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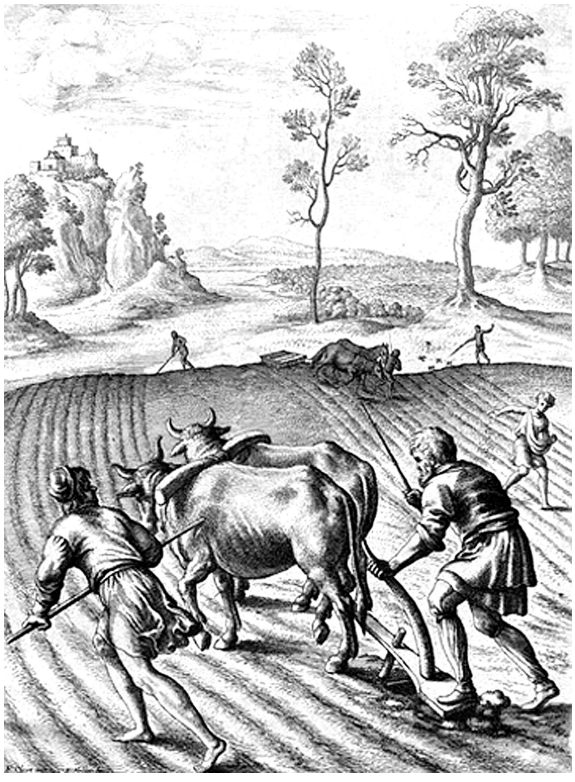

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The Biological Responses of Loquat (*Eriobotrya japonica* Lindl.) in Diverse Ecotypes of Sichuan

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Abstract: Loquats (*Eriobotrya japonica* Lindl.) have formed different ecological types in various zones during the long course of their cultivation and acclimatization. The data of biological responses and ecological suitability was very important for loquat plantation in different eco-zones. In this study, we evaluated the growth and development characters, flowering and fruiting habits and fruit quality of loquat in three diverse ecotypes of Sichuan by field survey. The results showed that in mid-subtropical damp and heat ecotype, the loquat trees grew vigorously and young shoots sprouted four times annually. The flower buds were mainly originated from the Summer shoots and the flowering stage most centered from September to December. In addition, a rapid growth stage of fruits was observed from March to April and fruit quality was fine in May. In Southern subtropical dry and hot eco-zone, young shoots might be developed four or five times annually. Flowering and fruiting could occur several times a year as the development differences of Spring and Summer shoots with flower buds differentiation without trees treatments. In the valley of Southern temperate warm and dry ecotype, the phenophase of loquat were late about 20 to 30 days. The loquat fruits were mainly originated from Summer flowerings and mature at June with more than 15% soluble solids, super quality and nice appearance. These results obtained from comprehensive investigation would provide valuable information for techniques of cultivation in distinctive ecotypes and facilitated the economic plantation for loquats in the diverse eco-zones of the world.

Key words: Loquat, biological responses, ecological character, horticultural technologies, Sichuan Province

INTRODUCTION

Loquat (*Eriobotrya japonica* (Thunb.) Lindl.) originated in China (Condit, 1915; Lin *et al*., 1999) and is a typical subtropical evergreen fruit tree that increased tremendously in the last few decades (Lin, 2007). Although, the tree is traditionally considered to be confined in sub-tropical regions, loquat is actually very well adapted to virtually environments and scattered widely. Loquat trees are adapted to cool tropical (high elevation areas), subtropical and mid-temperate climates and have been widely distributed throughout the world (Caldira and Jonathan, 1999). The regions of natural distribution and economic cultivation for loquat are far beyond people's understanding of the past.

