Studies on the Problem of Citrus Growing in Coastal Mud Flat

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Abstract: Citrus trees growing in coastal mud flats must overcome difficulties brought on by the soil salinity, alkalinity and by the high level of the ground water table. 'Satsuma' mandarin (*Citrus unshiu* Marc.) on trifoliate orange rootstock (*Poncirus trifoliata* (L.) Raf.), could tolerate the soluble salt content in the soil below 0.1%, and notable injury would occur when it is over 0.2%. A ditching system could reduce the soluble salt content in the subsoil by 36.4% after a period of a 2-year rainy season, about 10 times the reduction in a nonditched grove. Ditching could lower the ground water table 13-24 cm. Planting green manure and turning it under are recommended in a young grove. The pH value is above 8. Therefore, chlorosis is a widespread problem mainly due to iron deficiency, associated with manganese or other minor element deficiencies. Use of 0.3-0.5 M citric acid plus ferrous sulphate solution by means of a root injection method gave prompt recovery. Trifoliate orange is the rootstock most sensitive to salinity and alkalinity. 'Goutau Cheng' (*C. aurantium* L.?) and 'Bendizao' mandarin (*C. reticulata* Blanco) are considered to be more suitable as citrus stocks in coastal mud flats at present.

INTRODUCTION

The history of citrus growing in China was thought to be about 4 thousand years as "Yu Gong," the Book of Xia Dynasty, mentioned. But the history of it in coastal mud flats is no longer than 25 years. The Jingqing Farm, located in Huangyan County, Zhejiang Province, made the first citrus planting on the beach facing toward the Pacific Ocean in 1958, where there was once an original mud tideland enclosed only 3 years (1). Since then, citrus plantings along the beach have spread rapidly over the province. The area of such groves in 1981 was about 4,700 hectares (70,395 mu), making up 13.4% of the total citrus area in the province.

The coastal mud flats orchard encounters some intolerable factors, such as heavy clay soil, high salinity and alkalinity, high ground water table and strong wind, which bring about difficulties to citrus growing and seriously affect both tree growth and yield. The author has made a series of investigations on these problems since 1973 and the results have been summarized (2, 3, 4, 5, 6, 7).

I. SOLUBLE SALT CONTENT IN SOIL IN RELATION TO DRAINAGE PRACTICE

High content of soluble salt in the soil is the major factor which limits tree growth in coastal mud flats.

1) The critical value of soil salt content for young citrus tree growth. Young Satsuma trees on trifoliate orange stock grew well in the soil which contained soluble salt <0.1% level in its root zone, as a harmless range; 0.1-0.2% was considered as an influencing range; >0.2%, as a harmful range; and >0.4%, a devastating range (Table 1). However, harmful effects vary with climate, soil temperature and moisture, as well as cultivars, stocks, age, vigor, amount of fruit bearing, etc. The salt level must be kept below 0.2% for citrus growth and below 0.1% for the best growth.

2) Availability of ditching for salt drainage in clay soil groves.

Fresh water with low salt content used to leach the salt from the soil should be available as a basic requirement. A drainage and irrigation system for groves should be established

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Table 1. Soil soluble salt content in relation to citrus growth, March 1973.

Sites	Salt content (%)			Trunk circumference (cm)
	Surface soil (0-20 cm)	Subsoil (20-50 cm)	Under soil (50-80 cm)	
Normal growth	0.058	0.080	0.120	9.08
Tolerable growth	0.084	0.140	0.194	8.51
Poor growth	0.078	0.186	0.273	6.57
Declined	0.273	0.492	0.473	—

prior to the planting operation. A ditch 80 cm deep connected to a drain canal enhances salt removal.

Ditching single rows gave an apparent effect on salt drainage (Table 2). It reduced the salt content at the rate of 36.4% in the root zone, about 10 times faster than the nonditching system, after a period of a 2-year rainy season.

II. FLUCTUATION OF GROUND WATER TABLE AND THE MOUND-PLANTED METHOD

The annual total rainfall is around 1600 mm in Zhejiang Province, with a large percentage occurring during June and July. For example, the rainfall in June 1973 reached 208.6 mm in Huangyan County. In this season, the ground water table in most of the citrus groves remained high.

1) Effects of ditching on lowering the ground water table.

Ditching lowered the ground water table 13-24 cm as compared to nonditching treatment (Table 3). The ground water table was measured for 30 days, from May 30 to June 28, 1973, and under light rain conditions, the water table in the nonditching site rose more rapidly than that in the ditching site. Under heavy rain conditions, the water table in both systems increased significantly, but it dropped more rapidly in the ditching system.

2) Use of the mound-planting method.

