THE EFFECTS OF HIGH PROTEIN JERSEY SIRES FROM NEW ZEALAND AND NORTH AMERICA ON DAIRY FARM PROFITABILITY AND IMPLICATIONS FOR THE NEW ZEALAND DAIRY INDUSTRY

A thesis presented in partial fulfilment of the requirements for the degree of Master of Agricultural Science at Massey University

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ABSTRACT

Due to the increasing value of milk protein to New Zealand dairy farmers, a computer model was developed to evaluate the changes to farm production and profitability which could be expected from using dairy sires with high genetic merit for protein yield. The model simulates the influence of differing sire BI and daughter liveweight on average yields of fat, protein and milk, as well as liveweight per cow in a base herd. The assumed productive and genetic characteristics of the base herd are taken from 1992 average figures for the New Zealand population of Jersey cattle (Dairy Statistics, 1992), with the main objective of the model being to calculate the marginal profitability (ie. 'improved' herd - base herd) generated per cow and per hectare by an individual sire after his first generation of daughters have completed one lactation in the base herd. This assumes an annual herd replacement rate of 25%. The prices of milk and meat, as well as the costs of production are 1992 season values. Only those costs directly affected by genetic improvement are included in the calculations. Fourteen proven Jersey sires were put forward by the New Zealand Jersey Cattle Breeders Association (NZJCBA) to be evaluated using the model. Included were 10 New Zealand (NZL) Jersey sires and four North American (USA) Jersey sires with New Zealand proofs.

Positive relationships were established between sire protein BI and his average effect on yields of fat, protein and milk per cow in the base herd. By the time their daughters had completed their first lactation, the four USA sires had, on average, generated greater changes in per cow yields of fat (+3.3kg vs +2.5kg), protein (+2.6kg vs +1.3kg) and milk (+100kg vs +29kg) than their New Zealand counterparts. This resulted in the NZL sires generally boosting milk solids concentration per cow in the herd while the greater proportional milk yields of the daughters of the USA sires decreased milk solids concentration per cow.

No relationship was observed between the effect of sire BI's for fat, protein or milk on the average liveweight of their daughters. Changes generated to average liveweight per cow in the base herd were only small, ranging between -2.2 and +2.5kg. On average, the four USA sires tended to decrease cow liveweight while the NZL sires tended to increase it (-0.2kg vs +0.3kg).

Achievable stocking rate decreased as sire protein BI increased. The influence of a sires high genetic merit daughters on greater average production per cow in the herd caused associated increases in annual feed requirement per cow. These ranged between -4 kg and +52kgDM/cow/year. The effects of individual sires on achievable stocking rate ranged between -0 and -0.04 cows/hectare by the time daughters had completed one lactation. The greater influence of the USA sires on average milk and solids yields per cow was evident by their larger depressing effect on stocking rate compared with the NZL sires (-0.03 cows/ha vs -0.02 cows/ha).

The positive relationship observed between sire protein BI and marginal profit generated per cow in the herd was mainly due to their associated increases in yield of milk solids rather than changes to average cow liveweight. For individual sires, marginal profit per cow ranged between +$5 and +$24, with the 4 USA and 10 NZL sires averaging +$21 and +$15 per cow respectively. Using theoretical values for sire BI's (fat, protein, milk) and average daughter liveweights in the model, it was found that for two sires differing by 5 protein BI units to achieve equal profit per cow, the lower BI sire must have either +7 fat BI units, -32 milk BI units or daughters weighing an average of 20kg more.

The marginal profit per hectare generated by individual sires increased with greater sire protein BI. Estimates ranged between +$14 and +$33 per hectare, with the 4 USA sires and 10 NZL sires averaging +$28 and +$22 per hectare respectively. It was estimated that for two sires differing by 5 protein BI units to achieve equal profit per hectare, the lower sire must have either +10 fat BI units, -14 milk BI units or daughters weighing an average of 10kg less. The economic influence of a 1kg increase in the average liveweight of cows in the herd was estimated as a reduction of $0.49 in marginal profit per hectare.

A sensitivity analysis of the results generated by the model was carried out by varying the prices of milk components and carcasses. Assumed price changes ranged between ± 25%. Changes to protein prices had the greatest influence on both the marginal profit per hectare and the ranking of the 14 selected Jersey sires. The average marginal profit per hectare generated by the 4 USA sires remained ahead of the NZL sires in all cases but the difference was reduced by both a decrease in protein price relative to other milk components and/or an increase in the milk volume charge. Changing carcass prices had very little effect on either marginal profit per hectare or ranking of the sires.

The second part of the study involved assessing the potential impact of using both New Zealand and North American genetics on the supply of milk and milk solids to the New Zealand processing industry. Based on past rates of genetic improvement in both countries, two scenarios were assumed ie. using only New Zealand sires or using only USA sires in the New Zealand dairy industry. These cases were chosen to represent the possible extremes between which actual milk composition could vary in the future. Estimated genetic gains in the two countries indicate that USA Jerseys have in the past achieved greater annual rates of improvement in fat (1.4% vs 1.3%) and milk (1.6% vs 1.2%) yields per cow while protein yield has improved at a lesser rate (1.1% vs 1.4%). Under the assumption that only USA sires (ie. USA rates of genetic gain) were used in the New Zealand dairy industry, the predicted yield increases for the average New Zealand Jersey cow after 30 years would be greater for fat (+64kg vs +61kg) and milk (+1260kg vs +990) yield per cow and less for protein yield (+35kg vs +45kg) than if only New Zealand sires were used. A significant result of the changes to milk composition generated by the USA sires are the decreases in milk solids concentration and protein:fat ratio per cow. Under current New Zealand prices for milk components and methods of milk payment the effect of decreasing milk concentration will probably mean that in future years using the 'average' New Zealand bred Jersey sire over a given herd should provide an increasing economic advantage over what could have been achieved by using an 'average' USA sire.

Using the predicted increases in yields per cow, trends in the supply of milk components to the processing industry from the New Zealand Jersey population were established. This assumed that the increases in production and hence annual feed requirement per cow would require a practical reduction in achievable stocking rate of 15% over the next 30 years. Using only USA sires boosted the annual supply of fat (+19.5 vs +18.1 million kg) and milk (+416 vs +273 million kg) to the industry and lowered the supply of protein (+8.2 vs +13.7 million kg) relative to the case when using only New Zealand sires. The implications of such increases in volumes of milk available for processing each year would mean a required increase in total industry processing capacity of +9 million kg (+0.5%) and +14 million kg (+0.8%) per year under New Zealand and USA rates of genetic gain respectively. The long term marginal cost to the industry of using USA genetics is therefore likely to be a larger investment by dairy companies in additional processing capacity, over and above that required from using solely New Zealand sires. This was supported by the findings of a case study involving a major New Zealand dairy cooperative in which the predicted effects of using only USA sires generated supply increases of fat and milk which exceeded past rates of annual company improvement. However future market developments which see milk components such as lactose incorporated into the milk payout and/or a reduction in the value of protein relative to fat could see a favourable swing towards the greater milk yields of USA Jerseys. The predicted long term negative influence of USA Jersey genetics under past rates of genetic gain illustrates the importance of maintaining selection objectives in line with current and future New Zealand systems of payment for milk.

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1. INTRODUCTION

The historical and modern basis of primary industry has been the systematic cultivation and harvesting of organic raw materials from plants and animals. These raw materials collectively provide the majority of man's requirements for clothing, shelter and most importantly nourishment. Today the significance of these resources is rapidly increasing in proportion to the demands of an expanding world population (Unit. Nat. Conf., 1974). To some extent this demand has been matched by the huge leaps in agricultural production achieved through improved farming methods and technologies. However previous world surveys have revealed that an ever-widening gap exists between global food demand and supply with the main requirement being for large increases in dietary protein (Report. Unit. Nat, 1968; Unit. Nat. Conf, 1974).

There are many criteria by which the overall efficiency of a particular protein food is determined. These can include such factors as palatability, transport and distribution, simplicity of production and capital cost (Whittlestone, 1972). Under such criteria the source of protein able to be contributed most effectively by New Zealand to world demand is milk. Not only does it have enormous versatility and widespread acceptance (Whittlestone, 1972) but studies have shown dairy production to be the most effective method of converting pasture protein into a form suitable for human consumption (Hutton, 1972). Indeed the latter found that even when compared to crops such as Soyabean and Maize, grass pasture was 40% more productive of protein and also far cheaper per unit weight. Thus even though the actual efficiency of conversion of available feed proteins to milk protein is only approximately 17% (Hutton, 1972), the lactating ruminant can still compete with plants as producers of high quality proteins.

In the past, improving milk protein yields through artificial selection has not been a direct objective of genetic improvement in New Zealand dairy cattle. Rather the selection for animals with superior milkfat production meant a correlated increase was also observed in the protein component of milk. However the marginal price paid for milk protein over the years, in line with increasing world demand, now exceeds that paid for milkfat. Recent trends in the relative values of protein and milkfat taken over all product groups and markets are shown in Table 1.1.

Table 1.1 Milkfat and Protein values* for New Zealand dairy product sales (Marshall, 1992)

Year	Milkfat ($/kg)	Protein ($/kg)	Ratio (MF/P)
1990/91	2.40	3.36	0.72
1991/92	2.42	3.89	0.62
1992/93 (est)	2.39	5.08	0.47

* 3 year rolling averages

This has meant that systems of selection and payment for milk based solely on milkfat have become inaccurate in reflecting the true market value of milk produced (Dennis, 1973; Creamer, 1985). With this in mind, genetic improvement in the New Zealand dairy cow population is now based on an economic index containing both milkfat and protein traits, weighted by their respective economic values (REV) to ensure genetic progress consistent with present and future market trends for milk components (Wickham, 1988).

