
New technologies for improving quality and efficiency of citrus fruit production in mountainous area of Japan

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Introduction

Sloping lands in south-western Japan provide suitable environmental conditions for production of high-quality citrus fruits. The region extending from Shizuoka to Kyusyu is called as 'citrus belt'. Most citrus orchards are located on 15° or steeper slopes. Japan produced 2 million t of citrus fruits in the year 2002. Satsuma mandarin (*Citrus unshiu* Marc.) represented about 60% of total citrus production.

As slope lands constitute a difficult terrain, most horticultural operations are carried out manually. Traditional citrus cultivation is thus a highly laborious occupation. With aging of traditional citrus growers and a tendency of getting away from the labour intensive farm production system in the younger generations, citrus orchard based land use is on decline. The area and number of abandoned orchards are increasing, more so in high altitude and steep slope regions. Development of mechanized production system enabling saving in human time and energy can thus enable rejuvenation of this land use. National Agricultural Research Center for Western Region has been making efforts in this direction since last 10 years. Researchers, growers, and extension workers joined hands for developing appropriate technologies based on computer programming, utilization of new materials and information processes. Some aspects of these new technologies are outlined in this article.

Drip irrigation and liquid fertilization system with year-round plastic mulching

Citrus growers in Japan are expected to produce high quality Satsuma mandarin having 12-14% sugar and about 1% acid content in fruit juice. Departures from such standards mean lower profits to growers. Fruit quality is seriously affected by weather, particularly precipitation between summer and fall. Many growers have utilized plastic sheet mulching to avoid such negative impacts. However, there are several problems in using plastic sheet mulching such as: (a) Plastic sheet mulching results in water stress levels that reduce tree vigor, (b) There are practical problems with the growers such as labor intensive tasks of covering the soil surface with plastic sheet in hot summer and its removal after harvest.

The technology developed by us to resolve these problems has been named as 'drip irrigation and liquid fertilization method with year round plastic sheet mulching (abbreviated as DLYM, *Marudori* in Japanese)'. It has three elements: (a) utilization of year round plastic sheet mulching, i.e., saving of labor spent in removing the sheet during hot summer, (b) drip irrigation to improve fruit quality and tree vigor, and (c) application of liquid fertilizer using drip tube and automatic water supply system (Figure 1).

A comparison of quality of fruits grown using DLYM

technology and in control is given in Figure 2. Sugar content of fruits obtained using DLYM technology was higher by 1-2% in both early and late Satsuma cultivars compared to fruits obtained from traditional cultivation. Apart from a significant improvement in juice quality, fruit color was improved. Components such as β -cryptoxanthine, β -carotene and Vitamin A in juice from fruits produced under DLYM system increased by 50-70% compared to fruits from control trees. The improved fruit quality implies more benefits to growers.

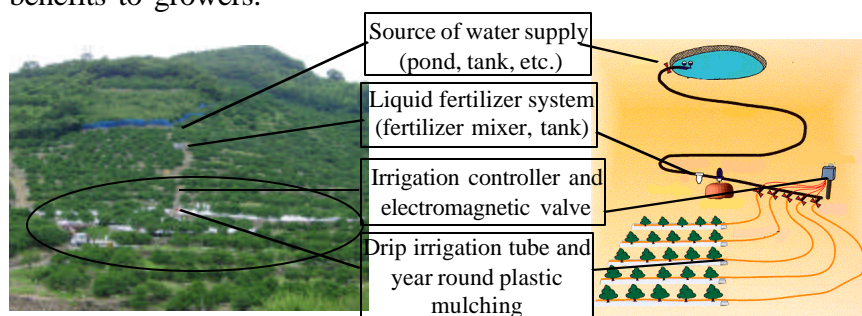


Figure 1. Outline of drip irrigation and liquid fertilization system with year round plastic mulching

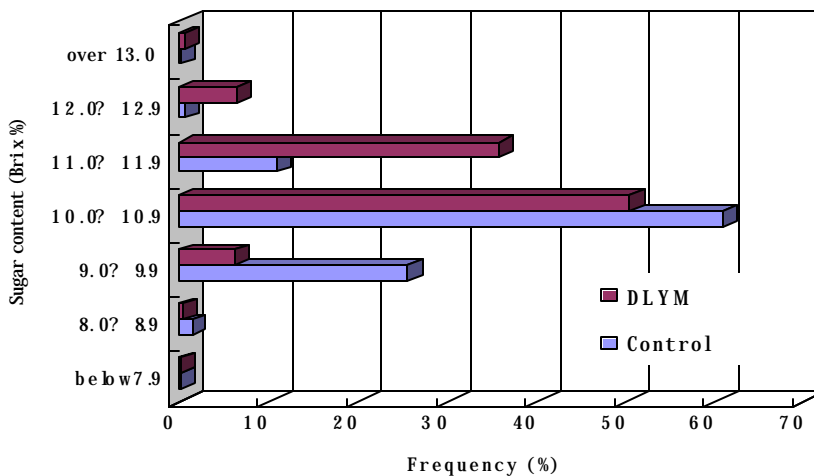


Figure 2. Improvement in sugar content in early satsuma mandarin juice cultivated by DLYM method

