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Growing Fuji in Australia

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The first importation of standard Fuji into Australia was made in 1973, just 10 years after it was released to the Japanese fruit industry. The initial screening tests in Tasmania indicated that this was a high quality cultivar worthy of further evaluation. The variety showed superb eating quality, storage and shelf life. The bicolor striped appearance was quite variable and did not impress the growers during the early seventies. With the emergence of many red sports in Japan further importations were carried out in the early eighties and four selections (Naga-Fu 1, Naga-Fu 2, Aki-Fu 1 and Aki-Fu 7) were released for commercial tests in 1984-85.

Since 1989 a number of striped Fuji strains and variants from overseas or local sources have been included in the testing program in Tasmania. Naga-Fu 2 and Naga-Fu 1 are currently the most prevalent red strains in Australian orchards. Over the last 2 years Naga-Fu 6 and Naga-Fu 12 have received some attention in the commercial scene.

Fruit quality, maturation and storage research on Naga-Fu 2 was first conducted in Tasmania during the 1989 and 1990 seasons. Further detailed studies on all four red Fuji strains were made when the trees were older, in 1992 and 1993. Results for harvest maturity and storage of the fruit were confirmed in South Australian research conducted in 1993. In Victoria, commercial experience with harvest maturity and fruit storage has been documented by a private consultant confirming the commercial adoption of the previous research.

Although Fuji has many outstanding attributes, precocity, fruit size, eating and keeping quality, it has some weaknesses. Poor skin finish and inconsistent color quality have been the most troublesome characteristics under Australian conditions. Crop regulation also presents some difficulty to growers. Sunburn and bird damage affect the packout to a lesser extent.

Under cool temperate conditions, Fuji has an extended flowering period and produces flowers on all ages of fruiting wood. The blossoming habit creates difficulties in crop regulation and invariably exposes young fruitlets to inclement weather which contributes to unsatisfactory skin finish. Fruit cracking and skin staining have not been observed to date.

GROWING CONDITIONS AND PRODUCTION

Fuji has been planted in all major apple growing regions of Australia from the southernmost areas in Tasmania (43˚S) to Stanthorpe in Queensland (28˚S). This wide geographic spread includes mild temperate coastal, Mediterranean, inland continental and subtropical zones modified by high altitudes. Due to its site sensitivity Fuji has produced disappointing returns in some locations. In general, apples receive sufficient winter chilling. The growing season is long with prevailing hot and dry summers in most districts. Drip and minisprinkler irrigation are widely used for at least 5 months of the growing season.

On the Australian scene, Fuji, Red Gala and Pink Lady lag behind the three major cultivars, Delicious, Granny Smith and Golden Delicious (Table 1). Based on current planting, it may challenge the third position by the end of the decade. By the year 2000 the production should reach 35,000 metric tons or 10% of the national crop. The area of plantings should rise from 1,000 ha (2,471 acres) (1996) to 1,250 ha (3,089 acres) in the year 2000.

In Tasmania, Fuji commands the leading position amongst the new cultivars (Table 2) and is second only to Delicious in terms of overall tree numbers. The current Fuji plantings of 250 ha (618 acres) should produce around 7,000 metric tons in year 2000. The area of planting should rise to 400 ha (988 acres) over the next 3 years.

FUJI STRAINS

In the search for better color, a number of Fuji strains have been introduced since 1981. The first group of high colored strains included Naga-Fu 1, Naga-Fu 2, Aki-Fu 1 and Aki-Fu 7. Evaluations in Tasmania determined that the two Naga-Fu strains and Aki-Fu 7 display predominantly uniform red color. Aki-Fu 1 is mainly striped and the most variable selection, particularly on vigorous rootstocks (Table 3). The blush strains also produced fruits with a greater red color area and intensity compared with Aki-Fu 1 which was the least attractive in the test and appeared less suitable for commercial development.

Wider experience in commercial orchards across a comprehensive range of sites and growing conditions have revealed that Naga-Fu 1 and Aki-Fu 7 may be more grower friendly in respect to appearance as both selections produce brighter red color and improved skin finish. This could be related to the color pattern (Table 3) and the level of tree vigor. Naga-Fu 2 has exhibited a high incidence of russet.