The objective of this study is to identify the effects of using dairy sires with high merit for milk protein yield and the implications of greater milk protein production, both for New Zealand dairy farms and the dairy industry as a whole. The influence of foreign genetics on trends in industry milk composition will also be considered.

The on-farm effects of selected Jersey sires will be assessed by modelling the changes in;

* average herd production generated by the use of individual sires
* the quantities of feed required to achieve this production
* the achievable stocking rate as a result of available feed supply

Research shows that the production of milk solids is positively correlated with other traits such as milk yield and liveweight (Harville and Henderson, 1966; Hooven et.al, 1968; Ahlborn and Dempfle, 1992). It is possible that selection for higher protein yields could cause correlated increases in both milk yield and liveweight with resulting increases in profit per cow, but lower profit per hectare due to the greater amounts of feed required for the maintenance of larger animals. The relative magnitude of these changes will determine the overall value of using a certain sire for increasing farm profitability per hectare.

The implications for the dairy industry of greater protein yields and probably more importantly, higher milk volumes depends on the current processing capacity existing in New Zealand dairy companies. Recent claims suggest that processing capacity during the peak milk production period is currently challenged and even exceeded in several companies (Cooper, 1979; Bay, 1983) with further changes to seasonal production being pointless with present industry structure. Changing ratios of milk products could require large additional investments by some dairy companies with associated costs being ultimately transferred back to producers (Cooper, 1979). The extent and significance of these industry effects will be influenced by future methods of improving milk yields per cow and per hectare, in particular the rate of genetic gain achieved in the New Zealand dairy industry. The adoption of foreign genetics for use in New Zealand could also have a lasting impact on the composition of milk supplied for processing.

Finally, the link between on-farm production and industry performance is the system of payment for milk. Past systems have been based on a value per kilogram of milkfat supplied which supposedly reflected the true value of the milk itself. However with changing prices for milk components, emphasis has been placed on payment for protein in addition to fat, with penalties being incurred for the volume of milk which must be processed to yield these products. This is the basis of the A+B-C system currently employed by several companies (Dennis, 1973; Bay, 1983; Creamer, 1985). However with further changes in the ratio's of milk components and their relative importance, even this present system may become inaccurate in fairly reflecting the market returns from various milk products (Rennie, 1979). In particular, the negative economic value of increasing milk volume could disadvantage farmers using certain sires despite a corresponding increase in fat and protein yields.

The implications of increasing use of high protein dairy sires in the New Zealand dairy industry will be described and discussed in the following sections. The three key areas will be:

* On-farm productivity and profitability
* Trends in industry milk supply and composition
* Payment for milk

2. DAIRY FARM PROFITABILITY

Farming in New Zealand is based largely on the utilization of grazed pasture grass as a cheap source of animal feed. The temperate climate provides ideal growing conditions for a variety of pasture plants and is suitable for animals to graze all year round. This has led to the belief that pastoral grazing is more economical under New Zealand conditions than intensive systems involving winter housing and the purchase of high cost, high energy feeds.

However in light of the changing emphasis on the relative value of milk components and the gradually decreasing economic returns to dairy farmers in real terms, the search continues for new methods of increasing both production and profitability per cow and per hectare. Of increasing interest in recent years is the lasting impact that genetic improvement can have on the performance of the average dairy herd. Compared with other more 'temporary' means of boosting milksolids yields which usually see a return to previous levels once the change is halted, genetic gains made through annual breeding and culling decisions represent a permanent and sustainable improvement in per cow and per hectare production.

Clearly, proposed changes to parts of any system must be evaluated in terms of their effects on the system as a whole. In the context of selection for a perceived trait of merit, the genetic relationships between the trait of interest and other genetically determined characteristics may mean that correlated responses are achieved in occasionally undesirable areas. Thus although the original trait may have benefited the farming system on its own, the net effect of the change on the system may be less than that expected (or even detrimental) in terms of future economic production.

Maximising the economic returns from available land is a common objective of many New Zealand dairyfarmers. Measuring the efficiency (outputs/inputs) with which the various components perform and identification of factors which may be limiting potential profit per hectare requires a reasonable understanding of how the dairy system works. A simple illustration of the key components of profit per hectare is given in Figure 2.1.

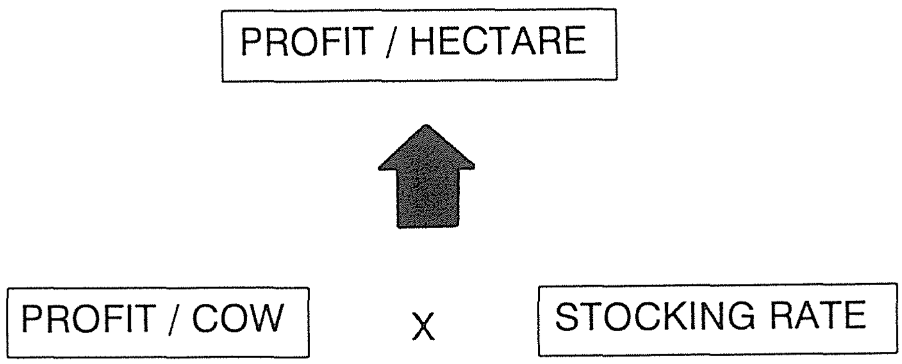
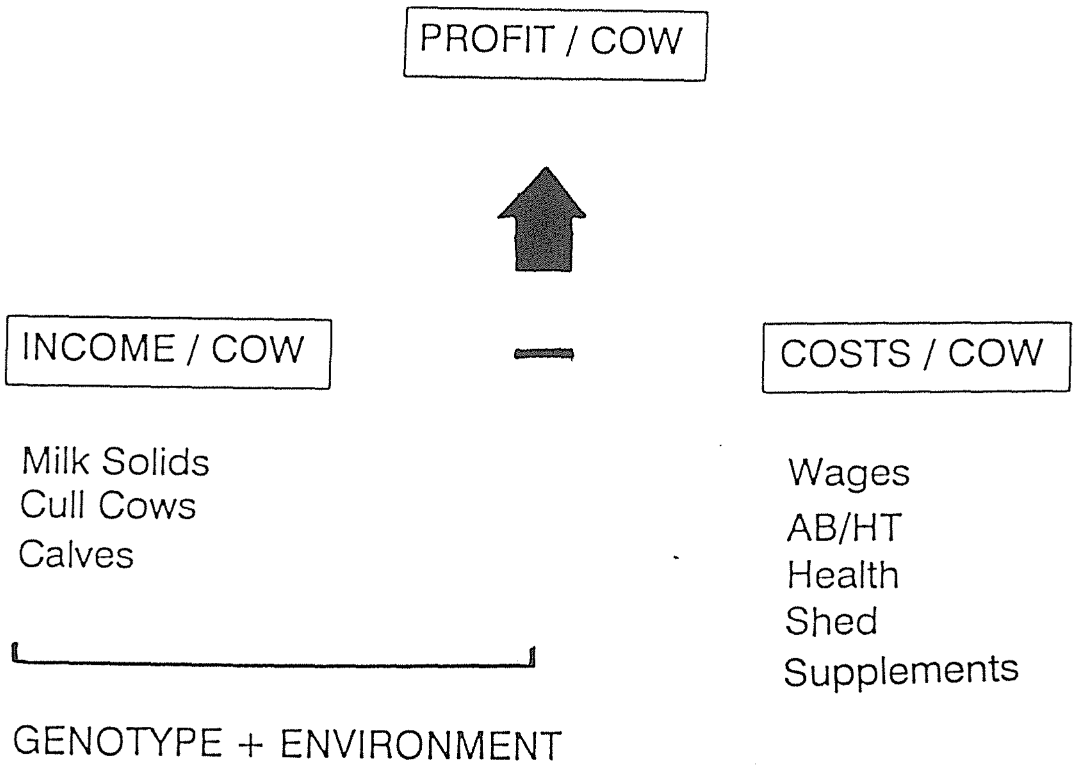


Figure 2.1 The key components of profit per hectare

The importance of stocking rate in grassland farming is evident by the wide-ranging and influential effect it has on nearly every aspect of farm productivity. The number of animals per unit area of pasture determines the severity of grazing and hence the growth rate and productivity of the sward as well as the availability of feed per animal for the combined annual requirements of maintenance, pregnancy, growth and lactation. The correct choice of stocking rate is therefore vital to the profitable running of any dairy farm.

The income generated per cow minus the costs incurred in achieving this output constitutes the actual cash surplus per cow. In addition to the individual yields of fat, protein and milk, the income from saleable cows and calves can be spread over the remaining animals in the herd to give the gross earnings per cow. Per cow output is determined by both the cows inherited genetic merit and the strong environmental influence exerted by factors such as feeding level. The key components of profit per cow can be shown in Figure 2.2.

Figure 2.2 The key components of profit per cow



3. FACTORS AFFECTING MILK PRODUCTION PER COW

The main source of revenue on a dairy farm is the production of milk solids. From an economic point of view, any factors which influence per cow production of milk solids will directly affect the profitability of the farm as a whole. This section reviews several of the important components of a dairy system which determine yield per cow.

3.1 ENERGY SUPPLY

As the energy available above maintenance requirement increases in the dairy cow, the marginal gains in milk yield will be determined by the relative partitioning of this 'net' energy between lactation and liveweight gain. This partitioning effect is influenced by such factors as the genetic merit of the cow, daily yield, stage of lactation and lactation number (Broster, 1976). Although large variation in patterns of energy use exist between animals, several trends have been identified. The response in milk yield to increasing feed intake is negatively curvilinear while the response in liveweight change is positively curvilinear (Broster, 1976) (see Figure 3.1.1).