The DLYM cultivation method has several labor saving effects. Year round plastic mulching does not require removal of sheet after harvesting every year. Weeding of the orchard, which is a very laborious task, can also be avoided with this method. Watering not only increases fruit yield but also improves fruit quality. The DLYM cultivation system also saves labor spent for manual irrigation. Grower only needs to install a watering program taking into account the tree requirements and weather conditions. Fertilization during harvest season is necessary to maintain tree vigor in the following year. However, this task competes with harvesting and marketing. The automatic system enables adaptations to labor availability.

The DLYM cultivation method has been introduced in several citrus producing areas in western Japan such as Wakayama, Kagawa and Ehime prefectures in recent years. In areas dominated by old growers, this system is getting a greater degree of acceptance possibly because of its labor saving effect. However, if this system is introduced on sloping lands, it will be necessary to improve drainage to prevent erosion.

A new transportation system

In the first stage of the citrus project (1993-97), small size machinery and a simplified process of construction of farm path were developed to save labor. Although the small sized machinery system (a walking type air blast sprayer for pest and disease control, a crawler type transporter, portable weed controllers etc.) is less efficient than a power driven large machinery widely used in flat orchards, our small sized machinery system was able to significantly reduce labor involved in transport. In the computer aided farm path designing system developed in 1998, first a grower draws farm paths of target orchards on a computer display. Then, the program calculates functions based on topography and path length. Several alternatives could be evaluated before making final construction plan. This system consists of two programs: a digital elevation model and a farm path simulator.

Although some reclamation methods, such as orchard terraces and hillside ditches, have been developed for reducing the effect of slope, construction cost is quite high for farmers. The farm path based mechanized farming system is quite cost-effective. However,

such a farm path system can be adopted only for orchards with a slope of 25° or less, because a pick-up truck can climb only on slopes of 15° or less. Also, it is dangerous to operate hydraulic excavator on steep sloping orchards for constructing farm paths. In this background, we developed a new transportation system for citrus orchards on steep slopes ($>25^\circ$) which is a combination of monorail system and contour narrow paths.

In steeply sloping citrus orchards, the monorail system, in which the truck travels along a single rail placed above ground, is in place since 1960s to transport harvested fruits and agricultural inputs. The monorail truck with a 2.2 kW engine can carry about 200 kg load on slopes $<45^\circ$. In the last decade, about 2.5 million m of monorail was laid and 23,000 truck units were installed. The monorail system remarkably reduced transport workload. However, the working environment did not change, because farmers had to stand and work on steep slopes.

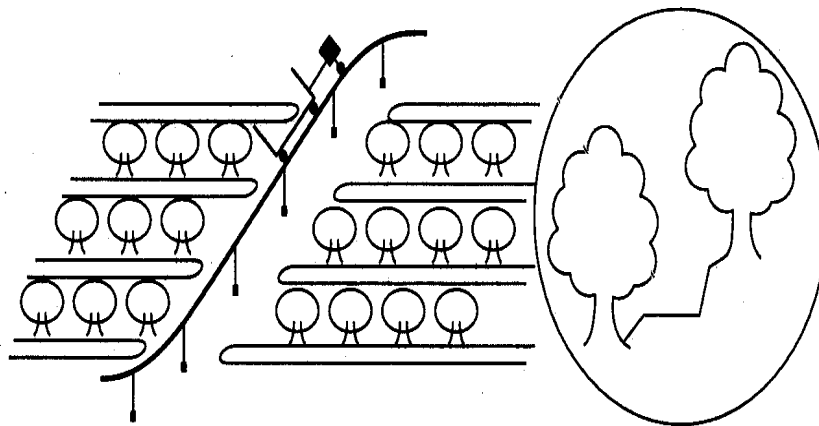


Figure 3. New transportation system for steep slope orchards

A small hydraulic excavator was used for construction of farm paths. We combined monorail system with narrow contour paths. The width of the contour path is only 0.3-0.5 m which is just enough for the farmer to move. The monorail system is connected to the

narrow path for transportation up and down along the slope (Figure 3). This system can be introduced in areas where fruit trees are already mature. Although narrow paths can be constructed manually using a hoe or a scoop, we developed a narrow path excavating technique using a walking cultivator. This small walking cultivator is used for ridge making and a ditch scoop for pushing up soil. A front mounted up-cut rotary in which the rotor revolves in direction opposite to that of wheels, should be provided. The traveling wheel treads should be narrower than the width of the rotary tiller. In order to excavate and to simultaneously clear soil from the upper to the lower side, the curved tines were aligned in one direction.

