New Zealand Experience Growing Fuji Apples

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Introduction

Several Fuji sports were imported into New Zealand in the late 1960s. Trees were evaluated on a number of orchards and considerable re-selection was carried out to select the best performing, well-colored strains. Fuji was not widely planted until the 1980s when the New Zealand apple industry underwent a phase of considerable expansion. Braeburn and Royal Gala were the most planted varieties while Fuji was third in popularity over this period. Fuji now accounts for approximately 10% of New Zealand apple production. Fuji is mostly grown in the 3 main fruit-growing regions of New Zealand. Initial plantings were equally popular in each region (Figure 1).

Fuji is regarded as a challenging variety to grow. Dr. Stuart Tustin has referred to Fuji as a "bi-colored Granny Smith" which perhaps describes its acrotonic growth habit, high total productivity and often low recoveries of marketable fruit. Our experience has been that:

- Good fruit color is difficult to achieve and is greatly influenced by tree vigor and canopy light environment.
- Fruit quality attributes are affected by rootstock and regional climate.
- Fruit russet and sunburn often reduce packouts.
- Watercore is a characteristic of Fuji which is not readily tolerated by some markets.

Research has been undertaken to understand Fuji's behavior and to develop management practices that improve fruit quality. This paper will primarily focus on our experience with fruit color and fruit quality issues.

Young Tree Management

It is recognized that, in New Zealand, fruit quality and in particular fruit color of Fuji generally improves as trees mature beyond the age of approximately 6 years. Fuji is a very productive cultivar and fruits require adequate, season-long exposure to light to achieve good color, size and sugar levels. How then should the natural growth habit be manipulated to encourage a sufficient number of fruiting sites which intercept adequate light over the growing season?

We studied the effect of three different pruning intensities and cropping levels over years 3-5. Trees were Fuji/MM.106 planted at 5 x 3 m (16.4 x 9.8 ft) giving 667 trees/ha (270 trees/acre) and managed as central leader Slender Pyramids (Tustin et al., 1990). Thinning rather than heading cuts was used and branches that had flattened to below the horizontal plane were shortened if required (renewal pruning). In "light" pruned trees, up to 8 basal tier fruiting limbs per tree were retained and pruning above the basal tier was restricted to removal of excessively pendant or upright growth. Up to 6 basal fruiting limbs were retained on "moderate" pruned trees and more attention was paid to removal of ill-positioned growth and selection of fruiting laterals from the central leader. For "severe" pruned trees, 4 basal tier limbs were retained and considerable attention was given to the selection of suitable fruiting laterals in the upper canopy. Lighter pruning of young trees achieved less shoot growth and higher bloom density compared to more severe pruning (Table 1). Lighter pruning also resulted in a higher proportion of short shoots (<15 cm; <6 inches) and fewer long shoots (>45 cm; >18 inches) than heavier pruning. As overall tree growth (measured by trunk growth) continued at a similar rate across all pruning intensities, more severe pruning promoted the annual growth of numerous long shoots which were not useful and most required removal.

Higher total yields produced by lighter pruned trees did not cause a commensurate increase in the production of export quality (first grade) fruit. Although lighter pruning increased yield, many fruit from these young trees lacked sufficient color (Figure 2).

Moderate pruning intensity over years 3-5 has proven the best overall approach in developing Fuji for medium density growing systems. This includes initial retention of up to 6 basal tier fruiting limbs, paying attention to selection of well-positioned laterals above the basal tier and removal of poorly placed and upright shoots by both summer pinching and dormant pruning. Maintaining an open-textured tree to enable fruit to be directly exposed to sunlight is essential.

Effects on Young Tree Development

Growth of young trees may be affected more by the availability of water and nutrients than by factors such as crop load or pruning intensity. Growth of trees which were freely supplied with irrigation and fertilizer inputs exceeded by almost 50% tree growth where irrigation and nutrition were deliberately restricted. In contrast, the effect of cropping level on growth was slight. Differences in trunk size between high and low cropping trees only became apparent by the fifth season. When developing Fuji orchards, irrigation and fertilizer inputs must be given consideration along with pruning intensity and regulation of cropping.

Management of Mature Trees

We have found that the natural growth habit of Fuji lends it to central leader Slender Pyramid tree management. A broad basal tier can readily be developed without excessive top dominance and renewal pruning techniques promote good light exposure to fruit.