Tree size differences were more pronounced in the latter stage of the test. On MM.106 grown on shallow duplex type soil in the Huon Valley, Naga-Fu 2 produced the smallest tree with consistently less vigor than the Aki-Fu strains. This may be linked to latent viruses “Spy epinasty and decline” and “stem grooving” that are present in Naga-Fu 2.

Aki-Fu 1 and 7 were more productive, particularly during the early phase of the trial. These two selections also had the best crop efficiency (yield/tree size) with Aki-Fu 7/MM.106 being the most productive (Table 4). Inconsistent cropping was apparent.

The second wave of Fuji strain trials focused on striped strains and included overseas importations Naga-Fu 6, Naga-Fu 12 and a variant of Aki-Fu 1 released from quarantine in 1994, and a series of promising local selections mainly arising from Naga-Fu 1 plantings.

Preliminary tests in Tasmania indicated that Naga-Fu 6 has quite prominent and somewhat inconsistent stripe over green-yellow undercolor. Naga-Fu 12 displays a mixture of blushed and striped fruits with striped color patterns often fused with blush red overcolor. The stripes are finer and less continuous in comparison with Naga-Fu 6. The 1994 Aki-Fu 1 strain has color characteristics similar to Naga-Fu 12 and may prove to be superior to the 1981 introduction. Naga-Fu 6 and Naga-Fu 12 are now entering the commercial test stage.

Additional striped colored selections and variants are awaiting preliminary screening in Tasmania. These are Fuji 2001, Ogura, Ayano, Moriho-Fu 3A, Iwa-Fu 10, etc., from Japan and BHP 1-6 from Washington State.

ROOTSTOCKS

In a test with a limited range of rootstocks in Tasmania, M.26 was the most productive rootstock selection during the first 4 years of the trial (Table 5). The other three rootstocks produced identical results. As expected, M.26 tree size was 50 percent smaller than with Northern Spy or M.1. However, it is not fully clear why MM.106 was smaller than M.26. The reverse vigor performance could be due to a strong replant effect on MM.106 and differences in nursery tree quality. M.26 nursery trees had more primary feathers which reflects in comparative early yield performance. Under the management approach in this trial which had no pruning and no fruit thinning, Fuji displayed classical biennial crop characteristics in all four rootstock combinations (Table 6). M.26 and M.1 showed the largest annual yield variations.

An experiment with Naga-Fu 2 on an expanded range of dwarfing rootstocks conducted in Adelaide Hills, South Australia, provided further information on Fuji response to dwarfing and some medium vigor rootstocks (Table 7). The trial was established on fully ameliorated medium sandy loam soils. MM.106 produced the highest total crop per tree and the largest trees during the first 6 years of the test. Conversely, Ottawa 3 had the poorest outcome with Naga-Fu 2. The trial confirms this rootstock's extreme sensitivity to the latent viruses, stem grooving and Spy epinasty and decline, which are present in this Fuji strain. Tree losses (50%) were also a problem with this scion/rootstock combination. Similar difficulties with Ottawa 3 were observed in Tasmania even at the nursery phase. Mark, M.26 and M.9 all had good total crops in relation to the tree size which translated into good yield efficiency. Mark and M.9 were the most productive rootstocks in the experiment while MM.111 and MM.106 gave disappointing results. M.9, M.26 and MM.106 exhibited pronounced signs of biennial bearing in the 5th and 6th year of the test. In regard to mean fruit weight, Mark, M.9 and M.26 had the greatest mean fruit weight.

On the commercial scene, MM.106 and N. Spy are the most common rootstocks in semi-intensive plantings. M.26, M.7, M.793, MM.104 and MM.111 are also used by growers. MM.106 frequently produced poor fruit quality on weak growing sites and in replant situations. Any marked decline in vigor due to unsatisfactory soil conditions or other factors invariably resulted in high incidence of russet. On typical podsolic duplex type soils in Tasmania, N. Spy, M.1, M.2 and similar high vigor rootstocks appear to have positive effects on skin finish. The more dwarfing rootstocks MM.102, M.26 and M.9 can produce good fruit quality on virgin deep fertile soils and high level of orchard management.

GROWING SYSTEMS AND PRUNING

Central Axis (C. Axis) and its variations, planted at medium density of 800-1000 trees/ha (324-405 trees/acre), has been the most common system of growing Fuji in Australia. Multi-leader "Regulated Bush" and, most recently, "V7" canopies have also been adopted by growers.