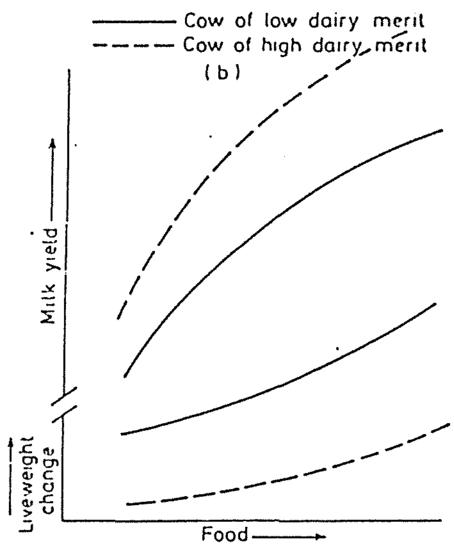


Figure 3.1.1 The relationship between feed intake, milk yield and liveweight change in dairy cows (Broster, 1976)

It has been concluded that the <u>total</u> energy retained in milk and liveweight increases linearly with changes in energy intake (Broster, 1976).

Breeding cows which preferentially divert energy into milk is important for maximising the efficiency of dairy production (kg milk solids per kg pasture DM eaten). However if body tissue deposited during periods of generous feeding can be later mobilized and used for milk production, further contributions to dairy efficiency can be made in the long term.

The enormous increase in energy requirement with the onset of lactation in the dairy cow was graphically demonstrated by Hutton (1963) who found intake differences of approximately 50% between lactating and dry twin cows fed fresh pasture. The drain on dietary energy supply and body reserves as a result of milk synthesis is evident by the extensive liveweight loss observed in high producing cows during early lactation (Bryant and Trigg, 1981; Davey et.al, 1983) despite high levels of feeding.

Under grazing conditions, the effect of pasture allowance on intake and milk yield per cow has been widely investigated. Results consistently show increases in milk production (see Figure 3.1.2) with greater pasture allowance up until some upper limit of the animal is reached (Le Du et.al, 1979; Glassey et.al, 1980; Grainger et.al, 1982).

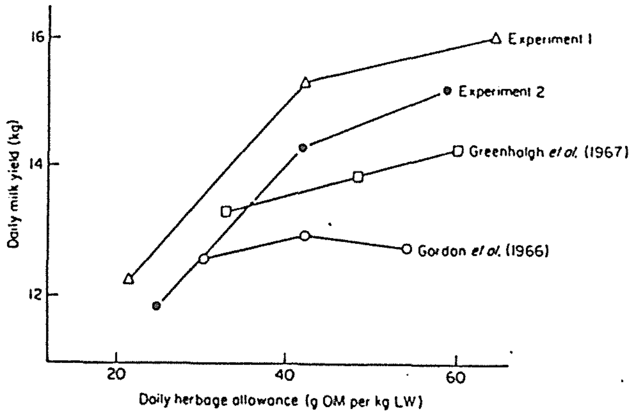


Figure 3.1.2 The effect of herbage allowance on daily milk yield per cow (Le Du et.al, 1979)

At high allowances, the milk yield response to additional feed increments usually decreases as a greater proportion of energy is partitioned into liveweight gain and body condition (Holmes, 1989).

Feeding high-energy concentrates can increase milk and milk solids yields of cows above those fed solely on pasture (Castle et.al, 1960; Brown et.al, 1962; Stockdale and Trigg, 1985). Although some substitution of concentrate for pasture does occur, at lower pasture allowance there is usually a net increase in total intake per cow (Grainger and Matthews, 1989).

Level of feeding during the dry period can also have important consequences for subsequent lactational performance through deposition of body reserves. Although liveweight gain *per se* does not influence production in the short term (Rogers et.al, 1979), body condition at calving can have significant effects on yield of milk and milk solids (Rogers et.al, 1979; Grainger, 1980; Grainger et.al, 1982).

In general, reducing a cows food intake in the short term will increase the fat concentration of milk slightly, while depressing the Solids-Not-Fat (SNF) concentration (Bryant, 1979; Le Du et.al, 1979; Thomson, 1988) (see Table 3.1.1).

Table 3.1.1 Effect of Pasture Allowance on Milk Yield and Composition (Le Du et.al, 1979)

	Daily Herbage Allowance (gDM/kgLWT)		
	25	50	75
Yield (kg/day)			
Milk	14.0	17.1	17.7
SCM	12.5	15.3	16.0
Composition (g/kg)			
Fat	37.4	35.6	34.8
Protein	32.2	33.1	33.4
Lactose	44.3	45.4	45.5
Energy (MJ/kg)	2.92	2.90	2.87

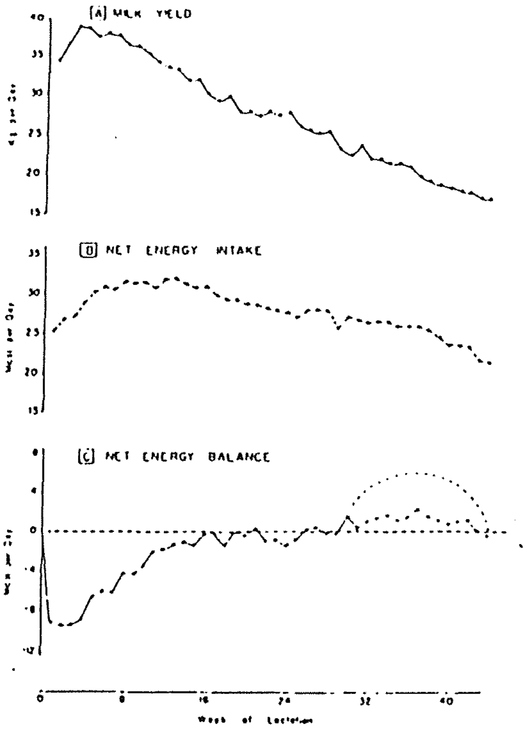
The results of Le Du et.al (1979) show a 5% increase in fat concentration with 3% and 2.5% reductions in protein and lactose concentrations for a 50% reduction in pasture allowance. Similar results were reported by Bryant (1979). These changes were found to be only small when compared with the effects of breed, age or season.

The short term increases in fat concentration of milk produced by underfed cows, although partly attributable to a reduction in milk yield, is also supported by mobilization of body fat reserves (Holmes, 1989). In this way synthesis of milkfat is less subject than other milk components to variation in dietary nutrient supply. Milk proteins are derived from amino acids supplied in the blood. During periods of feed scarcity, the supply of amino acids can be reduced by both lack of dietary precursors and a tendency for available amino acids to be preferentially diverted into the essential manufacture of glucose. Hence the observed trends in SNF concentration of milk with restricted feed intake. Longer term periods of underfeeding may eventually depress milkfat concentrations with this effect becoming more noticeable as body reserves dwindle (Mitchell, 1985).

3.2 BODY CONDITION

Assessment of body condition provides a useful estimate of the stored reserves of the animal (Earle, 1976). The importance of these reserves during early lactation is illustrated by observations that peak milk yield and maximum digestible energy intake per cow occurred at 6 and 16 weeks after calving respectively (Hutton, 1963) (see Figure 3.2.1) causing a period of negative energy balance in early lactation.

Figure 3.2.1 Relationship between energy intake and energy requirement for lactation in the dairy cow (Bauman and Currie, 1980)



This negative energy balance is an inherent aspect of high producing cows with clear positive relationships being demonstrated between body condition at calving and production levels in early lactation (Rogers et.al, 1979; Grainger, 1980; Grainger et.al, 1981). Grainger and McGowan (1982) described this relationship as ΔFat Yield = 0.29 ($\pm$ 0.04) ΔLiveweight. Based on this relationship a difference in liveweight at calving of 35 kg would result in an extra 10.2 kg milkfat in the subsequent lactation. Experiments by Rogers et.al (1979) concluded that feeding levels and rates of gain or loss prior to calving had little effect on production provided cows were at the same level of condition at the start of lactation. High BI cows had greater production and lost more body condition than low BI cows during a complete lactation (MacMillan et.al, 1982; Davey et.al, 1983) (see Table 3.2.1).

Other reviews have also emphasized the contribution of body reserves and tissue catabolism to milk production (Blake and Custodio, 1983; Bauman et.al, 1985; McCutcheon et.al, 1989).

Table 3.2.1 Lactation Performance (1979-80 and 1980-81) for High and Low BI Friesian cows (Grainger, 1981)

	1979-80		1980-81	
	High BI	Low BI	High BI	Low BI
No. Cows	10	10	19	17
Av. BI	127	100	126	102
Av. CS (calving)	4.7	4.7	4.7	4.9
Days in Milk	249	249	220	216
Av. Fat (kg)	150	117	156	132
ΔCS over lactation	-0.8	+0.1	-0.6	0

The composition of milk can be affected by condition score and feeding levels during early lactation. Higher liveweight at calving was associated with a greater fat content of milk, a difference of 35kg resulting in an extra 0.4% milkfat (Grainger and McGowan, 1982). Presumably this was due to a greater mobilization of adipose tissue and hence a greater supply of lipogenic substances in the blood. The proportion of long and short chain fatty acids in milk is also altered with generally a greater loss of body condition and/or a lower feeding level after calving causing an increase in the percentage of long chain fatty acids (C_{16}-C_{18}) (Grainger et.al, 1982). This is consistent with findings that hydrolysis of adipose tissue releases predominantly long chain fatty acids into the systemic circulation (Bauman and Davis, 1974).

3.3 GENETIC MERIT

The genetic merit of an animal describes its potential performance as a result of the particular combination of genes inherited from its parents. Genes control the physical expression of a particular characteristic through various biological regulatory mechanisms such as enzymes and hormones acting within the animal body. However the action of these genes can be strongly influenced by external environmental factors which mask the genetic potential of an animal. The assessment and improvement of average herd genetic merit is a key component of increasing milk production per cow over many years.