Fruits borne on branches that change their orientation over the season and become severely pendant are likely to become either sunburnt or move into shady areas and not develop sufficient color. Ideally, fruit should be borne on spur rather than terminal sites and on branches that are relatively stiff for their length so that they are less prone to excessive drooping or sagging as the season progresses.

Shortening back of branches that have flattened to below the horizontal plane (renewal pruning) is effective in preserving well-exposed sites and regulating cropping. Heading cuts on branches orientated above the horizontal tend to invigorate shoot growth and create shade and are avoided.

Improving Fruit Color

Achieving desired fruit color has been a significant challenge for us. Difficulties in achieving good export packouts with Fuji are often associated with inadequate blush (red color) and advanced fruit maturity. How then can we achieve early blush development relative to fruit maturity?

A number of factors and practices have been examined in our attempts to improve fruit color:

- hand thinning
- nitrogen and sward management
- summer pruning
- trunk girdling and root pruning

Selective Hand Thinning

Initial attempts to improve fruit color with different selective hand thinning methods were not very successful. Neither thinning to singles, doubles or to fruits with visible red blush at the time of thinning improved packout. In follow-up trials, the role of blush intensity (brightness) and blush coverage (percentage) was examined more closely.

Blush intensity within a block of trees was uniform with respect to fruit position in the tree and only slightly affected by crop load (fruit from light cropping trees was slightly brighter than fruit from heavy cropping trees). Blush coverage was affected by fruit position in the tree and, depending on fruit position, whether or not blush was present at the time of hand thinning. Fruits in the upper canopy develop relatively high blush irrespective of blush presence at the time of hand thinning while, in the lower canopy, fruits with blush at the time of hand thinning have more blush at harvest compared to unblushed fruits. Hand thinning to visible blush in the lower canopy and removing less fruit in the upper canopy may be a useful means of improving fruit color.

Nitrogen and Sward Management

Early survey work indicated that tree nitrogen status (N) might contribute to orchard-to-orchard variation in skin color seen in young Fuji orchards. Orchards with high leaf N (measured in summer) or high fruit N (measured at harvest) tended to produce fruit with poor red color at harvest. Trial work confirmed that by altering N fertilizer inputs and naturally depleting orchard of N, color could be improved and the proportion of fruit harvested early in the harvest interval could be increased. Completely grassing down the entire sward and eliminating spring N inputs improved production of export quality fruit compared to using conventional 2 m wide herbicide strips and use of N fertilizer in the spring.

Summer Pruning

Summer pruning has, in our experience, done little to improve fruit blush development, maturation or quality attributes. This may be because summer pruning introduces only slight and temporary changes in the tree canopy light environment.

Root Pruning and Trunk Girdling

Root pruning and trunk girdling have been used to improve fruit coloration and increase the export yield. Root pruning decreased the green chlorophyll concentration in the skin and increased anthocyanin accumulation. Not only were fruit better colored, but total yield remained similar and packouts increased. Blush intensity and soluble solids increased in response to root pruning and trunk girdling but this may occur only in the first season of treatment. Effects of root pruning are affected by seasonal weather conditions. Greater response is likely to occur when a dry season follows treatment while a less pronounced response is likely to follow a season of plentiful summer rainfall.

The main effects from trunk girdling of Fuji appear to be advancement of fruit maturity indicated by higher fruit background color and reduction of tree vigor. Trunk girdling increased red color and decreased green color but not to the same degree as root pruning.

We observed a clear response gradient where more severe root pruning increased red color, decreased green color and reduced tree vigor (trunk growth and leaf size). Root pruning and girdling are considered useful tools to reduce excessive vigor where required.

Regional Effects

A significant part of the New Zealand experience with Fuji involves the impact of regional environmental conditions on tree performance and fruit quality.

The fruit-growing regions Hawkes Bay, Nelson and Central Otago extend over a range in latitude of approximately 7˚ (39˚ to 46˚) or approximately 900 km (559 miles). Differences in latitude as well as eastern and western coastal influences give rise to significant differences in environmental conditions in each region. Hawkes Bay has a relatively long and warm growing season. Nelson is a little cooler than Hawkes Bay and tends to have higher rainfall, especially in spring. Central Otago is the least maritime and most continental climate of New Zealand's fruit-growing regions with shorter, hot summers, cold winters and little summer rainfall (Table 2). Some of these influences may help us explain sources of variability in fruit appearance and quality.