Loquats blooms during fall and winter and fruits ripen in Spring and early Summer, the unusual phenology of flower initiation and fruits forming make it different from other fruit trees in biological processes. Moreover, loquats have formed different ecological types in various zones during the long course of their cultivation and acclimatization (Vilanova *et al*., 2001). Unique biological responses and ecological suitability can be distinguished in diverse ecotype conditions. Sichuan is the principal province of loquat production in Southwest of China, the loquat acreage of Sichuan was over 61.334 ha and yield achieved more than 360,000 tons with total values of 2.88 billion RMB in 2008. With vast territory, complicated terrains, various climates and diverse ecological circumstances, the biological responses of loquat in Sichuan might be the overview of the ecological suitability of loquat around the world. Loquat bloom date and harvest time vary in different years, suggesting a strong environmental influence (Hueso *et al*., 2007). Consequently, the data of biological responses and ecological suitability for loquat is crucial in establishment of horticultural techniques and plantation management in diverse ecotypes.

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To make full use of the unique ecological conditions, we investigated the biological responses and ecological suitability for loquat based on various eco-zones of Sichuan. These results would be significant in developing prominent special industries for loquat with different maturity in the world.

MATERIALS AND METHODS

This experiment was conducted from the September of 2007 to the April of 2010 and three distinctive eco-types of loquat were selected in the study. Shuangliu County and Longquanyi District were selected on behalf of mid-subtropical humid eco-zones; Dechang and Mi Yi County behalf of the Southern sub-tropical dry and hot ecotypes; Wenchuan and Mao County behalf of the South dry and warm temperate ecological zones. Meteorological data was the average data and experimental observations of the past 20 years from the local meteorological department. Producing surveys, sentinel observation and statistical analysis were applied in the experiment.

Subtropical humid eco-zone is located in the Sichuan Basin, which is the main producing areas of loquat in Sichuan, where Shuangliu is a big loquat-producing county with cultivation area of 11000 ha. This area is a continental monsoon climate with planting region altitude of 435-794 m. The coldest month average temperature of 5.4°C, the hottest month average temperature of 25.2°C, extreme high temperature 39.4°C, extreme minimum temperature of -5.0°C and average annual temperature of 16.3°C. The accumulated temperature of ≥10°C is 5500-6200°C, annual average sunshine hours 1176.3 h, average annual rainfall 867.6 mm and frost-free period 291 day. The climatic character of the eco-zone is that temperature rose rapidly in Spring, heat abundance and low light with more rain and humidity in Autumn.

South subtropical dry and hot sunshine eco-zone included the Jinsha River of Panxi area in Sichuan, Anning River and Yalong River valley with loquat cultivation about 1400-1700 m altitude. In this zone, the coldest average January temperature is about 10°C with annual average temperature 16-19°C. The annual accumulated temperature of ≥10°C most was 5000-6000°C, frost-free period much more than 300 day and the frequency of low temperature ≤-3°C is very low, usually once in 10-20 years. Especially the temperature of the middle mountains was higher that valley bottom when the coldest time as the effects of temperature inversion. The annual sunshine is 2400-2900 h, annual rainfall of 879 mm. The climate characteristic of the eco-zone is to be abundant light and heat, low seasonal variation of temperature but high variation of daily temperature. Dry season and rainy season were distinct with great evaporation. The geographical environment is complex and mountain climate is obvious with the feature of mountain the season, ten-mile different days.

South temperate dry and warm eco-zone is in Mao and Wenchuan County of Aba Tibetan and Qiang Autonomous Prefecture with 1300-1700 m altitude. The average annual temperature is 11-14°C, the extreme highest temperature of 31.8°C and extreme minimum temperature of -11.6°C. The annual precipitation is about 500 mm and annual evaporation much more than 1300 mm. The annual average sunshine hours are 1400-1800 h and frost-free period of 210-260 day. The climate characteristic of the eco-zone is sufficient sunlight, mild climate and long winter without Summer. Spring connected to Autumn with distinctive dry and rainy season. In addition, cold and dry climate, low air humidity and large temperature difference between day and night could be found in Summer season.