Under the C. Axis method, Fuji tends to assume “willowy” pendulous growth habit, particularly on weak growing sites, dwarf rootstocks and under minimal pruning. From the general observations in experimental and commercial plantings, uncontrolled C. Axis does not produce satisfactory fruit quality. This decline in quality can be due to poor color, increased russet and sunburn.

Properly spaced structural wood and fruiting laterals along the center leader in a pyramid shape canopy contribute to good fruit quality. The main limbs are best positioned above horizontal and up to 45˚ to allow more even light distribution for good color development. The incidence of russet is also less apparent under this style of canopy management.

Preliminary observations in Tasmania to three levels of pruning on 10-year-old Fuji trees on MM.106 showed no effect on fruit numbers and size. The light pruning treatment was equal to an underpruned C. Axis. The medium pruning treatment was identical to normal chunk pruning, shoot thinning and replacement of fruiting wood as usually practiced with C. Axis. The severe pruning treatment included more vigorous chunk pruning, detailed shortening of all fruiting wood and complete removal of 1-year-old shoots.

The medium and severe pruning levels had a beneficial effect on the level of russet (Table 8). This effect could be due to changes in the position of main limbs and general tree shape, and an increase in shoot regrowth, thus better protection for young fruits with larger foliage cover. Flowers on young wood prolong the bloom period and provide an extended period for damage by sprays and unfavorable weather during sensitive phases of fruit growth. General observations in mature commercial plantings do indicate that more detailed hard pruned Fuji trees produce better fruit quality in respect to skin finish.

In a number of hail-prone apple producing districts in Australia, hail netting is regularly installed as a standard component of the production system. It has been observed in Queensland that the netting can reduce russet, sunburn and limb rub due to the modifying effects of the hail netting enclosure.

FERTILIZATION OF FUJI

A fertigation trial conducted at Grove Research Station has demonstrated some effects of nitrogen and potassium on red color development in Naga-Fu 1 (Table 9). The area of red color decreased with high nitrogen and under high nitrogen/potassium ratio. In addition to well-established direct influence of nitrogen and potassium on red color in apples there is an indirect effect. High nitrogen stimulates excessive shoot growth and causes poor color via reduced light distribution within the tree canopy.

Nitrogen has generally been linked with the incidence of russet in Golden Delicious. This has not been found to be the case in Tasmanian experiments on Fuji.

FRUIT MATURITY

In Australia, harvest of Fuji occurs during early to mid-April depending on location. In Tasmania, it has been found that Fuji Naga-Fu 2 ripens 175 to 185 days after full bloom. This occurs at about 145 days after the “T” stage of the fruit although, in warmer climates, harvest is reported to occur after 115 days after “T” stage. “T” stage of fruit development is when the top of the fruit is at right angles to its stalk.

Taste tests have determined that Fuji fruit harvested prior to optimum maturity have very poor flavor and are unacceptable to the market. These results highlight the need for this cultivar to be harvested at the correct maturity.

As with other apple cultivars, it has been found that the green background color, or ground color of the fruit, changes from green to yellow as the fruit matured. It has been found, however, that optimal harvest of Fuji occurs when the ground color is more yellow than other commercial cultivars of apple.

A problem commonly encountered with Australian grown red Fuji is a dull brown skin color, especially on young trees. This brown color decreases dramatically with increasing harvest maturity which highlights the need to harvest Fuji apples as mature as possible to ensure consumer satisfaction.

At optimum maturity there is a significant level of honey core (watercore) present in Fuji fruit. Honey core has not been found to be associated with overmaturity or breakdown in storage of Fuji. Indeed, it is now recommended that slight honey core be present in at least half the fruit at the start of harvest.

Other indicators of fruit maturity such as fruit firmness, sugar levels and starch have not been very useful in determining harvest maturity in Australia due to seasonal differences. Research on predicting when to harvest Fuji is currently focusing on weekly changes in sugar, firmness and starch levels rather than the actual values.

Sugar levels at optimal harvest maturity vary from 12% to 15%. Unlike Red Delicious, sugar levels do not increase during storage because at optimal harvest maturity most of the starch in the fruit has already been converted to sugars.