Rootstocks and Planting Systems

Tree size differs among rootstocks and these differences are characteristic for particular geographic regions. In Central Otago (cooler region), the difference in tree size (estimated using trunk size) between Mark and M.26 is not great, whereas in Hawkes Bay (warmer region) trees on Mark are considerably smaller than on M.26 (Figure 3). Rootstock influence on fruit quality is defined by a trend for more high quality fruit from trees on rootstocks with increasing dwarfing effect. Average export packouts over years 4-7 was higher in trees on M.26 and Mark than MM.106 in both regions (Table 3). Cumulative export yield was generally better from trees grown on more dwarfing rootstocks.

Rootstock x Regional Effects on Fruit Quality

Fruit quality is affected by regional environment and rootstock as well as numerous other factors including harvest date, season and tree management. A number of trends are evident when we confine our attention to just region and rootstock. Fruit tends to be firmer further south and with more dwarfing rootstock. Soluble solids and starch pattern index tend to be higher with more dwarfing stocks but not consistently affected by region. Background color, on the other hand, shows little rootstock effect but tends to be relatively less advanced further south. Greasiness (data not shown) and watercore appear to be unaffected by rootstock vigor but are of higher incidence and more prevalent in cooler regions with a shorter growing season (Table 4).

There has been little consistent rootstock effect on russet incidence although, in situations where trees on dwarfing rootstocks have had insufficient vigor, russet incidence has been high. Russet in the Nelson region is frequently a problem because of the cool, wet conditions often encountered in spring.

Fruit sunburn incidence varies with season but seldom exceeds 10% of the crop. Lower incidence of fruit sunburn has generally been found with MM.106 and M.26 than Mark. MM.106 trees have the highest incidence of poorly colored fruit, Mark was lowest and M.26 intermediate. It is considered that the greater vigor of MM.106 trees, particularly in Hawkes Bay where tree growth tends to be more vigorous, results in more shading of the lower branches and leads to poorer red color development.

Summary

Two key issues facing the New Zealand industry with Fuji are:

- to better manage tree vigor to improve fruit quality
- and to better understand Fuji's adaptation to different climatic regions.

We have found that increasing total tree yield with Fuji does not necessarily improve revenue. High productivity is often associated with excessive tree vigor, poor color, delayed harvest and soft fruit. On the other hand, low productivity is often associated with inadequate tree vigor, excessive fruit russet and sunburn.

Regions where the growing season is warmer and longer can produce high yields of large fruit but sometimes face difficulties in achieving required levels of fruit firmness and color. Cooler regions can achieve firmer fruit and higher color but greasiness and watercore are more problematic.

Nobody ever said that fruit growing was easy or for the fainthearted.

Fuji is a variety with a high potential for fruit quality, including visual and taste appeal, storage and shelf life. Delivering these attributes to the consumer remains a major challenge for us as we learn how to grow a better product.

Reference

Tustin, D.S., P.M. Hirst, W.M. Cashmore, I.J. Warrington and C.J. Stanley. 1990. The principles and practices of training slender pyramid trees for high intensity production. Compact Fruit Tree 23:83-87.

Table 1. Effect of pruning intensity on shoot growth (cm of growth per cm^2 of branch cross-sectional area) and bloom density (flower clusters per cm^2 of branch cross-sectional area) on 4- and 5-year-old Fuji.

	Pruning intensity		
Response	Light	Moderate	Severe
Shoot growth	52a[z]	66b	79c
Spur bloom density	3.6a	3.5a	2.6b

[z]Numbers in the same row which are followed by a different letter are significantly different at the 5% confidence level.

Table 2. Temperature and rainfall data for New Zealand's major fruit-growing regions.

		Average temperature (˚C)			
		Daily maximum		Daily minimum	
Region	Annual rainfall (mm)	Jan.	July	Jan.	July
Hawkes Bay	825	24	13	14	5
Nelson	1000	22	12	13	1
Central Otago	350	23	7	11	-2

Table 3. Yield performance of Fuji on MM.106, M.26 and Mark rootstock in Hawkes Bay and Central Otago.

