The Adaptability of Fuji to the Southern Apple Economic Cultivation Districts in China

Sheng Bincheng[1], Wang Chenliang[2] and Tao Jianming[1]

[1]Department of Horticulture, Nanjing Agricultural University, Nanjing 210095, People's Republic of China
[2]Fruit Research Centre, Xuzhou, People's Republic of China

The initial apple economic cultivation districts were localized around the Bohai Sea district, of which the north latitude is 36˚10' and the annual average temperature is 8-12˚C. Apple production was greatly increased in every phase after the 1950s, which made the apple's increase the fastest of all the fruit species. According to the statistical data from 1995, apple cultivation area was 2,933,300 ha, and the apple output was 14 million metric tons (t), of these 1,285,300 ha and 6 million t were of Fuji. Till now, there have appeared 6 major apple cultivation districts with their own characteristics: the Bohai Sea, the Huanghe River Old Course, the northern foot of Qinling Mountains, the highlands in northwest and southwest China, and the frigid zones. Compared to the Bohai Sea district, the Huanghe River Old Course district is a little south, and its annual average temperature is also higher. The Huanghe River Old Course district is often classified as a secondarily suitable region for apple cultivation or as the southern edge of the apple economic cultivation district. Except for the highland in southwest China, any other districts with lower latitude in China than that of the Huanghe River Old Course district are not suitable for apple production.

The Responses of Fuji and Its Red Selections to the Ecological Surroundings with Warm and Humid Climate

Fuji began to be introduced to the Huanghe River Old Course and the Huaihai Valley districts during the late 1960s and the early 1970s. The results of 10 years' experience and investigation from several cultivation districts indicate that Fuji is well adapted to the warm and humid climate. Since the early 1980s, Fuji has become popular in the above two regions. Now the cultivation area is about 140,700 ha, mainly localized in the Huanghe River Old Course district, of which the latitude is 33.5-35.0˚ north. This district, covering some regions of Henan, Shandong, Anhui and Jiangsu provinces from Zhengzhon in Henan province to Binhai in Jiangsu province, is more than 500 km (310 miles) in length and is now the major production area of commercial apple in China. Its climate is continental, as follows: droughty and warming rapidly in spring, high temperature and humidity in summer, cold and dry in autumn, plentiful sunshine in the whole year. In Xuzhou, the average temperatures for the whole year, for July and for January are 14.5˚C, 27.1˚C

and -0.8˚C, respectively. The maximum and minimum temperatures were 40.1˚C and -23.3˚C. The numbers of the days with the maximum temperature above 35.0˚C and with the minimum temperature below -10.0˚C were 12.3 and 5.3, respectively. The frost-free period lasted 204.8 days. In Xuzhou, it rains about 92 days per year, and the annual precipitation is 874.3 mm (34 inches), of which 511.3 mm (20 inches) falls in the 3 months of June, July and August (58.3 percent of annual precipitation). Annually there are 2441.1 hours of sunshine, with 251.3 hours in June, the most, and 166 hours in February, the least.

The soil-forming materials were the deposits of the Huanghe River's flooding. The pH is 8.0-8.5, and the organic matter concentration is about 0.4 percent. Just as other apple varieties, Fuji can also adapt to the above situations with a long growth period, early budding, blooming and fruit-maturing stages, etc., and late leaf falling (Table 1). The Fuji apple trees grow vigorously, and those of 3 years' growing could begin fruiting when effective controlling managements were adopted. When the trees reached maturity, their yield is 22.5 t/ha. The fruit qualities were excellent, and can be stored under normal cold storage into March and April of the following year. Fuji is adapted to the Huanghe River Old Course district. In the market, the consumers were in favor of Fuji, and therefore the farmers who planted Fuji acquired higher benefit.