Artificial Breeding and Selection

Selecting superior animals to be the parents of the next generation is the basis of herd improvement. In contrast to the often temporary production advantages gained through other management techniques, increasing the average genetic merit of the herd is a gradual but permanent process with improved yields of milk and milk solids being maintained, even when selection is halted.

There are two ways through which a dairy farmer can control rate of gain in the herd;

* Identifying and culling low producers
* Breeding high merit replacements through the use of proven dairy sires

(Garrick, 1991)

Herd wastage is a function of the chosen replacement rate and can be classified into both productive and non-productive culling (Jackson, 1983). Although it is only those animals removed from the herd for low productive ability which increases the average merit of the remaining cows, in practice non-productive culling constitutes the majority of wastage through unavoidable reasons such as empty cows, animal deaths, and old age.

The measure of genetic merit for production traits in the New Zealand dairy industry is the Breeding Index (BI). The BI describes the estimated genetic merit of a cow based on her own record and ancestry information, with animals in the early 1960's being assigned a BI of 100. A BI value of 125 represents an animal which is genetically superior by approximately 25% to the average cow in the 1960's.

By far the largest increases in genetic gain are achieved through the use of dairy sires which are proven to produce high-yielding daughters (Johansson, 1969). The common practice of incorporating Artificial Breeding (AB) into the first 4 to 6 weeks of the mating programme (MacMillan and Moller, 1977) means that sufficient high BI heifer calves can be reared to meet the herds requirement for replacements.

The development of AB technologies such as frozen and liquid semen have major implications for the dairy industry in that a few sires can be used to artificially inseminate large numbers of cows. This has decreased the number of proven industry bulls required and hence such sires can be subjected to a greater selection intensity. Although other pathways of selection exist in the dairy industry (Rendel and Robertson, 1950; Johansson, 1969, Garrick and Rendel, 1992) the large selection differential in the 'nucleus' of superior sires currently provides the greatest method of gain. The heavy dependence of New Zealand farmers on AB for producing replacements and the relatively small gains to be made through production culling means that the industry rate of gain is largely dependant on the annual improvement in the premier bull team (Garrick and Rendel, 1992).

The expected BI of a new replacement animal can be calculated as;

$$\text{Daughter BI} = \tfrac{1}{2}BI_{sire} + \tfrac{1}{2}BI_{dam}$$

Assuming an average bull team BI of 150 and herd BI of 125 the expected BI of daughters so produced would be on average 136. From this it can be shown that rate of genetic gain, particularly in lower BI herds will benefit to a large extent initially from the use of high BI sires. Continued use will see gains achieved at a diminishing rate, until an equilibrium rate of gain paralleling the improvement in the sire nucleus but lagging by several generations is reached. The effect of parent BI on the genetic improvement in offspring is shown in Table 3.3.1.

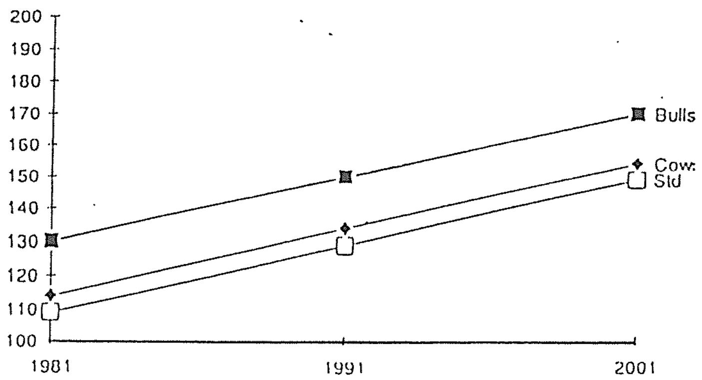
Table 3.3.1 The effect of average herd BI on the genetic superiority* of daughters

Av. Herd BI	Av. Sire BI	Av. Daughter BI	Superiority (%)
120	150	135	12.5
125	150	138	10.4
130	150	140	7.7

*** Relative to dams**

The lag period is generated by the time interval between the use of a sire, birth of his daughters and their first lactation. The current lag in the New Zealand dairy industry is roughly equivalent to the amount of improvement achieved in the bull team during two generations (Garrick, 1991). Lag can be reduced by adopting alternative management procedures such as selecting among potential replacements before they enter the herd or mating heifers to AB, but apart from an initial 'leap' in the first year, rate of gain cannot be improved above that in the bull team (Garrick, 1991). In addition, such practices inevitably involve greater difficulty and the policy must be maintained permanently in order to retain the decreased lag (see Figure 3.3.1).

Figure 3.3.1 Herd average BI with yearling AB and selection, relative to sire and herd BI from standard selection policies (Garrick, 1991)



Trends in Genetic Improvement in New Zealand

With the introduction of Artificial Insemination (AI) from proven sires in New Zealand in the 1950's, evidence accumulated for the real productive advantage carried by their genetically improved progeny. Carter (1964) demonstrated differences ranging from 14 to 19% between AI sired cows and 'naturally bred' cows under two stocking rates and two systems of grazing management. Similar trends were noted in a review of New Zealand genetic studies on dairy cattle (Wickham et.al, 1978). Experiments involving two groups of Friesian cows with respective average BI of 126 (High BI) and 102 (Low BI) found that HBI animals produced an average of 153 kgMF/cow over two lactations while LBI cows produced 125 kgMF/cow (Davey et.al, 1983) (see Table 3.3.2). This 22% increase in yield by the improved animals compares well with the 24% productive superiority predicted from the differences in BI. An observed 45 kgMF/cow difference between high (125) and low (100) BI Jersey cows also confirms the benefits of selective breeding (Bryant and Trigg, 1981).

Table 3.3.2 Milkfat production of High and Low BI Friesian cows (Davey et.al, 1983)

	1979/80		1980/81	
	HBI	LBI	HBI	LBI
No. Cows	10	10	19	17
Average BI	127	100	126	102
Days in Milk	260	256	238	233
Milkfat/cow (kg)	150	117	158	133
Milkfat %	4.58	4.22	4.50	4.36

Effects of Genetic Improvement in New Zealand

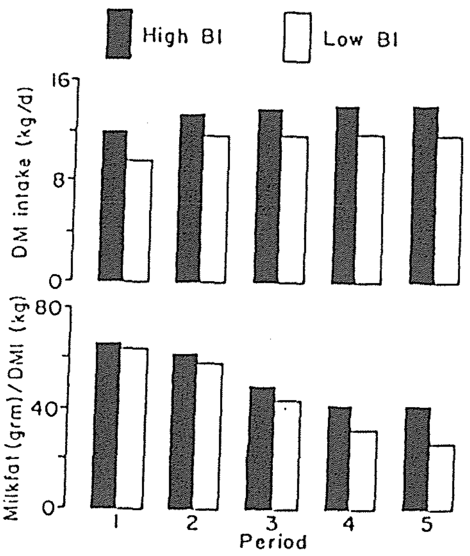
Past selection criteria in the New Zealand dairy industry was based solely on the yield of milkfat per cow with the object of maximising net farm income (Wickham et.al, 1978). This criteria has only recently expanded to incorporate protein and milk yields per cow plus various type traits. Previous studies on the genetic changes associated with the national breeding scheme therefore measured the effects of selection for milkfat alone.

Along with the greater amounts of milk energy produced by cows of high genetic merit comes a greater requirement for nutrients to attain this increase. HBI Friesian cows had significantly higher pasture dry matter (DM) intakes per kg of metabolic liveweight ($kg^{0.75}$), partitioned a greater proportion of dietary energy to milk energy and lost more body condition over lactation than LBI cows (Davey et.al, 1983). Similar results were observed in the Jersey breed (Bryant and Trigg, 1981). The high BI cows had higher values for dairy efficiency (kg milk solids per kg pasture DM eaten) in both studies.

Data presented by Bryant (1981) showed that although the efficiency of high and low BI Jersey cows was initially similar, differences became greater in favour of HBI animals as lactation continued (see Figure 3.3.2). Part of these differences were associated with liveweight changes with LBI cows gaining 31 kg over lactation while HBI cows gained only 14 kg. The overall increase in dairy efficiency of higher merit cows, despite larger feed intakes, is mostly due to the dilution of maintenance over a greater milk yield and their greater propensity to utilize stored body condition in support of dietary energy supply during lactation (Grainger et.al, 1985; Holmes et.al, 1987).

Figure 3.3.2 Relative efficiencies of High BI and Low BI Jersey cows during lactation (Bryant, 1981)

Figure 3.3.2 Relative efficiencies of High BI and Low BI Jersey cows during lactation (Bryant, 1981)



Other studies have shown that cow BI does not significantly affect the animals ability to metabolize dietary energy (Trigg and Parr, 1981; Davey et.al, 1983) or its energy requirement for maintenance and liveweight gain (Bryant, 1981; Holmes et.al, 1987). Reviews of the various factors contributing to dairy cow efficiency and their importance in explaining yield differences have been carried out by Bauman et.al (1985), Blake and Custudio (1984) and McCutcheon et.al (1989).

Conflicting evidence exists for the influence of body size on milk production and the possible changes being made to average herd liveweight by selection for yield traits. Significant genetic correlations have been reported between liveweight and stature characteristics and milk and milk solids yields in two year old New Zealand dairy cattle (Ahlborn and Dempfle, 1991). High BI Jersey cows were 45 kg heavier at calving than their LBI counterparts at similar condition score (Bryant and Trigg, 1981). Greater udder size and liveweight in HBI compared with LBI Jerseys has been suggested as a physiological basis for increased yields (Davis et.al, 1983). However in a study involving Friesian cows with both high and low BI, the difference between genotypes in size was not regarded as significant (Grainger et.al, 1985). Differing experimental conditions and the confounding effect of body condition changes complicates the correct interpretation of these results. The influence of body size on milk production is discussed in more detail in section 3.4.