Rootstock	Spacing (m)	Accumulated total yield over years 4-7 (t/ha)	Accumulated export packout over years 4-7 (t/ha)	Average export packout over years 4-7 (%)
		Hawkes Bay		
MM.106	5x3	339	137	40
M.26	4x2	377	204	54
Mark	4x2	216	113	53
		Central Otago		
MM.106	5x3	153	76	50
M.26	4x2	174	95	55
Mark	4x2	201	118	58

Table 4. Fruit quality at harvest of Fuji on MM.106, M.793, M.26 and Mark in Hawkes Bay, Nelson and Central Otago. Data represents the mean of 3 harvests from trees aged from 7 years old in Hawkes Bay and Central Otago and 5 years old in Nelson for the 1994-5 season. (Rating scales used are: starch index, 0 = no starch hydrolysis, 6 = complete starch hydrolysis; fruit background color, 1 = green, 7 = yellow; watercore, 0 = no watercore evident, 5 = complete watercore development.

Rootstock	Crop density (fruit no./ cm^2 TCA)	Flesh firmness (kg-f)[z]	Soluble solids (%)[z]	Starch pattern (0-6)[z]	Backgroun d color (0-6)	Watercore (%>3 using 0-5 scale)
			Hawkes Bay			
MM.106	5.5	6.7	13.9	4.9a	2.5	0
M.26	4.7	6.9	13.8	3.8b	2.4	1
Mark	6.7	7.0	14.7	5.0a	2.6	1
			Nelson			
M.793	4.7	7.1b	13.9b	3.9a	2.1	10
M.26	4.7	7.4b	14.6ab	3.6a	2.4	26
Mark	6.8	7.8a	15.7a	2.8b	2.2	12
			Central Otago			
MM.106	4.8	7.3b	14.5	5.7a	1.9	39
M.26	5.0	7.4ab	14.2	5.5b	2.3	40
Mark	6.3	7.9a	14.7	5.2c	2.2	54

[z]Numbers within columns and within regions sharing the same letters or not showing letters are not significantly different (P=0.05).

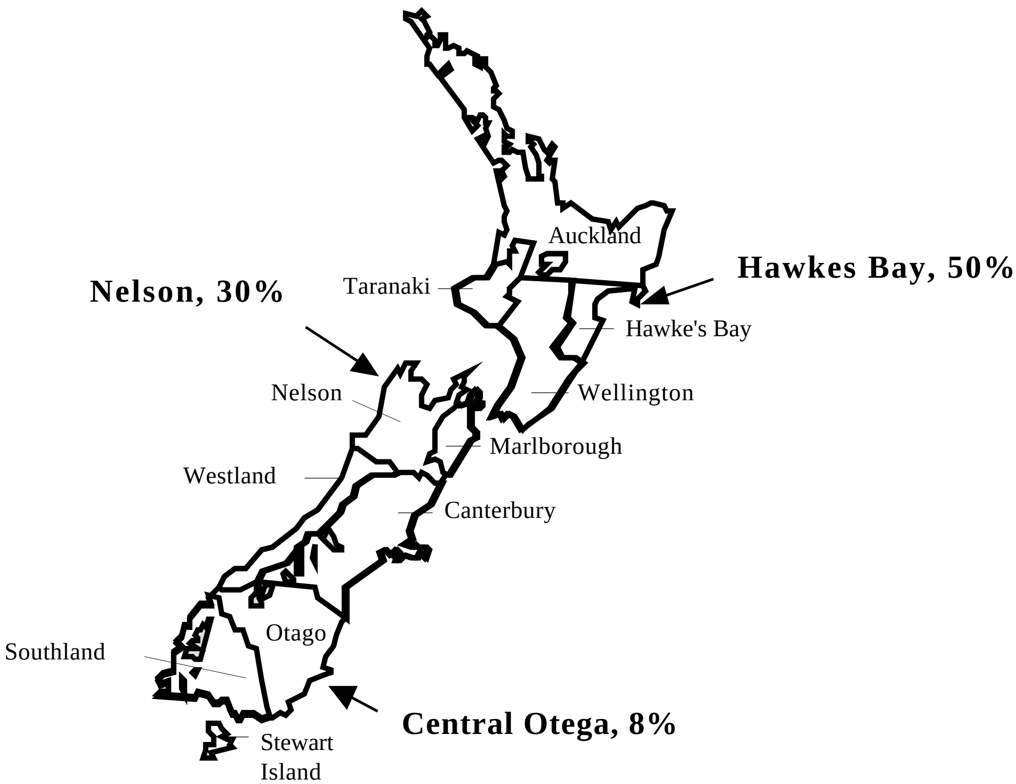

Figure 1. Map of New Zealand, showing relative size of major apple growing regions and Fuji production.

