one or two greenhouses to manage for themselves (Wang, Z. personal observation).

These energy efficient solar lean-to houses may have a sunken floor (0.5-1.5 m below grade, Figs. 7 and 8), they may be cut into

Fig. 5. "Chunmei" peach in high tunnel greenhouse in P.R. China. *(Photo by Z.Q. Wang).*

a hillside in mountainous areas (Gao et al., 2004), or they may stand on the surface of the ground (at normal grade). If the back wall is cut into the hillside, it already has good insulation properties and the construction cost is reduced (Gao et al., 2004). The key to the success of the solar lean-to greenhouse is that supplemental heating and illumination is not required. This is obviated by the ability of the greenhouse to maximally harvest sunlight energy throughout the day and retain absorbed heat by the back wall, north roof, sidewalls and floor (soil). Nontransparent thermal insulation blankets (rice straw quilts, bulrush/cattail mats, woven fabric, etc.) are rolled down (from the top/north side to bottom/south side) over the transparent polyethylene film on the reinforced framing structure (bamboo, zinc-coated steel frame, etc.) at night to retain heat and limit heat loss (Figs. 6-10). If the framing structure is bamboo, concrete support pillars are used because the insulation mats are heavy (Fig. 6). If it is a zinc-coated steel frame, which is stronger, support pillars are not necessary (Figs. 10 and 16). Gao et al. (2004) noted that over the range of latitudes where these greenhouses are used in northern China, because of the variation in sun angle elevation, as you move further north, the greenhouse structure needs to be narrower in span and lower in height.

To achieve very early production (30-90 day crop advance) in the solar lean-to houses, after leaf drop in the fall, the house is recovered with plastic and then covered with the insulation blanket (Fig. 8) during the day (to keep cool) and uncovered at night (to release heat) usually beginning late November so that the chilling requirement can be satisfied early in some cultivars (Gao et al., 2004; Jiang et al., 2004). This period usually takes one month. Afterwards, the heat conservation practice begins where the insulation blanket is rolled up during the daytime (to absorb heat energy in the greenhouse) and it is rolled down at night (to conserve/retain heat energy in the greenhouse). Typically,

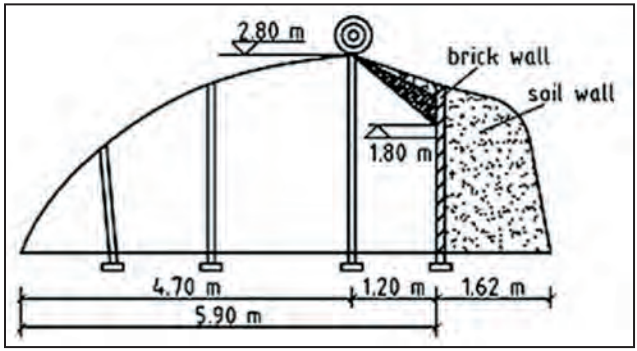

Fig. 6. Diagram of modified solar lean-to greenhouse (1986-1995 era) spanning 6-8 m with arch height of 3-4 m. Frames are bamboo, steel, or a mixture of both with support pillars inside. This structure is still used extensively today in P.R. China. *(From: Jiang and Yu, 2008; used with permission).*

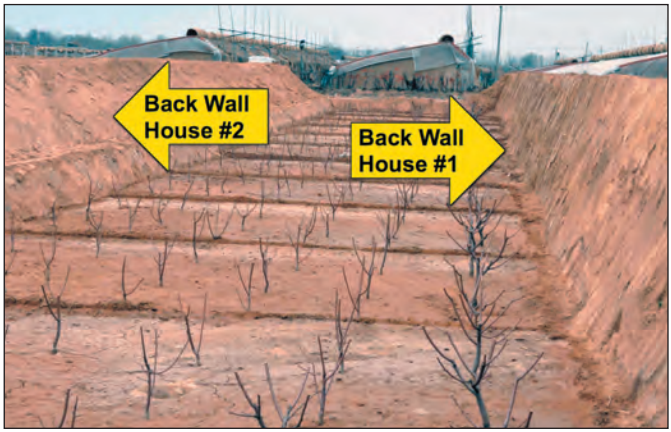

Fig. 7. Foreground view of solar lean-to greenhouse with sunken floor before superstructure and side-walls established. Typical, established, simple, south-facing, solar lean-to greenhouses in the background in Changli, Hebei province, P.R. China in April, 2010. *(Photo by D.R. Layne).*