FUJI STORAGE

The Australian experience is that Fuji apples store extremely well, remaining crisp after 7 months of storage even in conventional coldrooms. Storage in a controlled atmosphere at 2% oxygen and between 1 and 2% carbon dioxide has provided superior quality with fruit remaining firmer than in air. Fuji fruits tolerate oxygen levels in storage below 1%, however, it is essential to maintain carbon dioxide at lower levels than oxygen.

Australian grown Fuji fruit do not appear to suffer from bitter pit during storage. They are prone to superficial scald especially if harvested early. Australian grown Fuji apples, harvested at the end of the optimum period, are subject to increased incidence of core rot problems during storage and appropriate control strategies must be employed.

CONCLUSIONS

Red Fuji is relatively widespread in new commercial plantings across all major growing regions of Australia. It is grown in a diverse range of climatic and soil conditions which contributes to variability in fruit quality and inconsistency in quality. The variety is site sensitive and can produce unsatisfactory packouts of high quality fruit in some locations.

Fuji is a “high tech” cultivar that requires detailed and precise management and is not well suited to the “ranch” style of management practiced in most countries outside Japan and Korea.

The most common Fuji selections in Australia are Naga-Fu 2 and Naga-Fu 1. Naga-Fu 6 and Naga-Fu 12 are being used in most recent orchard developments. Further improved striped strains will be adopted in future plantings. Medium vigor rootstocks MM.106 and N. Spy are most frequently used by growers for semi-intensive C. Axis growing systems.

Fuji has some excellent characteristics which have encouraged growers to continue new plantings. Excellent eating and keeping quality, time of harvest, wide window of harvest, fruit size and productivity are its strongest points. Red Fuji appeals to consumers who prefer a firm but sweet apple. It retains its firmness and its flavor during long-term storage. Early harvested fruit, however, lack flavor and are prone to superficial scald. The best indicator of harvest maturity is honey core (watercore) with harvest when at least 50% of the crop displays slight honey core.

Inconsistent coloring characteristics, russet and, to an extent, crop regulation present the biggest problems for the Australian growers.

Table 1. The distribution in 1996 of apple varieties in Australia (Australian Bureau of Statistics).

	Tree numbers		Production	
Variety	(x 1,000)	%	(metric tons)	%
Red Delicious and Delicious	3,008	35.2	103,303	36.9
Granny Smith	1,114	13.0	77,286	27.6
Golden Delicious	510	6.0	26,512	9.5
Fuji	735	8.6	9,073	3.2
Red Gala	821	9.6	8,767	3.1
Pink Lady	809	9.5	7,646	2.7
Others	1,546	18.1	47,634	17.0
Total	8,543		280,221	

Table 2. The distribution in 1996 of apple varieties in Tasmania (Australian Bureau of Statistics).

	Tree numbers		Production	
Variety	(x 1,000)	%	(metric tons)	%
Red Delicious and Delicious	719	43.6	24,948	47.6
Golden Delicious	167	10.1	8,801	16.8
Democrat	74	4.5	4,218	8.1
Fuji	186	11.3	3,619	6.9
Jonagold	90	5.5	421	0.8
Red Gala	76	4.5	595	1.1
Pink Lady	54	3.3	389	0.8
Others	284	17.2	9,407	17.9
Total	1,650		52,398	

Table 3. Red color evaluation in year 6 of Fuji selections at the Grove Research Station, Tasmania.

		Color pattern %				
Selection	Rootstock	stripe	semi-stripe	blush	Color area[z]	Color intensity[y]
Aki-Fu 1	Seedling	73.6	23.7	2.8	2.7	168
Aki-Fu 1	MM.106	50.9	24.1	25.0	3.1	163
Aki-Fu 7	Seedling	0.0	34.3	65.7	3.6	158
Aki-Fu 7	MM.106	3.3	37.6	59.1	3.5	160
Naga-Fu 1	Seedling	0.8	42.4	56.8	3.6	162
Naga-Fu 1	MM.106	0.0	33.8	66.2	3.5	162
Naga-Fu 2	Seedling	0.0	17.9	82.1	3.7	163
Naga-Fu 2	MM.106	0.0	20.3	79.7	3.8	162
LSD (P=0.05)		17.3	17.6	20.8	0.4	2.9

[z]1=20%, 5=100% color area.
[y]Color reflectance measured by Minolta 200B chrome meter.