3.4 BODY SIZE

The relationship between dairy cow size and milk production traits has been the subject of a multitude of studies in an attempt to define and predict the potential performance of animals according to type. Results have often been conflicting and varied, however the general conclusion is that the genetic relationship, if any, is small and positive (Morris and Wilton, 1976). Three possible explanations for this association have been proposed by Harville and Henderson (1967):

(i) Body size serves as a measure of animal maturity ie. available energy is partitioned into lactational requirements rather than growth.

(ii) Environmental conditions favourable to high milk production may also lead to greater body size.

(iii) There is a genetic correlation between size and production.

The confounding effects of environment (ie. age, feeding level) and also the differing measures of body size among authors makes it extremely difficult to make accurate comparisons between studies. The use of liveweight as a point estimate of body size without taking account of the fluctuating nature of body condition is a potential source of variation which is often ignored (Hickman et.al, 1971; Morris and Wilton, 1976; Lin et.al, 1984; Blake and Custodio, 1984).

In contrast to the possible lactational benefits of greater body size is the increased partitioning of available feed energy into meeting additional body maintenance requirements (Wallace, 1956; Hutton, 1963; McCutcheon et.al, 1989). This is based on the currently accepted estimate of maintenance as a function of metabolic liveweight (kg $LWT^{0.75}$) (ARC, 1980). Dairy efficiency in cows can be defined as the proportion of total dietary feed intake that is converted to milk ie. Net energy in milk produced per cow / Metabolizable energy in feed eaten per cow. This refers to the ability of a cow to dilute the energy cost of maintenance across the volume of milk produced. Following from this, at similar yields the lower maintenance requirement of smaller cows per kilogram of milk produced will mean they have marginally greater efficiency for milk production than larger cows.

Any analysis of body size effects on efficiency must take account of the economic returns from cull cows and calves. Taking the 'whole farm' approach rather than focusing on the biological consequences for milk production alone will provide the most reliable indicator of the relative profitability of farming different sized animals.

Body Size and Milk Production

It has previously been considered that larger cows are not only better producers of milk but have a longer productive life due to their superior constitution (McDaniel and Legates, 1965).

Genetic relationships between liveweight and yields of milk and milk solids have been measured ranging from 0.46 to -0.53 (Mason et.al, 1957 ; Erb and Ashworth, 1960; Clark and Touchberry, 1962; McDaniel and Legates, 1965 ; Harville and Henderson, 1966; Hooven et.al, 1968; Brum and Ludwick, 1968; Ahlborn and Dempfle, 1992). Negative genetic relationships between heart girth and Fat-Corrected Milk (FCM) (-0.02 to -0.25) were found by Syrstad (1966) using large numbers of records, as well as by Grantham et.al (1974) between predicted differences of milk and fat (-0.11) and stature of half-sib progeny. However height had a positive genetic relationship with fat-corrected milk (FCM) (Mason et.al, 1957) and stature with yield of milk solids (0.42-0.46) (Ahlborn and Dempfle, 1992) in several other studies.

Phenotypic relationships between body size measurements and milk production have generally been shown to be small and positive, ranging between 0.1 to 0.3 (Mason et.al, 1957; Clark and Touchberry, 1962; Freeman and Roache, 1962). Syrstad (1966) recorded small negative phenotypic correlations (-0.02 to -0.05) for heart girth with FCM yields (see Table 3.4.1).

Apart from the latter study, the consistently positive nature of these phenotypic observations compared with the greater variability among the genetic relationships would suggest a strong environmental influence on body size and milk production. In other words, although a genetic correlation could exist, environmental conditions favourable to high milk yields ie. high feeding levels, could also contribute to greater body size (Harville and Henderson, 1966).

Several studies involved taking comparative measurements on animals while feeding them according to milk yield (Erb and Ashworth, 1960; Lin et.al, 1984). If larger animals truly did produce more milk, this system of differential feeding would simply exacerbate the effect and result in over estimates of the true relationship. In the case of Lin et.al (1984), the trial involved heifers undergoing first lactation. Faster maturing, bigger animals would be expected to partition less feed energy into growth and more into milk synthesis during first lactation, with additional feed compounding any measurable associations. Concurrent with this are the extremely large genetic and phenotypic correlations of liveweight with milk yield observed by these authors (0.76 and 0.72 respectively). On the other hand, McDaniel and Legates (1965) calculated increasingly negative genetic correlations between body size (heart girth) and milk yield for lactating cows between one and ten years of age when fed according to production.

Table 3.4.1 Summary of correlations between body size and milk production

Author(s)	Data Source	Phenotypic	Genetic	Details
Mason et.al	Progeny from	-	0.28	FCM:Height(const. age)
(1957)	247 test bulls	positive	-0.07	FCM:LWT (const.age)
Erb & Ashworth	216 lactations	-	0.27	Milk:LWT (Jersey)
(1960)	on 154 cows	-	0.32	Fat :LWT (Jersey)
		-	0.26	Prot:LWT (Jersey)
Clark & Touchberry	1,344 lactations	-	0.02	Milk:LWT (1st lact)
(1962)	from 6 herds	positive	-0.53	Milk:LWT (2nd lact)
		-	-0.12	Milk:LWT (1-4 lact)
Harville & Henderson	22,767 1st lact.	0.17	0.45	ME Milk:age-adj. LWT
(1966)	records	0.18	0.35	ME Fat :age-adj. LWT
McDaniel & Legates	3168 lactations	-	0.21	Milk:LWT (1st lact)
(1965)	on 1593 cows	-	-0.02	Milk:LWT (1-5 lact)
		-	-0.25	Milk:LWT (5-10 lact)
		-	0.02	Milk:LWT (all lact)
Syrstad (1966)	32,000 cows from	-0.02	-0.08	Milk:Heart girth (3yr)
	100 AI sires	-0.03	-0.13	Milk:Heart girth (4yr)
		-0.05	-0.09	Milk:Heart girth (5yr)
Hooven et.al (1968)	661 lact. of 318 cows from 17 sires	0.44	0.30	FCM:LWT (const. age)
Brum & Ludwick	529 to 2367	0.02	0.03	Milk:LWT
(1968)	observations	0.11	0.02	Milk:Height
		0.11	0.33	Milk:Chest depth
		0.07	0.11	Milk:Body length
Ahlborn & Dempfle	128 half-sib groups	0.19	0.34	Fat :LWT (Jersey)
(1992)	of 3967 1st lact.	0.22	0.39	Prot:LWT (Jersey)
	Jerseys	0.20	0.29	Milk:LWT (Jersey)
	(New Zealand)	0.21	0.42	Fat :Stature (Jersey)
		0.24	0.46	Prot:Stature (Jersey)
		0.23	0.43	Milk:Stature (Jersey)

* LWT = liveweight

Selection for Body Size Traits

New Zealand dairy cows vary greatly in production and size (Ahlborn and Dempfle, 1992). Within breeds, this inherent variation provides the basis for selecting individuals which are 'superior' in terms of desirable characteristics, to their peers. However since the observable merit (phenotype) of an animal is determined by

Selection for Body Size Traits

New Zealand dairy cows vary greatly in production and size (Ahlborn and Dempfle, 1992). Within breeds, this inherent variation provides the basis for selecting individuals which are 'superior' in terms of desirable characteristics, to their peers. However since the observable merit (phenotype) of an animal is determined by a combination of environmental and genetic components, it is difficult to assess its true value on the basis of one or two production records .

For most traits of interest this genetic component of variation is relatively small (20 to 30%) (Ahlborn and Dempfle, 1992) with environmental factors having a far greater influence on phenotypic expression. An illustration of this is the recent comparison between daughters of both Canadian and New Zealand sires in common environments (Peterson, 1988). The average first calving liveweight of heifers in New Zealand was 145kg lighter than their half-sibs in Canada. Within countries this difference between strains narrowed to 13kg and 4kg for Canada and New Zealand respectively. Thus the differing feeding and management systems between the two countries was largely the cause of liveweight differences, although a small genetic contribution was evident from the differences between the strains (Wickham et.al, 1992).

The existence of a genetic correlation between body size and milk production could provide a basis for inclusion of size estimates in predictive indexes of dairy merit (Wilk et.al, 1963; Harville and Henderson, 1966; Brum and Ludwick, 1968; Hooven et.al, 1968). The use of body size data as an aid to selection for milk yield requires either a high heritability for the size trait combined with a moderate genetic correlation between yield and size, or a strong genetic correlation combined with a moderate heritability (Wilk et.al, 1963; Brum and Ludwick, 1968). Low phenotypic correlations would also increase the accuracy of selection (Harville and Henderson, 1966).

Estimated heritabilities of body size traits range from 0.16 to 0.5 (Mason et.al, 1957; Clark and Touchberry, 1962; McDaniel and Legates, 1965; Harville and Henderson, 1966; Brum and Ludwick, 1968; Ahlborn and Dempfle, 1992) for first lactation dairy cattle. Measured genetic correlations between body size traits and milk production range between -0.53 up to 0.46 (see Table 3.4.1). Estimates of phenotypic correlations between size and production traits showed consistently small and positive relationships ranging from effectively zero (Wilk et.al, 1963; Brum and Ludwick, 1968) to 0.2 (Freeman and Roache, 1962; Harville and Henderson, 1968; Ahlborn and Dempfle, 1992). Phenotypic relationships were generally smaller than genetic relationships (Harville and Henderson, 1966; Brum and Ludwick, 1968; Ahlborn and Dempfle, 1992) and there is an indication that stature traits are slightly more correlated with production than liveweight measurements.

Harville and Henderson (1966) calculated Breeding Values (BV) based on first lactation records plus age adjusted bodyweight, first lactation records only and age adjusted body weight only, for primiparous dairy heifers of three breeds. Using estimated genetic correlations between yield and weight of 0.4 and 0.45, and heritabilities between 0.16 and 0.4, indications were that once a cows productive record was available liveweight data supplied little additional information about her productive breeding value (see Table 3.4.2). Selecting on liveweight alone would result in an estimated genetic gain in milk and milkfat yields per cow equivalent to only 29% of the gain achieved by selection on milk yield alone.