Fig. 8. Typical, simple, south-facing, solar lean-to greenhouse with sunken floor growing white-fleshed peaches in Dalian, Liaoning province, P.R. China in April 2010. Side and back walls are made of earth. Crop advancement is 30-90 days using this system. Note non-transparent insulation blanket (straw mat; see arrow) rolled up at top of house. *(Photo by D.R. Layne).*

from the onset of heat conservation, it takes 30-40 days for bud break (Gao et al., 2004). The nontransparent insulation blankets may be rolled up and down each day by hand or by using a simple motorized system. Newer insulation blankets made of synthetic fibers are waterproof and easier to handle by machine than those made of straw or cattails (Jiang et al., 2004).

Some disadvantages with the solar lean-to greenhouses include difficulty for automation and inadequate light for some crops (Jiang and Yu, 2008). Land use efficiency is reduced since greenhouses need to be spaced properly (Fig. 7) so that there is no shading interference between adjacent structures (Jiang et al., 2004). Because the greenhouse is nearly airtight, relative humidity is high – both from moisture evaporation from the soil and plant transpiration and this can increase disease pressure (Gao et al., 2010). Further, toxic gases such as ammonia (NH_3) can also build up over time necessitating more frequent ventilation (Fig. 9). This is because large amounts of ammonium fertilizers are utilized (Gao et al., 2010).

The second type of protected cultivation greenhouse is basically a high-tunnel (Figs. 11-14). Contrary to the solar lean-to house that is south facing and oriented east-west, the high tunnel greenhouse is oriented north-south. These high tunnel houses do not have a back wall (Figure 12). The amount of light that is absorbed by these greenhouses ex-

ceeds that of the single-slope solar lean-to greenhouse (Gao et al., 2010). Early production (15-30 day crop advance) is achieved in these greenhouses when using the insulation blanket. Structural spans in the greenhouse may be made from bamboo, steel frame or concrete (Figs. 11-14). These spans are supported inside the greenhouse by concrete pillars and cross braces (Fig. 11). The difference in this production system from the solar lean-to house is that the grower waits until after the chilling requirement is fully satisfied naturally in the winter before using the insulation blanket if at all. In this system, the insulation blanket is only deployed in the winter for conserving heat at night. If there is no insulation blanket, a 15-day crop advance can be achieved.

Planting Design and Culture for Greenhouse Systems

Grafted trees with the desired scion cultivar on wild peach seedling rootstock are typically planted at high density (1.0 m x 1.5 m, or 1.2 m x 1.5 m, or 1.5 m x 2.0 m) (Fig. 7 and 11). They are usually trained to a central leader where laterals may be horizontally positioned by strings for better sunlight exposure and improved fruit coloration and

Fig. 9. Solar lean-to greenhouse without sunken floor with nectarines in JiuZhai village, Shandong province, P.R. China in April, 2010. Grower showing how insulation plastic is in overlapping layers and can be lifted up for ventilation as needed. *(Photo by D.R. Layne).*