Fuji apple trees were more resistant to the early leaf-falling disease. The incidence of the disease was very low in a year with normal precipitation. The diseased leaf percentage was about 18.0% with plentiful rainfall, which was also much lower than that of Ralls Janet (36.0%) and Delicious (33.0%) trees in the same year. Fuji was much more resistant to apple bitter rot (*Glomerella ciugulata* Schr. et Spauld), which is the major disease harming the apple fruit in the Huanghe River Old Course district, and the diseased fruits were just seven to five times less than those of Ralls Janet. However, Fuji was more susceptible to apple ring spot (*Physalospora piricola* Nose), being more severe in the southern area. If effective control methods were not adopted in time in the years of severe disease, the diseased fruit percentage was up to about 40-50%, including the diseased fruits during the storage. The apple ring spot also severely affected the trunks and branches. The resistance of Fuji to apple canker (*Valsa mali* Migabe et Yamada) was similar to that of Ralls Janet. However, its drought resistance was lower than that of Ralls Janet, Delicious and Golden Delicious, and severe drought could cause leaf falling, shoot withering and fruit peel wrinkling.

The dehisced fruit percentage of Fuji was much less than that of Ralls. Surveying the Ralls fruits harvested in October in the Huanghe River Old Course district showed that the dehisced fruit

percentages were 20-50%, and the most severe were about 80%, while that of Fuji was between 0.2-2%. Usually, spring freeze injury does not occur. The late frost of April 4, 1980, lowered the atmospheric temperature to -3.0˚C, and 71% of the king flowers were damaged, which was higher than those of Jonathan (5%) and Delicious (11.5%).

The Suitability of Fuji Apple in the Districts to the North and South of the Huaihe River

Xuzhou, lying north to the Huaihe River, and Yiangzhou, lying south to the River, are respectively the northern edge of the warm temperate zone and the north subtropical zone, and their latitude difference is 2.0˚. The main climatic indexes in the two districts are shown in Table 2.

The Influences of the Two Kinds of Soils on Fuji Root Distribution

The sandy soil in the Dashahe orchard is soft, and the yellow soil in the Gaoyou orchard is sticky. In these soils the root distribution is different. When Fuji trees grow in the former soil, their roots grow strongly and reach the depth of 100 cm. Of the roots, 84.8% are distributed in the depth range of 10-50 cm, and 98.1% of all the roots are fibrous ones. When in the latter soil, the roots could not reach the depth lower than 60 cm, and just 94.6% of the roots are fibrous (Table 3).

The Influences of the Two Kinds of Surroundings to Fuji Tree Growth

The different climate and soil situations caused the obvious growth differences between the Fuji trees in the two orchards. The trees growing in the Dashahe orchard grew more vigorously than those in the Gaoyou orchard, and the trunk circumference, shoot length and diameter of the trees in the former orchard were respectively 15.3, 19.9 and 0.15 cm longer than those of the trees in the latter orchard (Table 4).

Leaf growth was also affected by the site. The leaves, both on the long and short shoots, of Fuji trees in Dashahe orchard had larger leaf size, thickness, and palisade tissue thickness than those in the Gaoyou orchard (Table 5).

The Differences between Fruit Quality of Fuji in the Two Districts

The quality of Fuji fruits in the district north to the Huaihe River were obviously superior to that in the district south of the river (Table 6). The average weight in Dashahe orchard was 200.3 g,

which is 19% larger than that in Gaoyou orchard, and the fruit smooth and clean surface, the coloring index and the fruit shape index in the former orchard are much higher. The results of fruit quality appraisals by the Jiangsu province appraisal organization in the years before 1997 were that the flavors of the fruits in the both orchards were the same, while the soluble solids and the acid concentrations of the fruits in the Gaoyou orchard were higher.

The data in Table 6 show that the district south of the Huaihe River is less suitable to Fuji than the district north of the river. Also apple ring spot in the south was more severe. Therefore, considering tree growth, profit and some other factors, Fuji is a variety that is well adapted to the district north of the Huaihe River, while in the district south of the River, there should not be large scale plantings.