RESULTS

Subtropical humid eco-zone: Loquat trees grew vigorously and young shoots sprouted 4 times annually. The flower buds were mainly originated from the Summer shoots and the flowering stage most centered from September to December. In addition, a rapid growth stage of fruits was observed from March to April and fruit quality was fine with centralized maturity of May.

There was no serious drought, frost and hail, typhoons and other disasters in this eco-zone. Suitable circumstance was available for loquat in growth and development, as well as in the establishment of output and quality. However, the main diseases affecting loquat production was leaf spot, flowers rotten diseases. In addition, the adverse circumstances that chilling injury of flower and young fruits in coldest winter, Spring drought or rain, sunburn, fruit cracking and shrinking in Summer, flower rotten disease and premature senility of inner and lowest tier effected by rainy and less light season of Autumn should be paid attention.

South subtropical dry and hot sunshine eco-zone: Shoots might be sprouted four or five times annually in young or vigorous loquat trees. Various flowering and fruiting could occur per year due to the differences for Spring and Summer shoots development and differentiations for flower buds without trees treatments. Spring shoots mainly sprouting in the March to April and stopped early in drought season, so the flower buds were stimulated to differentiation and produced earlier primary panicles in

June or July. As in high-temperature season, flowering short, petal closing, stigma mucus is so poor to complete pollination fertilization. With low setting rate and short development period, bad and small loquat fruits formed in September to October. The early inflorescences would consume much more nutrition of loquat trees and limited the differentiation of the second and third flower. The second and third panicles were occurred in August to September and October to late November with maturity of December to February and March to early April, respectively.

Through regulating sprouting period of loquat fruiting branch by horticultural techniques, natural early flowers were avoided and inflorescences were concentrated in August to October. Under high temperature conditions of winter, no stagnation or chilling damage was occurred in flower and young fruit. Fruits ripen in December to March of the following year and to be the early-maturing and off-season loquat without facilities. The large and super quality loquats had a high value in merchandise and market competition with smooth and brightly-colored surface.

Altitude and micro-climate had a great influence on the production of loquat in this region. In addition, early inflorescences were formed much profusely and less panicle was occurred in the proper period of August to September. Loquat canker, bud blight and fruit quercus disease should to be prevented.

South temperate dry and warm eco-zone: The ecological response of loquat in the valley with lower altitude was similar to those in less sunshine and humid subtropical eco-zones. However, the phonological period was postponed for 20-30 days and panicles were mainly from Summer shoots and fruits ripened in June with more than 15% soluble solids, smooth and brightly-colored surface and good quality.

With the altitude increases, the amount yield of annual loquat showed a gradual reduction. Only one or two sprouting could be occurred and fruiting branches were from Spring shoots. The bloom period was from September to early February and most panicles had a significantly high survival rate as chilling stress of winter. Fruit maturation was also delayed with altitude increasing, usually in mid-June to late August. With long period of fruit development and large temperature difference between day and night, multiple loquats per ear could be well developed to be super quality merchandise with more than 17% soluble solids and high sugar accumulation.

However, the panicles were difficult to be formation in the high altitude region and amount yield of loquat could fall sharply in some year that serious chilling injury occurred.

Economic characteristics and cultivation techniques: There were no significant difference in fruit size, edible rate and numbers of seeds for loquat in diverse eco-zones by sampling analysis. However, loquat fruit appearance and internal quality were distinctive in different ecotypes. For example, the fruits of loquat variety Dawuxing in the South subtropical dry and hot eco-zone (Xichang, Dechang) were sweet tasty, soft and juicy with smooth surface, bright orange color. The soluble solids of Dawuxing loquat in this area was up to 14.9-15.3%, which high 3 to 4% than those in the subtropical humid ecological zones (Longquan Chengdu, Shipan Jianyang). The phase of fruit growth and development for loquat in Southern dry-warm temperate eco-zone (Wenchuan, Maoxian) was so long that sugar accumulation was sufficient and soluble solids content was as high as 17.4%. In addition, acid content of flesh was very low, good quality with few strip spot and soft and juicy flavor (Table 1).