Table 3.4.2 Estimated correlations (r_{GI}) between BV's and selection indices for milk and milkfat yields in Holstein Friesian cattle (Harville and Henderson, 1966)

	r_{GI}	
Index	**Milk Yield**	**Milkfat Yield**
1st lactation yield + 1st lactation age-adj. body weight	**0.610**	**0.550**
1st lactation yield	**0.606**	**0.549**
1st lactation age-adj. body weight	**0.177**	**0.138**

McDaniel and Legates (1965) used a selection index based on monetary returns to calculate the gains in milk production to be made from including a liveweight trait. In this context, liveweight was assigned a negative weighting to balance the increased cost of maintenance with greater body size. The authors concluded that for genetic correlations in the range 0.15 to -0.15, considering bodyweight in an index would be practically no more effective in increasing milk yield. This was true for both high and low heritabilities and all economic situations.

In contrast to the previous two studies, Brum and Ludwick (1968) calculated that inclusion of bodyweight, wither height, chest depth and body length measurements recorded from 3 to 6 months of age, along with first lactation milk yields, may result in 20 to 30% greater progress in production traits. In addition, selection solely on body measurements taken between 3 to 12 months of age could be 80 to 90% as effective as using production records alone. Estimated genetic correlations used ranged from effectively zero for body length up to 0.4 to 0.6 for weight, height and chest depth. Heritabilities were between 0.2 and 0.4. The larger values for genetic parameters used may explain the discrepancy in results between authors, although using a genetic correlation greater than 0.3 is in agreement with the findings of McDaniel and Legates (1965).

A recent New Zealand study on the effectiveness of including body size in a selection index also produced positive results (Dempfle, 1986). However this study differs significantly from earlier ones in that the relative returns from both milk solids and saleable animals are considered. Unfortunately previous studies considered only the genetic implications of body size for dairy traits rather than the contribution of liveweight to overall farm profitability (Harville and Henderson, 1966). The objective of selection in the present case was assumed to be maximum profit per hectare rather than milk production per cow. Taking into account the balance between returns from milk, cull cows and calves, and the increased maintenance cost of heavier animals, it was estimated that incorporating body size into the existing form of selection index could increase the economic benefits of genetic improvement for the farmer by approximately 4%. This was based on estimated genetic correlations of between 0.25 and 0.45 for body size and milk production traits and heritabilities of 0.16 to 0.29 for liveweight and stature measurements. Although these results are not strictly comparable with earlier studies, it does illustrate the varying importance of body size under different selection objectives.

The correlations between body measurements taken at early ages, with milk yield are as large if not larger than the correlations derived from measurements on older cows (Clark and Touchberry, 1962; Wilk et.al, 1963; McDaniel and Legates, 1965). This finding has possible implications for early selection and culling of animals with few or no production records (Harville and Henderson, 1966).

Retrospective surveys in New Zealand of the effects of dairy selection policies on body size attributes have revealed several interesting points. Carter (1969) found small but positive associations between production proofs and mature liveweights of AB bulls of three different breeds. This result was only significant for the Friesian breed. The suggestion is that the heavier daughters sired by larger bulls also produce more milk. Bryant and Trigg (1981) found that high BI Jersey cows were of similar condition but approximately 45 kg heavier at calving and gained less weight and condition during lactation than low BI cows. This increase in size of AB Jersey animals is supported by observations of MacMillan et.al (1984) but Davey et.al (1983) found that in contrast, high BI Friesian animals were not significantly heavier than low BI cows. The indication is that selection for greater milk production is acting in different ways between breeds. In high BI Jerseys, udder size and liveweight are increased while in high BI Friesians, udder productivity (per unit volume) was increased relative to low BI animals (Davis et.al, 1985). This latter observation was deduced by the fact that while production differences were noted between high and low BI groups, there was no difference in udder volume at both peak and later stages of lactation. Although the accuracy of gland measurements is low, it is tempting to suggest that within each breed, selection resulted in increases in traits which were previously most limiting to production ie. size and associated gland volume in Jerseys and tissue productivity in Friesians.

3.5 AGE

Replacement dairy cattle are inherently inefficient from the point of view that up until time of first calving they produce no milk. Thus pasture which could be converted to milk by mature lactating cows must be used to ensure the sustainability of the farming system. Logically a reduction in the time between birth of a replacement animal and its first lactation will decrease this level of wastage. However a balance must be set between reducing the non-productive interval and minimising the losses in production associated with earlier calving animals.

Cows which first calved at three years of age produced more milk in their first lactation than cows which calved at two years (Little and Kay, 1979; Lin et.al, 1988). Similar trends were reported in a review by MacKenzie (1984) with the difference in production being 10% to 20% greater as animal age increased up to 36 months. However milk yields in subsequent lactations were found to be very similar between the two groups suggesting that past a certain age, production was not affected by age at first calving. Indeed the differences have been suggested to be so negligible that overall lifetime production of earlier calving animals usually exceed that of those calving later (MacKenzie, 1984).

Erb and Ashworth (1960) concluded that on an interbreed basis age contributed more than twice as much variation as liveweight to observed yield . Harville and Henderson (1966) and Clark and Touchberry (1962) indicated that approximately equal proportions of the variation in milk yield were caused by liveweight and age. Ridler et.al (1965) in regression analysis of records of 81 heifers found age at calving to have no significant effect and discarded this variable from further investigations. Instead they found a highly significant positive relationship between lactation yield and bodyweight at calving within half-sib groups. This observation is supported by other studies on first lactation animals with phenotypic correlations between milk yield and liveweight ranging from 0 to 0.7 (Harville and Henderson, 1966; Brum and Ludwick, 1968; Lin et.al, 1985; Van Arendonk et.al, 1991).

Age at first standing oestrus is inversely related to rate of liveweight gain in dairy heifers (Little et.al, 1981), but within each treatment (plane of nutrition) group the fastest growing heifers reached puberty at the same age but at a heavier body weight. However rapid liveweight gain over this pre-pubertal period causes decreased secretory tissue weights and decreased milk yield in at least the first and second lactations (Gardner et.al, 1977; Little and Kay, 1979; Sjersen et.al, 1982; Valentine et.al, 1987). These studies all reflect the difficulty of using animal age alone as an index of maturity without considering the effects of such important biological parameters as growth and liveweight.

Heifers calving at higher liveweights may produce more milk for several reasons. Larger animals may divert less dietary energy into liveweight gain or alternatively, have greater body reserves during lactation. They may also be able to eat more relative to maintenance and have a greater degree of mammary development at parturition (MacKenzie, 1984). The latter will depend on previous rate of liveweight gain and its influence on mammary growth.

The association between liveweight and milk yield has been reported to be positive in young cows but increasingly negative with greater lactation number (Clark and Touchberry, 1962; McDaniel and Legates, 1965). The reasons for this are unclear although it is possible that the influence of body weight on maturity is of greater importance than the additional maintenance requirements in determining first lactational performance of young animals. Also cows which produce more milk over a lifetime may consequently weigh less due to early lactation weight losses becoming compounded over several seasons.

4. FACTORS AFFECTING MILK PRODUCTION PER HECTARE

The yield of milk solids per hectare is an indicator of how effectively available land is being used to convert pasture Dry Matter into saleable product. As a function of both average yield per cow and the number of cows farmed per hectare (stocking rate), the amount of fat, protein and milk produced per hectare is affected by every aspect of the farming system. Several important components of production per hectare are reviewed in the following section.

4.1 STOCKING RATE

Stocking rate, in combination with method of grazing management, is a useful tool for matching feed supply to animal demand. Indeed it could be argued that it is the choice of stocking rate which determines the effectiveness of grazing management, with its associated effects on pasture productivity and animal intakes.

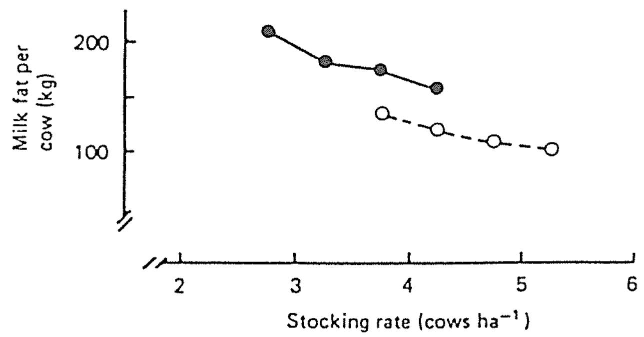
Production per cow will be influenced by intake per cow while production per hectare will be influenced by both intake per cow and feed utilization efficiency (Holmes and MacMillan, 1982). There is conclusive evidence to show that increasing stocking rate can lead to a drop in milk yield per cow but a corresponding increase in milk yield per hectare (McMeekan, 1958; McMeekan and Walshe, 1963; King and Stockdale, 1980; Holmes, 1989). The size of these effects for an increase of one cow per hectare was estimated as -17.7 kgMF/cow ($\pm$ 7.5) and +69.8 kgMF/ha ($\pm$ 10.2)(Holmes and MacMillan, 1982). However at very high stocking rate, per cow production can be depressed to such an extent that production per hectare is depressed as well (McMeekan, 1961; King and Stockdale, 1980). This suggests the occurrence of an 'optimal' stocking rate, (Wright and Pringle, 1983) although it could be expected to vary greatly with different farm and seasonal conditions.

Cow liveweight has also been shown to be affected by stocking rate with an inverse relationship existing between the two variables (McMeekan and Walshe, 1983; King and Stockdale, 1980). This could have important consequences for overstocked farms with regard to lactational and reproductive performance in the long term.