The Adaptiveness of Fuji to the West and East Parts of the Huanghe River Old Course District

Overall, Fuji is adapted to the Huanghe River Old Course district, which is north of the Huaihe River, but if Xuzhou is taken as the center of this region, the east and the west parts of the district have different climate situations (Table 7).

From the west to the east, there is the tendency for temperature lowering, sunshine hours decreasing, precipitation and rainy days increasing and relative humidity increasing, all the above due to the influences of the Huanghai (Yellow) Sea. As a result, the outer and inner qualities of the fruits of the west were superior to those of the east. The distance between Xuzhou City and the two districts of Feng County and Pei County is just 60 km, and the different microclimates made fruit quality of the two counties a little better than those of the Xuzhou suburbs. Long-time production practices showed that the west part of the Huanghe River Old Course is an important area for the production of high quality Fuji fruit.

Fuji, a Suitable Late Maturing Variety in the South Apple Economic Cultivation Zone in China

According to the comprehensive assessment of the climate, the district of Huanghe River Old Course is a secondary region for apple cultivation and also is the south edge of the apple fruit production area. Higher temperatures make the bloom and fruit maturing period about 15 and 20 days earlier than in the Bohai Sea district. Therefore, early and middle-early apple varieties, which can miss the season with high temperature and precipitation, provide markets with fruits earlier. These varieties also have less diseases and pests and need lower investment, which can bring high profit. On the contrary, because of the high temperature, low difference of the temperature during

the later growing period of the late mature varieties, which decrease the fruit's coloring percentage and carbohydrate concentration, together with long fruit growing period, severe disease and pest damages, high management cost and low profit, there had been no suitable late mature apple varieties found adapted to the Huanghe River Old Course district before Fuji was introduced.

The summary of our work of more than 20 years from the beginning of testing to the ultimate stage of vast popularizing give the following scientific conclusion: 1) Fuji is well adapted to the Huanghe River Old Course district and is an excellent late mature variety; 2) Fuji is adapted to highest temperatures shown by thermal quantity index (112.3˚C) of Pei county in Xuzhou (the thermal quantity index is often used as the criterion to assess the fruit trees' suitable temperature in Japan, and those for Delicious and Fuji are 70˚C and 90˚C, respectively); 3) Fuji fruit quality in the district of Huanghe River Old Course is the same as that in the Bohai Sea district.

The successful cultivation of Fuji in Huanghe River Old Course district offers new opportunities for apple production, and shows that a southern apple ecological group with excellent varieties acquired by selection and cultivation can gradually be established in the secondary apple districts. At the same time as developing good varieties, the arrangement of varieties of different maturity periods should be possible.

Table 1. Phenological period of Fuji (month/day) near Xuzhou in the Huanghe River Old Course district (Dashahe orchard 1979).

						Leaf bud		
Sprouting stage	Beginning bloom stage	Full bloom stage	Bloom withering period	Fruit coloring period	Mature period	Budding stage	Leafing stage	Shooting period
3/19	4/11	4/15	4/22	9/21	10/5	3/26	4/7	4/15

Spring shoots' slow growing or terminal bud set	Autumn shoots' beginning period	Autumn shoots' stopping period	Leaf falling stage	Fruit growing days	Plant growing days
6/20	7/9	9/29	11/30	173	251

Table 2. Comparison between climate and soil factors of two districts north (Xuzhou) and south (Yiangzhou) of the Huaihe River.