Variety combination scheme for advancing or prolonging the mature period of loquat could be applied in diverse eco-zones according to loquat phenotype characteristics especially florescent properties and chilling tolerance. Key horticultural technologies of cultivation for increasing production could be established according to the loquat phenotypes in diverse ecotypes. In mid-subtropical humid eco-zones, the tending skills, such as pruning trees with high photosynthetic performance, abundant fruit fertilization, heavy cutting after harvest and frost protections in open air cultivation, simple shed cultivation and deeper furrow to improve soil drainage facilitated the production of loquat. In the Southern subtropical dry and hot eco-zone, the practices

Table 1: Comparison of fruit characters of loquat Dawuxing in different ecological zones

Location	Mean weight (g)	Pericarp color	Fruit stripe	Soluble solids (%)	Acid content (%)	Edible rate (%)	No. of seeds
Long quan	52.4	Orange	Midding	11.5	0.39	71.2	3.5
Sipan	52.6	Orange	Midding	12.1	0.36	71.4	3.4
Taihe	51.2	Orange red	Little	15.3	0.28	71.5	3.2
Xiaofeng	51.3	Orange red	Little	14.9	0.26	72.0	3.3
Qipan	48.5	Orange	Little	15.6	0.21	71.0	3.4
Fengmaoping	63.4	Orange	Little	17.4	0.19	72.3	3.4

that Spring shoot topping to develop side shoots as bearing branches, timely application of fertilizer and promoting flowers, picking early and thinning late flowers, spraying honey and auxiliary agent, fruit bagging with leaves were good in regulating flowering and fruiting of loquat. In the Southern drying and warming temperate eco-zone, the techniques that water controlling, uprooting, increasing phosphate and potassium and reducing nitrogen fertilizer were explored in middle June. In addition, the other technical measures including plucking twigs, twisting branches and spraying of plant growth regulator also promoted flower budding and achieved good returns with the successive high yield.

DISCUSSION

It is obvious that the production of loquat depend upon different genotypes, years and environmental conditions at a very high level. In spite of China's leaderships, loquat was also well adapted to mild-winter areas of the Mediterranean basin (Hueso and Cuevas, 2008). The mainly other counties of loquat production is Japan, India, Pakistan, Madagascar, Reunion Island, Mauritius Island, the Mediterranean countries (Spain, Turkey, Italy, Greece, Israel), United States (mainly California and Florida), Brazil, Venezuela and Australia (Badenes *et al*., 2000). These eco-types of loquat production were similarly to that of Sichuan in part or all, so the three distinctive ecological zones of Sichuan could represent the other eco-zones of loquat production in the world.

Among environmental conditions, climate factors directly affect the yield and quality of loquat cultivars, these results were supported by the previous studies (Polat, 2007; Alburquerque *et al*., 2004). The management practices and regulation of flower buds differentiation and other measures were favorable in suitable ecological conditions with vertical climatic differences, which were in consistent with the outcome of Durgac *et al*. (2006). In this study, loquat matured in October to March the following year in Panxi region, ripened in the April-May in the Sichuan Basin and harvest in June-August in the Valley of Minjiang River. Consequently, the annual production of loquat could be realized on the whole based on adjustment of harvest time in diverse ecotypes of Sichuan.

Now some studies about morphophysical characteristics of loquat were performed (Polat, 2007; Hussain *et al*., 2009). However, limited work has ever been reported regarding the description of loquat ecotypes based on meteorological data. In this study, the abundant ecological treasures of light and heat resources in Panxi region were available to build a very special production base of loquat with early-maturing, good quality and highly market competitive. In the dry and warm valley of the Aba Tibetan area, super quality fruit with late ripening and harvest could facilitate the establishment of loquat industry base with considerable scale combined with the tourism development of Jiuzhaigou-Huanglong. The economic cultivation and loquat industries with distinctive character could be carried out, which might be used as reference for biological responses and ecological suitability of loquat production in different eco-zones of the word.

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