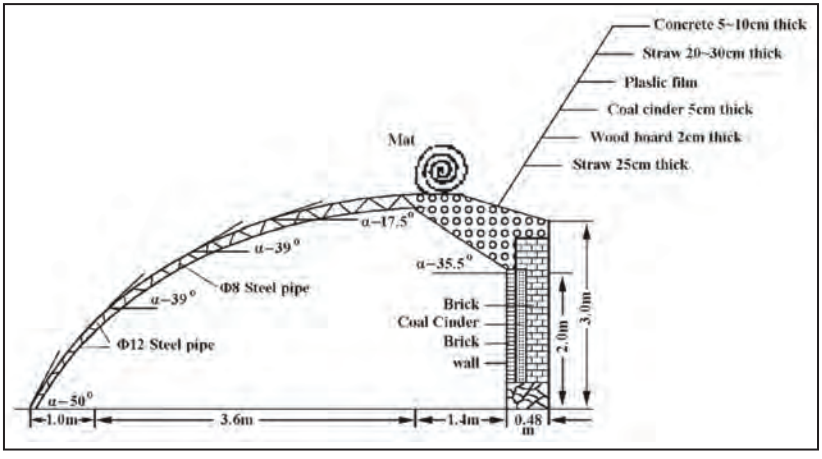

Fig. 10. Basic structure of modern (1996-present) solar greenhouse spanning 6-8 m with arch height of 3-5 m. Frames are made of zinc-coated steel and pillars are not necessary. *(From: Jiang et al., 2004; used with permission).*

Fig. 11. New high tunnel greenhouse with raised beds and young grafted trees growing prior to application of plastic after planting in first year in Fexgxian county, Jiangsu province, P.R. China in April, 2010. *(Photo by D.R. Layne).*

Fig. 12. North-South oriented high tunnel greenhouse with nectarines in Dangshan county, Anhui province, P.R. China in April, 2010. Note the absence of a back wall as in the lean-to type houses. *(Photo by D.R. Layne).*

Fig. 13. High-tunnel greenhouse (left) beside conventional outside orchard trees (right) in Dangshan county, Anhui province, P.R. China in April, 2010. *(Photo by D.R. Layne).*

Fig. 14. Side of high tunnel greenhouse open for both ventilation and disposal (see shoots on ground) of preharvest shoot prunings, in Dangshan county, Anhui province, P.R. China in April, 2010. *(Photo by D.R. Layne).*

Fig. 15. Central leader trained nectarine tree (attached to bamboo pole) in solar lean-to greenhouse following preharvest pruning in P.R. China. *(Photo by Z.Q. Wang).*

quality (Zhu, 1999). They may or may not be on a raised bed depending on the preference of the grower (Fig. 11). Irrigation is most commonly by flooding but some growers use a drip system. Both production systems are typically productive for 10 or more years. The greenhouse may be intercropped with another fruit such as strawberry during the first or second year.

Generally, for peach and nectarine, dormant grafted trees from the nursery are planted in the greenhouse and are covered with plastic beginning the first year of growth so that flower buds can be differentiated and the first crop can be harvested in the second year (Gao et al., 2004). After planting in spring and before mid-July, best fertilization, irrigation and other agricultural strategies are used to promote vegetative growth. From late July of the first year, moderate drought and no nitrogen are imposed and 0.075% paclobutrazol (PP333) is sprayed on the canopy (especially new shoots) to stop vegetative growth and promote flower bud development. Winter pruning prior to heat conservation is conducted to a lesser degree than with outdoor cultivated peach trees. Prior to harvest in the second leaf, new shoots are tipped to make fruits

Fig. 16. V-trained peach trees in modern solar lean-to greenhouse following post-harvest pruning in summer. Note that plastic over the house has been removed at this time and trees are exposed to outside weather. *(Photo by H. Huang, South China Botanical Garden, Guangzhou).*

Fig. 17. Reflective plastic mulch on floor to improve light levels in solar lean-to greenhouse in Dangshan county, Anhui province, P.R. China in April, 2010. This mulch may also be attached to the surface of the back wall of the structure. *(Photo by D.R. Layne).*

color well (Figs. 14, 15). Following harvest, heavy summer pruning is done (Fig. 16). Old fruiting branches are usually removed and only the new current season's shoots are left for fruiting the next year (Wang et al., 1999b).

Gao et al. (2010) indicated that the light environment in a given greenhouse may be altered by several factors including season, daylength, latitude, greenhouse structure and dimensions, and age and transparency of the plastic film. They noted that light levels in the greenhouse may be reduced 30-40% from outside. Some light supplementation measures may be necessary such as solar reflective film on the back wall or floor to improve the fruit color and quality (Fig. 17).