Place	Northern latitude	Annual temperature average (˚C)	July and August (˚C) Temperature average	July and August (˚C) Night temperature average	July and August (˚C) Difference of temperature
Xuzhou Dashahe Orchard	34˚55'	13.8	26.3	22.9	7.7
Yiangzhou Gaoyou Orchard	32˚48'	14.7	27.0	24.1	6.7

September (˚C) Temperature average	September (˚C) Night temperature average	September (˚C) Difference in temperature	October (˚C) Temperature average	October (˚C) Night temperature average	October (˚C) Difference in temperature	Annual precipitation (mm)
21.1	17.0	10.9	15.7	10.2	12.9	800.5
22.5	19.2	7.3	16.8	12.6	9.4	1022.2

From April to September Relative humidity	From April to November Sunshine hours	Soil type
75	1656.0	Sandy
81	1615.4	Sticky

Table 3. Distribution of Fuji roots in the soils.[z]

Depth from soil surface (cm)	Sand soil Root no.	Sand soil Root %	Sand soil Root diameter (cm) <2	Sand soil Root diameter (cm) 2-10	Sand soil Root diameter (cm) >10	Yellow soil Root no.	Yellow soil Root %	Yellow soil Root diameter (cm) <2	Yellow soil Root diameter (cm) 2-10	Yellow soil Root diameter (cm) >10
0-20	146	21.3	144	1	1	165	21.4	161	4	0
20-40	352	51.4	346	3	3	382	49.5	351	28	3
40-60	102	14.9	100	2	0	224	29.1	217	7	0
60-80	63	9.2	60	3	0	0	0.0	0	0	0
80-100	22	3.2	22	0	0	0	0.0	0	0	0
Total	685	100	672	9	4	771	100	729	39	3

[z]Naga-fu 2/Ralls Janet/Xifuhaitang (*Malus micromalus*); Fuji scions were grafted on 20-year-old Ralls Janet middle stocks; the data in Table 3 and the following ones were surveyed in 1990.

Table 4. Comparison of trunk and branch growth of Fuji Naga-fu 2 trees in two districts.

Place	Tree vigor degree	Trunk circum ference (cm)	Total branch no.	Shoot				Spring shoot		Autumn shoots %
				Length (cm)	%	Diameter (cm)	%	Length (cm)	%	
Dashahe orchard	middle	90.8	7157	50.5	165.0	0.55	134.1	41.8	153.7	90.0
Gaoyou orchard	middle	75.5	5387	30.6	100.0	0.40	100.0	27.2	100.0	67.5

Table 5. Comparison of leaf growth of Fuji Naga-fu 2 in two districts.

Place	Leaf area (cm^2)		Leaf thickness (mm)		Palisade tissue thickness (mm)	
	Long shoot	Short shoot	Long shoot	Short shoot	Long shoot	Short shoot
Dashahe orchard	39.9	31.8	0.236	0.214	0.121	0.098
Gaoyou orchard	32.6	25.8	0.207	0.175	0.098	0.080

Table 6. Comparison of Fuji Naga-fu 2 fruit quality in two districts.

Place	Fruit weight (g)	Fruit shape index[z]	Coloring index (%)	Smooth and clean surface	Soluble solids (%)	Total acid (%)
Dashahe orchard	200.3	0.96	82.8	good	14.5	0.15
Gaoyou orchard	167.7	0.84	70.4	some russet spots	16.4	0.25

[z]length/diameter ratio.

Table 7. Major autumn climate factors of the different sections of the Huanghe River Old Course.

Month	Place	Temperature (˚C) average	Difference in temperature (˚C)	Sunshine hours	Precipitation (mm)	Rainy days
August	Feng County	26.3	8.8	8.0	153.6	10.5
	Xuzhou Suburbs	26.5	8.6	7.8	169.0	10.4
	Lianshui County	27.0	8.1	7.5	183.5	11.1
	Feng County	20.9	10.0	6.7	81.8	8.6
September	Xuzhou Suburbs	21.3	9.8	6.7	101.5	9.2
	Lianshui County	21.7	8.8	6.5	129.5	10.1
	Feng County	15.0	11.5	6.7	35.4	6.0
October	Xuzhou Suburbs	15.4	11.2	6.6	36.8	6.5
	Lianshui County	15.9	10.4	6.5	39.2	7.1