Breeding Apple Varieties for the World Market

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The New Zealand apple industry is geared toward the export of fresh fruit to the rest of the world. New Zealand, through its marketing organization ENZA, over the years has developed a reputation of being an innovator in new high quality apple varieties. This reputation is seen as important to us and has a strong influence on ENZA's marketing strategy and the willingness of growers to plant new varieties.

From its beginnings in the 1970s the HortResearch Apple Breeding Program has been invested in by both the New Zealand Government and fruitgrowers (via ENZA). Because of this we have been able to develop a program which integrates the more basic long-term work on genetics and molecular biology with the more commercially focused research of variety breeding, development and consumer science. Growers are involved in evaluation and orchard trials, ENZA in market research and licensing.

THE HORT RESEARCH APPLE BREEDING PROGRAM

The HortResearch apple variety breeding program is the end point of a much larger program which includes genetics, biodiversity, disease resistance breeding, molecular biology, consumer research and commercial development.

Genetics

Genetically apples are very heterozygous and the combinations of characters that make for a successful variety occur extremely rarely. A summary of the performance of some families from our breeding program illustrates this (Table 1). The scoring is our assessment of the commercial potential of the seedlings based on fruit characteristics only. Seedlings with scores of 7 or higher are advanced to the next level of evaluation and have about a 1:100 chance of becoming a commercial variety.

Little is understood about the genetics of apples, including how characters are inherited and how specific combinations perform. To a large extent the design and selection management of an apple breeding program are based on assumptions (experience?) rather than known parameters. The 1000 seedlings for each character is a rule of thumb that appears to hold in our experience. This means we require about 5000 seedlings to create in the chance of selecting one commercial variety.

Our genetics program is designed to provide us with an understanding of the heritabilities and correlations of the characters we are interested in and ultimately a selection index. This knowledge will enable us to become smarter in both the design of our crossing program and selection management. One area I think we will always struggle with, however, is information on the "specific combining abilities" of particular combinations. Apples being a long generation crop, we do not have the luxury of time to carry out test crosses to calculate these.

Biodiversity

Biodiversity is an important component of the overall program. We are sourcing new characters, resistance and fruit quality genes. HortResearch has a large collection of varieties, including old varieties, as well as seedling populations accessed from many countries including Kazakhstan. Novel quality characters in fruit color, flavor, texture and morphology are identified and introgressed into our breeding lines from this program.

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Pest and Disease Resistance

Tolerance of chemical management solutions to pest and disease problems is lowering. The "Desert Storm" approach is no longer appropriate as we look for more sustainable approaches to orchard management. On the one hand, growers do not want to use expensive and hazardous management practices which may have costly side effects; on the other, consumers want to feel safe when they are eating apples.

Plant-borne resistances to pests and diseases exist for many of the major diseases and some pests within the apple genome. However, combining these with commercial fruit quality has been difficult and takes a long time using conventional breeding techniques. There is a risk that by the time a variety emerges the resistance will have broken down.

The sourcing, introgression and pyramiding of resistances are separate, though closely aligned, parts of the program. The aim is to produce parents for use in the variety breeding program that combine a range of pyramided resistances with high fruit quality.

Marker Assisted Selection

Marker assisted selection (MAS) is a powerful tool to the breeder. We are already using MAS in our disease resistance program and are developing markers for fruit quality characters as well. As with all new technologies we need to take care in its introduction into our selection management strategy. Verification of markers in specific crosses, particularly of quality traits (QTLs), and the trap of tandem selection are two areas of which we are very aware.

An important spin-off from this work has been the development of a DNA fingerprinting capability which already has been useful in protecting ownership of our varieties.

Consumer Science

New Zealand has a diverse market (Table 2) that stretches through the regions of Asia, North America, Europe and the Pacific. Within these regions the markets differentiate also into groupings such as age, sex, ethnicity, socio-economic, acid tolerant, etc.

This diversity raises several questions for us such as:

- Should we be breeding a universal variety that will be acceptable to all our markets or should we breed many varieties targeted to specific markets?
- Do we try to do it all at once or spread our program objectives over several years?
- What priorities should we give to the different market segments in our program?

Hard information on the preferences of consumers is scarce. However it is important for a breeder to understand what motivates consumers to buy apples. What type of texture is preferred, how much acid or sugar is tolerated, what is the role of cosmetic appearance and what is the relative importance to other factors? Our consumer science group has several projects looking at various aspects of these questions.

Variety Breeding and Selection

The process of developing a new variety can be divided into 4 phases.

Phase 1: Breeding. Each year between 15,000 and 20,000 seedlings are produced specifically with the aim of developing new commercial varieties. This population is separate from the other populations involved in genetics, biodiversity and disease resistance introgression.