Table 4. Yield through year 6 for Fuji strains (Grove Research Station, Tasmania).

Selection TCA)	Rootstock	Annual yield (kg/tree) Year 2	Year 3	Year 4	Year 5	Year 6	Total	Yield efficiency (kg/cm^2
Aki-Fu 1	Seedling	0.53	9.2	56.4	9.7	44.9	120.7	1.47
Aki-Fu 1	MM.106	1.70	15.2	50.2	18.5	34.7	120.3	1.93
Aki-Fu 7	Seedling	0.20	7.3	35.1	22.7	45.3	110.6	0.98
Aki-Fu 7	MM.106	1.47	17.8	54.6	26.8	42.3	142.9	2.05
Naga-Fu 1	Seedling	0.28	8.4	48.4	12.5	42.1	111.7	1.10
Naga-Fu 1	MM.106	1.11	11.4	35.6	21.2	29.5	98.8	1.57
Naga-Fu 2	Seedling	0.28	7.5	41.8	14.2	42.0	105.8	1.14
Naga-Fu 2	MM.106	1.60	9.1	34.5	13.8	31.6	90.6	1.69
LSD (P=0.05)		0.62	4.4	4.1	10.2	9.7	18.4	0.22

Table 5. Rootstock comparisons with Fuji Naga-Fu 1 at the Grove Research Station, Tasmania.

Rootstock	Tree size (cm^2 TCA)	Cumulative yield 1989-91 (mean value of 20 trees) No. fruit/tree	Yield/tree (kg)	Yield efficiency (kg/cm^2 TCA)
N. Spy	19.3	156	25.8	1.3
M.26	10.9	178	20.9	1.9
MM.106	8.8	67	10.2	1.2
M.1	20.2	171	25.6	1.3

Table 6. Rootstock comparisons with Fuji Naga-Fu 1 at Grove Research Station, Tasmania.

Rootstock	Yield/tree (kg) Year 2		Year 3		Year 4	
	No.	Wt (kg)	No.	Wt (kg)	No.	Wt (kg)
N. Spy	78	11.9	24	3.8	54	10.1
M.26	57	7.1	7	1.1	114	12.7
MM.106	29	3.7	15	2.4	23	4.7
M.1	77	10.3	7	1.2	87	14.1

Table 7. Rootstock performance with Fuji Naga-Fu 2, 1990-1996 (data of Paul James, Lenswood Research Center, South Australia).

	Rootstock					
	M.9	Mark	O.3	M.26	MM.106	MM.111
Cumulative yield (kg/tree)	30.6	39.7	4.2	36.2	56.1	39.1
Trunk cross-sectional area at year 6 (cm^2)	25.5	29.9	7.0	39.1	79.3	52.9
Tree canopy volume (m^3)	3.9	3.7	0.7	5.2	11.7	8.3
Cumulative yield efficiency (kg/cm^2 TCA)	1.20	1.33	0.60	0.93	0.71	0.74
Mean fruit weight 1996 (g)	258	251	194	253	245	200
No. of trees surviving at year 6 (trees planted=12)	12	10	6	11	12	11

Table 8. The effect of three pruning levels on the incidence of russet in Fuji Naga-Fu 2, Grove Research Station, Tasmania.

Pruning treatment	% export fruit (categories 1 and 2)[z]	% acceptable fruit (categories 1 to 3)
Commercial level—underpruned	55.5 a	84.5 a
Grove Central Axis	68.4 b	91.5 b
Hard pruned central axis	69.6 b	91.1 b
LSD (P=0.05)	9.5	5.4

[z]Russet categories 1, 2, 3, 4, 5, and 6 have a percent russet of 0, 2, 5, 10, 15 and 20, respectively; category 3 equates with current industry standard for exporting fruit into Taiwan.

Table 9. The effect of nitrogen and potassium applied by fertigation on red color development in Fuji Naga-Fu 1, Grove Research Station, Tasmania.

	Percentage fruit with		Leaf	
Fertilizer treatment	>50% red color	>75% red color	N (%)	N:K
1. Autumn urea	89	75	2.69	1.23
2. Autumn urea + 1 x calcium nitrate	94	78	2.69	1.15
3. Autumn urea + 1 x potassium nitrate	90	64	2.70	1.26
4. Autumn urea + 2 x potassium nitrate	84	58	2.81	1.31