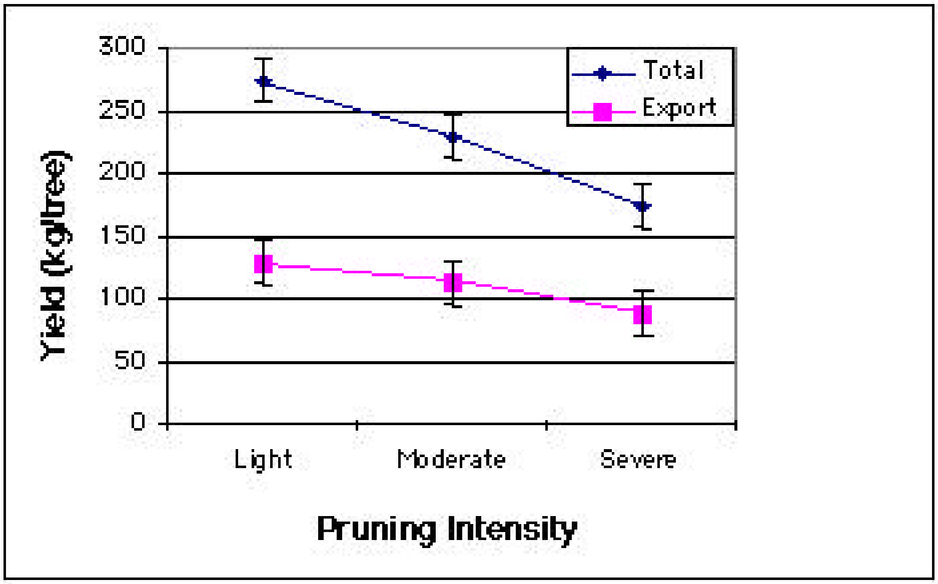

Figure 2. Effect of pruning intensity on cumulative total and export yield of 5-year-old Fuji.

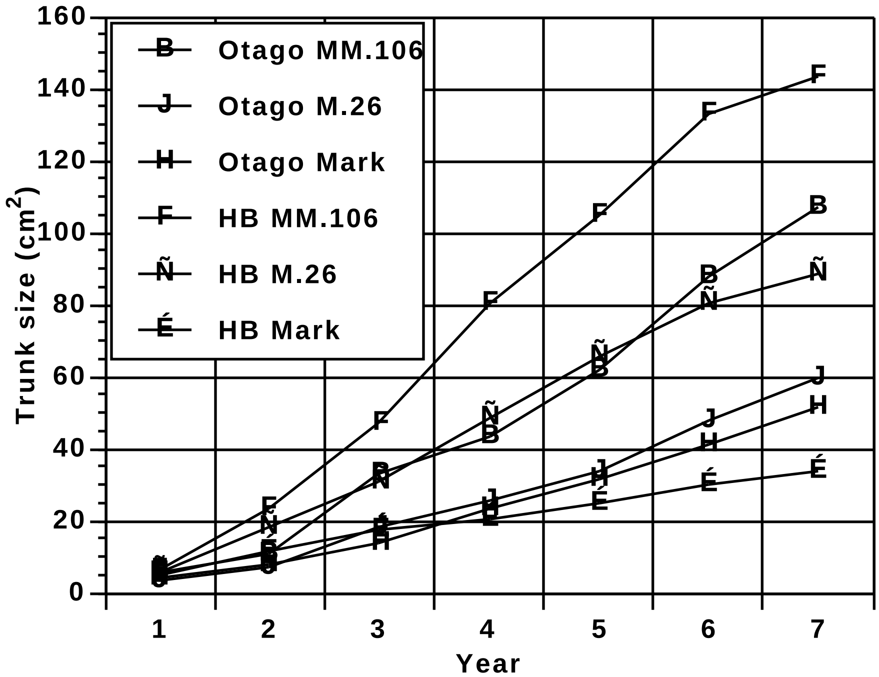

Figure 3. Increase in trunk size of Fuji on MM.106, M.26 and Mark rootstocks in Hawkes Bay and Central Otago.