4.2 GENETIC IMPROVEMENT

It has been previously demonstrated that past genetic improvement has not only resulted in gains in milk production but has also increased the feed intakes of high BI cows. Thus in a grassland farming context, increasing the genetic merit of the herd can be equivalent to raising the stocking rate. This can have important implications for per hectare production. On a farm where all feed grown is already fully utilized, increasing genetic merit of the herd may mean a reduction in stocking rate is required to ensure animals are fed enough to attain their productive potential. However the extent to which cows are being limited by feed supply is difficult to measure in commercial practice and lowering stocking rate too far may also decrease pasture utilization. It has been demonstrated that high BI animals can be farmed at lower stocking rates than low BI animals without any loss of milk production or pasture control (Bryant, 1983, 1984, 1985) (see Figure 4.2.1).

Figure 4.2.1 Performance of High (●) and Low (○) BI Jersey cows at different stocking rates averaged over three years (Bryant, 1983, 1984, 1985)



However the greater assurance of efficient pasture utilization at high stocking rates combined with high production per hectare may mean many farmers are willing to accept a slight drop in per cow production to maximise total profit. Undoubtedly the benefits of reducing stocking rates while maintaining per hectare production are numerous, including greater DM intakes above cow maintenance requirements, greater efficiency, less stress on animals and reduced costs. Table 4.2.1 outlines the potential benefits from combining AB with a reduction in stocking rate.

Under these assumptions increasing average per cow production by 2.5 kg would require an additional 0.06 t of DM to be grown per hectare annually to keep pace with herd improvement. Alternatively lowering herd numbers by one cow (less than 1 %) could alleviate the requirement for extra feed while achieving nearly the same yield per hectare as with original herd numbers. Further increases in herd milkfat yields will also require a drop in stocking rate to prevent animal requirement from outstripping feed supply.

Although these examples are hypothetical, they illustrate the potential of genetic improvement, in combination with appropriate management systems, to maximise both per cow and per hectare production while retaining the advantages of reduced stocking rates.

Table 4.2.1 The effect of using superior sires on production per ha (Garrick, 1991)

	No AB	Using AB*		
		Same cow numbers	Minus one cow	Minus 30 cows
Production per cow		31@166	31@166	
		119@154	118@154	
kg Milkfat	154	156.5	156.5	230
No. Cows	150	150	149	120
Prod/60ha	23100	23473	23318	27600
Feed.cow	3.40tDM	3.43tDM	3.43tDM	4.25tDM
Feed/ha	8.50tDM	8.56tDM	8.50tDM	8.50tDM

* Assumes genetic progress is made ie. replacements genetically superior to dams

4.3 BODY SIZE

Size of animals can influence nutritional requirement through both increasing the energy for maintenance and requiring additional energy to reach mature size (Wickham et.al, 1992). The higher intake of larger animals (Wallace, 1956) could also be expected to decrease the maximum achievable stocking rate. In order for such a decrease to be of benefit, the total increase in milk produced from bigger cows must at least balance the loss in production from farming fewer animals. This requires a degree of correlated response in milk yield from increasing body size, the strength of which will determine the resulting change in efficiency per cow. If size increased with no corresponding increase in milk yield then the additional maintenance requirement created by greater body mass will mean a smaller proportion of the total energy ingested is available for milk synthesis. In other words a greater feed input will be required for large cows to achieve the same yield as smaller cows. Of course if there is an increase in milk yield with greater body size, the extent to which efficiency increases or decreases will depend on how the ratio of maintenance requirements to energy available for milk production is altered. These points can be summarized in Table 4.3.1.

The calculated efficiencies are only approximations as they do not include the greater requirements for pregnancy and growth in larger animals. Table 4.3.1 shows that it should not be assumed that because an animal is of a heavier weight it is inherently less efficient than a smaller one. On a per hectare basis these results imply that larger cows which produce the same quantity of milk solids per hectare as smaller cows

Table 4.3.1 Effect of bodyweight on the efficiency of milk production per cow

LWT (kg)	Milkfat (kg/yr)	Protein (kg/yr)	Milk (kg/yr)	*MJ ME_{maint}	†MJ ME_{lact} (%)	‡Efficiency
400	160	110	2700	19163	16882	47
400	170	125	3085	19163	19099	50
450	180	125	3085	20933	19099	48
450	200	140	3470	20933	21317	50

*** Based on Holmes and Wilson et.al (1984)**
† Based on Tyrell and Reid (1965)
‡ Efficiency (%) = MJ ME_{lact} / (MJ ME_{maint} + MJ ME_{lact})

will, despite their larger feed intakes, have proportionally greater milk yields. In this case stocking rate will necessarily be lower while animal costs per hectare will be less. Returns from cull cows and calves may also be proportionately greater.

Alternately heavier cows producing the same as lighter cows but eating more feed will be economically inefficient at current milk and meat prices. An increase of only 50 kg in average herd liveweight, assuming per cow production remains unchanged, has been estimated to decrease farm income by more than $4000 per year (Ahlborn and Holmes, 1992).

5. THE NEW ZEALAND DAIRY INDUSTRY

5.1 DEVELOPMENT OF THE NEW ZEALAND DAIRY INDUSTRY

It is generally held that the Reverend Samuel Marsden, a major figure in New Zealand history, laid the earliest foundations of the dairy industry when he imported several dairy cattle from Sydney in 1814. The aim was to make the various established missions nutritionally self-sufficient and also to introduce European farming practices to the Maoris. The importation of cattle, mainly from Australia, increased markedly in the following years with the spread of farming settlements into many regions such as Banks Penninsula, Taranaki and Nelson.

In 1847 the first exports of New Zealand dairy products began with a shipment of butter from Banks Penninsula to Sydney. However the amount of dairy exports decreased in the 1850's and 60's as the discovery of gold and the rapidly growing population increased local demand. The late 1860's and early 70's saw the first offical export of butter and cheese to the United Kingdom and the opening of New Zealands first co-operative dairy company in Otago. This was followed by a proliferation of small dairy companies in the subsequent years. The development of refrigerated shipping in 1882 was a major step in the transport of quality dairy products and the export trade flourished markedly after this date.

The introduction of the Babcock method in 1890 for testing the fat content of milk and the invention of commercially viable cream separators provided farmers with a means of identifying their main product and avoiding the difficulty of transporting large quantities of whole milk to central processing plants. However this trend was reversed in the 1950's when improved roads and technological advances in transport and storage allowed tanker collection of milk to begin.

The passing of three Dairy Industry Acts between 1892 and 1898 set manufacturing and hygiene standards for the processing industry as well as providing strict grading and quality control for exported milk products. Commercial dairy companies at this stage numbered 124 (48 of which were co-operatively owned) being supplied by 569,900 cows. These produced approximately 3700 tonnes of cheese and 3000 tonnes of butter annually which earned the country nearly $800,000 per year from export.

The introduction of mechanical milking in the early 1900's saw a large expansion in the number of cows able to be farmed and coincided with the first attempts at systematic herd testing. The year 1923 saw the timely development of a New Zealand Dairy Produce Export Control Board as the number of dairy companies serving the industry climbed to a maximum of 540, producing in excess of $20 million in export receipts per year. This regulatory role was taken over by the Government in 1936 with various subsequent changes taking place before the New Zealand Dairy Board (NZDB) was established in its current form in 1965.

Other advances over the period between the 1920's and the 1950's were the development of herd testing on a national basis and investigation into the practical applications of artificial breeding for genetically improving dairy stock. These technologies combined with improved farming techniques, increasing milk prices and greater cow numbers saw annual dairy exports exceed 500,000 tonnes per year in 1967 with a value of $220 million. Further increases by 1975 saw export figures boosted to 562,000 tonnes per year, returning $391.4 million.

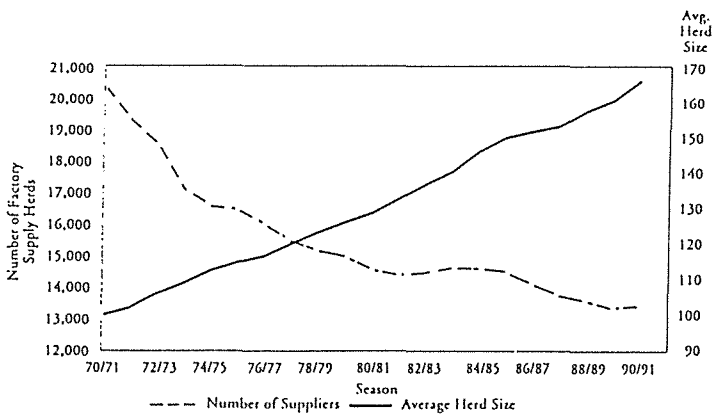
Since the 1920's the number of dairy companies processing the national milk output has dwindled until in 1981 there was about 30 companies owning 85 factories. This drastic change in industry structure was brought about principally through closures and amalgamations with associated gains in overall industry efficiency.

5.2 CURRENT DAIRY INDUSTRY STRUCTURE

Farms

New Zealand currently has 2.2 million dairy cows in milk, each supplying on average 152 kg fat, 116 kg protein and 3190 litres of milk per year. There are approximately 14.6 thousand herds with an average herd size of 166 cows milking on an area of 70 hectares. The trend over the past 20 years has been for total numbers of herds to decrease while herd size has increased (see Figure 5.2.1).

Figure 5.2.1 Number of suppliers vs average herd size (LIC, 1991)



However the change in herd size has been by far the biggest difference with national cow numbers having increased by approximately 20% while the numbers of herds have decreased by only 8% between 1981 and 1991. The South Auckland region has the largest concentration of dairy farms (38.24%) followed by Taranaki (19.25%), Northland (12.91%) and the Bay of Plenty (12%).