The mound-planting method has been one of the traditional citricultural operations for orchards on clay soils with high water table for more than a thousand years in the southeastern part of Zhejian Province. Beds of single or double rows of trees with furrows are constructed. Ditching between blocks of beds is required. Instead of planting in a depression, a mound of soil is piled up to give a lower water table, enlarge the root zone and decrease the salt content (Fig. 1).

III. SOIL TEXTURE AND SOIL MANAGEMENT

The soil texture of citrus groves in coastal mud flats is largely clay.

Table 2. Comparison of ditching and nonditching for salt drainage.

Sites	Depth (cm)	Salt content (%)		Decrease rate (%)
		March 1973	December 1974	
Ditching grove	0-20	0.084	0.060	28.6
	20-50	0.140	0.089	36.4
	50-80	0.194	0.136	29.9
Nonditching grove	0-20	0.076	0.058	23.7
	20-50	0.110	0.106	3.6
	50-80	0.184	0.163	10.4

Table 3. A comparison of water table depth (cm) with ditching and nonditching systems in 1973.

Grove	April 19	April 23	May 1	May 11
Ditching	67	58	68	65
Nonditching	39	34	55	44

1) Soil properties.

Soil samples taken from a citrus grove in Sanjia District, Huangyan County, after 11 years of planting (Table 4). The soil is a medium clay in which particles <0.01 mm reach to 78.55%. The coastal soil profile is not well differentiated and there is more clay in the deeper stratum of the soil.

This citrus grove contains rather low salt amounts, but the pH value remains at 8.1-8.3. In fact, the decrease of salt tends to increase the pH value (2). Some grove soil pH values have increased to 9 or more (2). Besides, these soils are calcareous, and the organic matter is rather low, rarely more than 1%.

2) Deep tillage and growing pioneer crops prior to the plants.

Tillage as deep as 30 cm is practiced prior to planting trees. Afterward, sowing salt-tolerant pioneer crops such as *Sesbania* improves soil structure and decreases soil salt content, as well.

3) Intercropping and plowing under green manures in young orchards.

Intercropping in a young orchard improves the soil structure and increases fertility. The most important green manures are legumes, such as *Sesbania,* soybean (*Glycine max* Merr.), mung bean (*Phaseolus aureus* Roxb.), broad bean (*Vicia faba* L.), pea (*Pisum* spp.), and alfalfa (*Medicago hispida* Gaertn.).

Plowing under these manures at 30-50 kg per tree to a depth of 30-50 cm once or twice a year proved to be profitable.

4) Mulching and hilling culture.

Clean tillage is still used. Mulching before the drought season or cold season proved beneficial. Hilling the surface soil around the trunk also proved useful as the soil around the roots had been eroded away.

IV. DEFICIENCIES OF MICRONUTRIENTS AND THEIR CONTROL

'Satsuma' mandarin on trifoliate orange stock has appeared to suffer chlorotic disorder to some extent.

1) Symptoms of chlorosis.

Chlorosis, locally called yellowish disease, commonly appears when the tree begins to bear fruit. The symptoms occur in new shoots of spring, summer or autumn growth flushes. It begins mostly in the middle and lower part of the foliage canopy, and then spreads over the whole tree. The southern side of the tree is affected most seriously. Green leaves fade color progressively, showing typical yellowish venation. At an advanced stage, leaves may become entirely yellow with only a tinge of green in the midribs, smaller and even thinner. The affected fruits begin to lose green color around August, remaining lemon colored up to harvest. Such fruits are smaller, with thinner and more smooth rind, of somewhat acid and watery taste. The total soluble solids of normal fruit is 11% and acidity is 0.824%,

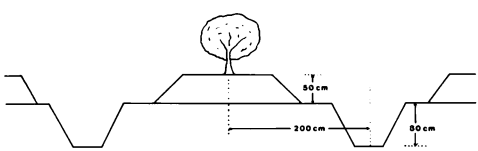

Fig. 1. Diagram of the mound planting.

Table 4. Soil properties of a citrus grove in coastal mud flats, December 1980.

Soil layer (cm)	Organic matter	pH	Cation exchange capacity (meq/100 g)	Salt content (%)	Negative ion + cation in soluble salt (meq/100 g)							Particle (%)			
					Cl	SO_4	HCO_3	Ca	Mg	K	Na	Texture	0.01 (mm)	<0.01 (mm)	$CaCO_3$ (%)
0-20	—	8.1	—	0.062	0.164	0.149	0.556	0.119	0.299	0.051	0.239	—	—	—	—
20-50	0.802	8.3	17.1	0.121	0.533	0.119	0.958	0.144	0.249	0.110	1.200	medium clay	21.45	78.55	5.51
50-80	—	8.5	—	0.191	1.090	0.328	1.260	0.100	0.179	0.123	2.240	—	—	—	—

Table 5. Results from leaf analysis of satsuma mandarin on trifoliate orange stock in 1980.