During the summer months, the temperature inside the greenhouse is similar to that outside since the transparent plastic is opened. During the winter, however, in cold locations (i.e., Dalian, Liaoning province) where the greenhouses are covered, outside temperatures may be -16°C while inside temperatures may be 16°C (Gao et al., 2010). At daybreak, internal temperatures rarely fall below 8°C but during the outdoor warm-up in spring, internal ventilation (Fig. 9) needs to be increased and insulation coverage time over the greenhouse needs to be reduced so that the temperature gradient between inside and outside the house is reduced (Gao et al., 2010).

Pollination in either type of greenhouse is conducted artificially by introducing bees or by hand-pollination because there are no insects in the greenhouse and there is no wind.

Challenges and Opportunities

Chinese scientists have noted many challenges facing the protected fruit cultivation industry. These include the need for better training of farmers and standardizing cultural practices (i.e., pest management, fertilization, irrigation, pruning and cultivar selection) and automation of environmental control (Jiang and Yu, 2008; Wang and Niu, 2012). Gao et al. (2010) noted that although the semi-underground solar lean-to greenhouses were widely utilized, there were some problems with shading in the winter and waterlogging in the summer when the plastic is removed. Jiang and Yu (2008) indicated that because water resources are limited in north and northwest China, water-saving irrigation techniques should be further developed and commercially practiced. Jiang et al. (2004) indicated that by combining drip irrigation and the use of plastic mulch in the greenhouse, water was conserved, relative humidity was reduced, and fruit yield and quality were improved.

Some breeding programs such as that at Zhengzhou Fruit Research Institute are developing new peach and especially low-chill nectarine cultivars specifically for use in protected cultivation greenhouses (Wang and Niu, 2012). This is necessary because most cultivars utilized in protected cultivation were bred for open field production and eating quality may sometimes be poor (Jiang and Yu, 2008). Ideally, researchers should conduct long-term, side-by-side, cultivar performance trials inside protected cultivation greenhouses at different latitudes comparing diverse fruit types (peach, nectarine, yellow and white flesh, peento, etc.) to make reliable recommendations for local commercial farmers. Of particular interest to breeders are characteristics such as low chilling requirement, semi-dwarfing and low-light tolerance, while retaining good eating quality (Gao et al., 2010; Wang and Niu, 2012).

To address some of these challenges, Jiang and Yu (2008) noted that local and central Chinese governments have developed more than 5000 demonstration farms where scientists and specialists teach this technology to local farmers. Such training facilities like the one in Yongning county, Ningxia autonomous region are vital to strengthen this growing industry (Wang and Niu, 2012). Although only 7% of total protected horticultural crop production in China is devoted to fruits and flowers, because they are more profitable than vegetables (the majority crops grown in protected cultivation), it is expected that the former will increase in area in the future (Jiang and Yu, 2008). In northern rural areas of China where fruits are grown in protected cultivation, in particular, a social benefit is realized where the surplus labor force that is idle in the winter can be utilized (Wang and Niu, 2012) and substantial economic benefit is realized for farmers as well.

Conclusions

Jiang et al. (2004) noted that the earlier the harvest, the higher the price to the farmer. Early ripening nectarines harvested in mid March received nearly five-fold higher prices than those harvested in May. Jiang et al. (2004) further observed that some farmers are also growing later-ripening cultivars in protected culture to improve quality and get them on the market sooner. These fruits are typically larger and have higher sugar concentration than early-maturing cultivars grown outside at the same location. Besides the benefit of early cropping for high market prices, Gao et al. (2010) suggested that the future is bright for protected cultivation because of minimal carbon dioxide emission and reduced energy use (i.e., coal burning for electricity and heat). Since the sun provides the light and heat for operation of solar greenhouses, Gao et al. (2010) estimated a savings of 750 $Mg \cdot ha^{-1}$ of coal compared to heated greenhouses. This energy savings also results in less air pollution. Gao et al.

(2010) noted that this simple technology is now being implemented for fruit and vegetable production in other countries such as Japan, Korea and Russia.

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