Parents are chosen to fit the particular theme for that year (e.g., early season, red color, high acid) and are selected on their characteristics (phenotype). Usually 3 to 4 families are produced of about 5000 seedlings each. About half the families include resistance to apple scab and powdery mildew. As disease resistant varieties tend to be poor parents for fruit quality (Fig. 1), we continue to make combinations between high quality nonresistant varieties so that we can make genetic advancement in quality characters as well. Families with specific resistances are screened in the greenhouse and nursery. Seedlings are grown in a field nursery on their own roots for 2 years, then replanted into the selection orchard where they are kept for 4 years before removal. By this stage about 50 to 60% of the seedlings have been eliminated through pre-selection for susceptibility to disease or poor growth characteristics.

Phase 2: Selection. There are two stages of selection. As soon as a seedling fruits, samples are taken and the fruit characteristics of economic interest are described. We use a 10-point scale, with values related to a standard (e.g., crisp 1 = banana, crisp 6 = raw capsicum). An overall quality value is given which is the main determinant as to whether a seedling proceeds to the next stage of selection. About 2% of the seedlings (250 selections) make the cut at this stage. These are propagated onto MM.106 rootstock (5 trees) and grown in two locations, Hawke's Bay and

TABLE 2

Average annual New Zealand apple exports by region, 1990-1998. Data taken from New Zealand Apple and Pear Marketing Board annual report, 1998.

Region	Cartons
European Union	8,390,000
Scandinavia	322,500
Other European countries	110,000
Americas	2,291,700
Caribbean	5,900
Middle East	48,100
Asia/Russia	2,244,400
Pacific	128,100
Africa	2,000

TABLE 1

Apple seedling evaluations for overall fruit quality for 1996 in Hawke's Bay, New Zealand.

	Rating[z]										
Cross	0	1	2	3	4	5	6	7	8	9	Total
Granny Smith x GS2363	0	2	12	34	12	35	4	1	2	0	102
Fuji x Pacific Rose	0	0	1	7	9	26	8	3	3	0	57
Golden Delicious x Priscilla	0	2	20	35	21	14	3	1	3	0	99
Fuji x A172/2	0	5	18	32	19	24	5	0	0	0	103
Granny Smith x A172/2	0	18	36	38	30	28	8	4	0	0	162
Royal Gala x GS1286	0	1	9	27	10	28	6	6	9	1	97
Royal Gala x GS1620	0	0	2	6	8	29	14	13	10	0	82
Royal Gala x GS1783	0	1	3	7	9	26	10	4	11	1	72
Royal Gala x GS1487	0	0	2	12	21	41	14	8	2	1	101
Royal Gala x Prima	3	28	167	207	156	246	28	30	52	1	918
Golden Delicious x Prima	0	8	32	39	27	34	6	3	2	0	151
Golden Delicious x Reinette Clochard	0	3	26	38	34	28	19	6	4	1	159
Golden Delicious x T31-12	0	1	10	28	15	63	23	10	11	1	162
Southern Snap x (Braeburn x A810-390)	0	2	15	29	27	31	9	5	2	0	120
Southern Snap x (Royal Gala x A810-390)	0	0	18	63	25	84	20	14	8	0	232
Southern Snap x A172/2	1	5	16	27	18	28	5	2	1	0	103

[z]0=poorest to 9=highest quality.

Nelson. Fruit from these trees is described more intensively. Selection to progress into the next stage includes input from ENZA as well as HortResearch staff. Eight to 10 selections are made each year.

Phase 3: Product Development. Plantings of up to 90 trees are made in three locations, Hawke's Bay, Nelson and Central Otago. Performance data are recorded, orchard and postharvest management requirements are evaluated in these trials. High yields in the preferred fruit size ranges with consistent color, shape, flesh quality and lack of disorders are all critical to achieving the margins necessary for economic production. New varieties will need to perform as well or better than existing ones to make it.

Initial evaluation of the market potential of the selections may also be carried out.

Phase 4: Commercial Development. On average we are achieving one new commercial variety every 2 years. The decision to commercially develop a selection from our program is made by ENZA. There is still a large amount of research and development required before full potential of the variety will be known. This phase is probably the most complicated step in the development of a variety and requires linkages between the research and development group and the commercial partner. In our case, the involvement of ENZA and its commitment to new variety development have been major contributors to what success we have had to date.

FIGURE 1

Distribution of overall quality in progeny from four crosses with Golden Delicious apple in the HortResearch apple breeding program, 1996 (parent values for fruit quality indicated by arrows).