Kind of leaves	%			ppm		
	N	P	K	Na	Fe	Mn
Chlorotic leaf	3.70	0.458	2.12	1750	24	24
Recovered leaf plus Fe + Mn	3.66	0.469	1.76	900	42	63
Recovered leaf plus Fe	3.89	0.458	1.32	1200	45	30

while the affected fruit is only 10% and 0.926%, respectively.

The chlorotic leaves are sometimes found necrotic at the apex and margin, or curled and dropped. The foliage canopy usually gives a thin and ugly appearance in the advanced stages. Fruit yield decreases sharply and the economic value is lost.

2) Identification of the cause for chlorosis.

Nutritional sprays were applied in 1973-74. Iron gave a quick response and manganese reacted slightly. Later, leaves from 7-month-old nonbearing spring shoots were analyzed as shown in Table 5.

According to the nutritional standards reported by Chapman et al. (9), a) N, P, K were at high levels; b) the chlorotic leaf was high in K; c) the chlorotic leaf contained Fe in insufficient amount; d) the chlorotic leaf contained Mn at a low level, but Mn increased to normal when applied (Table 5). Thus, it is recognized that the chlorosis of citrus trees in the coastal mud flats is mainly due to the lack of Fe, associated with Mn and other element deficiencies (6, 8).

3) Investigations on the corrective nutritional measures.

Treatments, including replanting, deep application of manure, addition of gypsum and sulphur, etc., had been tried since 1973 and various results were obtained. It seems inefficient to overcome the chlorosis in a short period. Symptoms could be reduced slightly or postponed by controlling nitrogen application and by intermittent sod culture. Application of iron by spraying, even with a spreader, was not satisfactory; only regreened dots or lumps could be found around the stomata. Ferrous sulphate plus citric acid injected into the trunk from a bottle caused only partial recovery. Adding ferrous sulphate to the root zone gave no response. Root injection with iron citric acid solution from bottles has been an effective, quick, and inexpensive method (3, 4).

4) The technique of root injection with iron citric acid solution in bottles.

Dilute ferrous sulphate plus citric acid solution at concentrations of 0.3 to 0.5 M was used. Steps used in the root injection were as follows: Prepare clean small bottle about 8 ml in volume, bury 3 or 4 bottles in different areas under a tree, choose small roots about 0.2-0.5 cm in diameter, cut them smooth, and insert them to the bottom of the bottles. The prepared solution is poured into the bottle and a leaf is placed on it to keep out the rain. The optimum period for treatment is from April to September. Use 0.3 M solution for summer; and 0.4-0.5 M for spring or autumn. (Fig. 2)

Leaves should recover within a week in the summer. Affected fruits treated at an early stage will start to grow again and regreen. The appearance can be improved and the yield increased. Effects of the recovery can last nearly a year. (Figs. 3 & 4)

V. SUITABLE CITRUS ROOTSTOCKS IN COASTAL MUD FLATS

After a series of surveys and experimentation, it has been shown that not all citrus stocks used today are suitable for coastal mud flats. Trifoliate orange is the most sensitive stock to salinity and alkalinity, and suffers se-

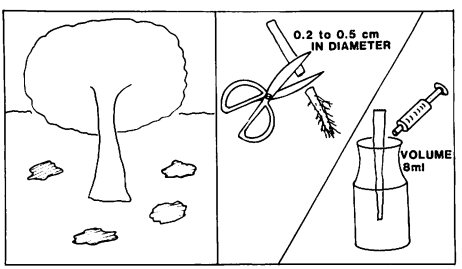

Fig. 2. Diagram of root injection with iron solution in bottles.

Fig. 3. Appearance of Fe deficient trees.

Fig. 4. Appearance of recovered trees.

riously from micronutrient deficiencies. So its use has been eliminated gradually. Two rootstocks recommended for mandarins are 'Goutou Cheng' (*C. aurantium* L. ?) and 'Bendizao' mandarin (*C. reticulata* Blanco). They are both quite tolerant of salinity and alkalinity and are satisfactory in culture. Either can be used as an inarching root.

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Citrus Scientific Symposium
Part 2

In the July issue of V39 of *Fruit Varieties Journal* 6 additional papers presented at the Citrus Symposium held jointly by scientists from China and the U.S. These papers will cover citrus culture under specific climatic conditions, rootstocks and the influence of nematodes, virus and virus-like diseases of citrus as well as packing house operations and handling.