Table 1 shows the kind of improvement in farm working conditions due to narrow path system. The increasing ratio of heart rate is calculated as the average of heart rate during work divided by the heart rate at rest. If increasing ratio of heart rate is more than 1.5, intensity of work is expressed as hard. The farmer was able to move faster on narrow leveled path than on slopes. Labor spent in broadcast of fertilizer got reduced by 10% as a result of adoption of narrow paths. An improvement in working posture was also observed. Farmers used to manually spray herbicides using a power sprayer. Working space and course created by narrow paths reduced spent in spraying. Transportation time was quite short compared to harvesting time. Although heart rate was increased during transportation work, growers took a break during harvesting. Therefore, the average heart rate for this task was relatively lower than for other tasks. The working space and leveled ground also ensured better safety of workers.

Table 1. Effect of narrow path on working hours and intensity of work

Farm work	Condition	Working hours (h/ha)	Average heart rate (bpm)	Increasing ratio of heart rate	Intensity of work
Fertilizer application	Narrow path	5.5	109	1.39	Middle
	Reference	6.3	120	1.52	Hard
Chemical herbicide	Narrow path	7.3	110	1.40	Middle
	Reference	9.2	112	1.43	Middle
Disease control	Narrow path	5.0	123	1.56	Hard
	Reference	5.0	139	1.76	Hard
Harvesting & transporation	Narrow path	-	98	1.25	Light
	Reference	-	99	1.26	Light

Computer aided disaster prevention system

Prevention of disasters in hilly areas requires not only checks on run-off and soil erosion but also on upward flow of underground water. Multipurpose highly functional farm paths serve functions such as proper use and flows of underground water. Path alignment is decided based on predicted underground water movement using a computer program. To construct the path, a gutter of 1.6-2.0 m depth was trenched and then a pipe with holes and gravels (5-15 mm diameter) was put inside the trench. The path paved by concrete has a vertical gradient of 2.3% and horizontal gradient of 2%. Surface as well as ground water was drained into a tank to be used for irrigation. After execution of a multipurpose farm path, upward flow of underground water was dramatically reduced. Underground water did not reach the soil surface.

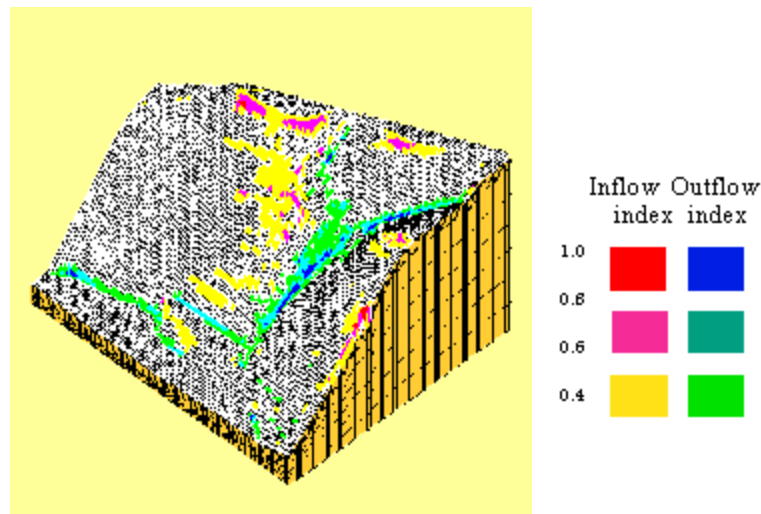


Figure 4. Disaster prevention mapping

Occurrence of citrus orchards on sloping lands was mapped based on computer aided seepage estimation and topographic data (Figure 4). The mapping can show zones of both ascending flow (upward seepage flow) and descending flow (downward seepage flow) of underground water during heavy rains in citrus orchards. This mapping is considered to be effective for management of

orchards and prevention of erosion on slope lands.

Conclusions

Some land uses such as citrus based horticulture on slopes are on decline because of huge labor required in maintenance of this system and the emerging tendency of reluctance towards labor intensive production systems among the youth. This study shows that simple additions/improvements to the existing citrus system can arrest or reverse the trend of its decline in south-western Japan.

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