The most common dairy breed of cattle is the Holstein-Friesian (1.3 million cows) with Friesian-Jersey crosses (675,000 cows), Jerseys (665,000 cows), Ayrshire (84,000 cows) and Milking Shorthorn (16,000 cows) comprising the remainder. Prior to the late 1960's Jersey cows were the predominant dairy breed in New Zealand with changes to farm management and the increasing market for dairy beef leading the considerable change to Friesians in the 1970's.

Of dairy farms in New Zealand 69% are run by owner/operators and 31% by sharemilkers, with 23% of the latter being on 50/50 contracts.

Factories

The milk produced on New Zealand dairy farms is collected and processed by 17 dairy companies owning 43 manufacturing plants throughout the country. Payment for milk is made on the basis of total fat and protein yields minus a processing charge for the volume of milk supplied. Payouts are made out at an advance price at monthly intervals during the season with increases being made if warranted by market returns. The balance between advance prices and final payout are made at the conclusion of each season. The seasonal nature of dairy production in New Zealand means factories operate for a peak period in early-mid Spring concurrent with peak milk yields, gradually tailing off over the Summer-Autumn months.

Production

During the 1990/91 season New Zealand dairy farms produced 7520 million litres of milk of which 7077 million litres was processed by factories, with the remainder supplying the domestic liquid milk market.

Whole milk can be broken down into three major components: milkfat, solids-not-fat and water. Although water has no economic value, the milk solids can be used to produce a large variety of products which cover nutritional, industrial and pharmaceutical applications. The quantities of the major dairy products manufactured in New Zealand are shown in Table 5.2.1.

Markets

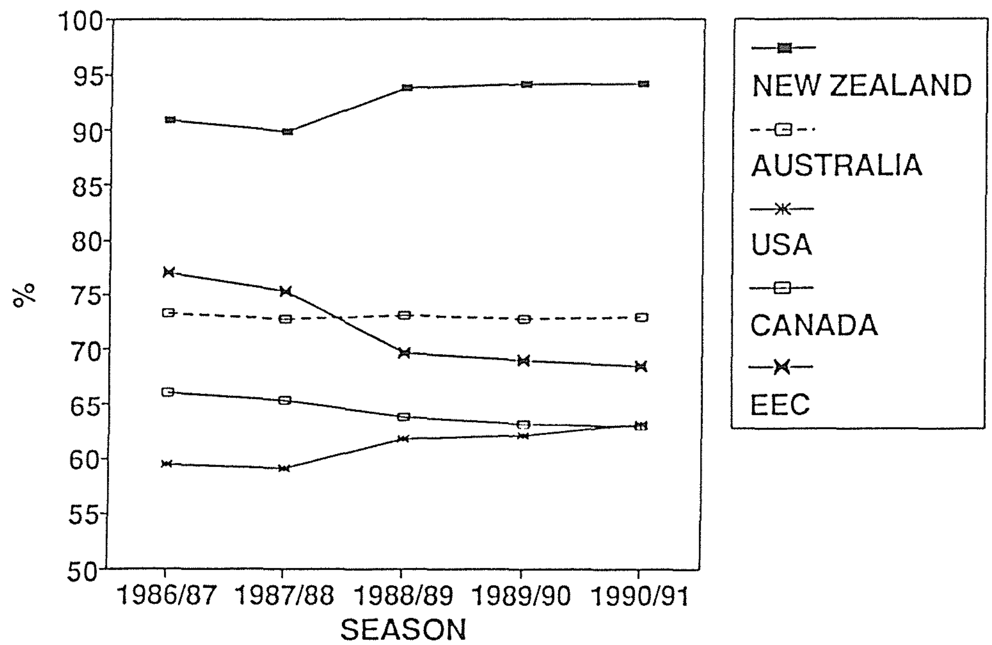
The markets where New Zealand dairy products are sold can be categorized as either domestic (within New Zealand) or export (outside New Zealand). Approximately 90% of the 900,000 tonnes of dairy produce manufactured each year is exported by the NZDB with total returns, including those to domestic markets of between $2.5 and $3 billion annually. When meat from the dairy industry is accounted for, its annual contribution is between 20% and 30% of New Zealand's total export earnings each year. As such its continued well-being is of major economic importance to the country as a whole.

Table 5.2.1 Volume of dairy products manufactured in New Zealand (NZDB, 1991)

Product (tonnes)	1989/90	% Total	1990/91	% Total
Creamery Butter	231,659	26.7	215,681	23.9
Anhydrous Milkfat	28,416	3.3	34,098	3.8
Frozen Cream	5,835	0.7	6,081	0.7
Cheese	121,993	14.1	126,990	14.1
Wholemilk Powder	159,803	18.4	233,295	25.8
Infant Food	14,889	1.7	16,214	1.8
Skimmilk Powder	183,867	21.2	147,528	16.3
Buttermilk Powder	27,204	3.1	24,104	2.7
Casein Products	62,907	7.3	65,657	7.3
Lactose	18,587	2.1	22,520	2.5
Whey Powders	12,337	1.4	10,580	1.2

Although producing only a small proportion of the total world milk supply, New Zealand is unique in that the majority of its national production is manufactured for markets overseas rather than used for domestic consumption (see Figure 5.2.2)

Figure 5.2.2 Percent of industry milk production used in manufacturing (NZDB, 1991)



This makes it one of the largest exporters of dairy products to the international market place, second only to the European Economic Community (EEC). Traditionally New Zealand's largest dairy market was supplying butter and cheese to Great Britain. However with the formation of the EEC restrictions were placed on the amount of product able to be sold there. This has led to the diversification of foreign markets so that now the NZDB exports to over 100 different countries around the world, including destinations in Europe, The Middle East, Asia and South America.

6. PAYMENT FOR MILK

6.1 DEVELOPMENT OF NEW ZEALAND MILK PAYMENT SYSTEMS

During the developmental period of the New Zealand dairy industry prior to the 1900's, the income of a co-operative dairy company was distributed among its suppliers in proportion to the quantity of milk they supplied (Creamer, 1985). With the introduction in 1890 of the Babcock milkfat test this volume payment became obsolete and was superceded by a straight payment for fat.

Although this system became the standard for many years, it did not remain unchallenged. A 1934 Commission of Enquiry into the dairy industry stated that fat content was not an accurate measure of the cheese-making capacity of milk. Instead they suggested that a more accurate representation of the value of different milks for processing should take account of both the casein protein and fat contents. However this advice was never acted upon, presumably because of the lack of reliable and economic methods of testing the protein content of milk at this time (Marshall, 1989).

In 1968 a Dairy Board Commission on payment for milk attempted to measure the disparity between the 'true value' of milk, determined by the yield of several dairy products and their processing costs, and the actual payout made under various milk payment systems. This payout disparity was defined as:

$$Disparity = 1 - \frac{Actual\ Payout}{True\ Value}$$

The size of this disparity, although commonly only a few percent, varied depending on the composition of milk

supplied, and in particular, with the mix of end products manufactured by each dairy company. Under these circumstances the Committee recommended the best or most equitable system as being one based on payments for milkfat and protein with a processing charge for volume: the A+B-C system. However the major drop in skim milk powder prices (Solids-not-fat) in the mid 1960's again provided little motivation to change (Marshall, 1989).

The 1970's saw the introduction of the A+B-C system by several dairy companies (Dennis, 1973) however industry adoption was still slow. In 1986 NZDB reports on how an alternative system of payment could be implemented led to a resolution at the 1987 industry conference to phase in the A+B-C system over the coming years. This decision has become evident by the changes which are currently taking place in payment for milk at the farm gate.

6.2 CURRENT NEW ZEALAND MILK PAYMENT SYSTEM

The A+B-C system of milk payment is made up of three components.

A = Returns from milkfat products minus costs

B = Returns from protein products minus costs

C = Costs of milk collection and volume processing

These are combined into a single price which reflects the net value of milk supplied to the processing companies
ie.

$$Payment = A \times Milkfat\,(kg) + B \times Protein\,(kg) - C \times Milk\,(kg)$$

For example:

The respective milk component prices paid by Tui Milk Products Ltd. to its suppliers in the early 1990/91 season are shown in Table 6.2.1.

Table 6.2.1 Milk Component Prices (Tui Milk Products Ltd.)

Component	Price (¢/kg)
Milkfat	299.47
Protein	499.12
Milk	-004.00

Assuming a 100 cow herd producing an average of 150 kg milkfat, 120 kg protein and 3500 kg milk annually per cow:

\$ Milkfat = 100 x 150 x \$2.9947 = \$44921

\$ Protein = 100 x 120 x \$4.9912 = \$59894

\$ Total = \$104815

Less Volume Charge

= 100 x 3500 x \$0.04 = \$14000

Total Payout = \$ 90815

The basic reasons for changing the milk payment system to include protein are:

* To provide farmers with a more equitable method of payment.
* To encourage farmers to adopt farm management practices which will be to their advantage.
* To provide market indicators to farmers of the relative values of milk components.

(Marshall, 1989; Creamer, 1985)

Equity of Payment

With past payment systems based solely on milkfat, an assumption about the relationship between the milkfat content and protein content of milk was required to allow returns from protein based products to be reflected in the payout price. If such a relationship were fairly consistent, the disparity between payouts received by farmers supplying differing quantities of milkfat would be negligible. However the reality is that for a given amount of milkfat supplied, there is a wide variation in the supply of protein by individual farms (Bryant et.al, 1988) (see Figure 6.2.1).

This difference in milk composition between suppliers is the main source of inequity in previous milk payments. Under a straight system of paying for milkfat, those producers with equivalent fat test but higher protein test than others are penalized despite the better quality of their product. They are in effect subsidizing the poorer production of other producers by foregoing payment for their extra protein. This can be shown in Table 6.2.2.

Figure 6.2.1 Relationship between Protein % and Milkfat % for 4400 New Zealand Co-op. Dairy Co. suppliers in 1986/87 (Bryant et.al, 1988)

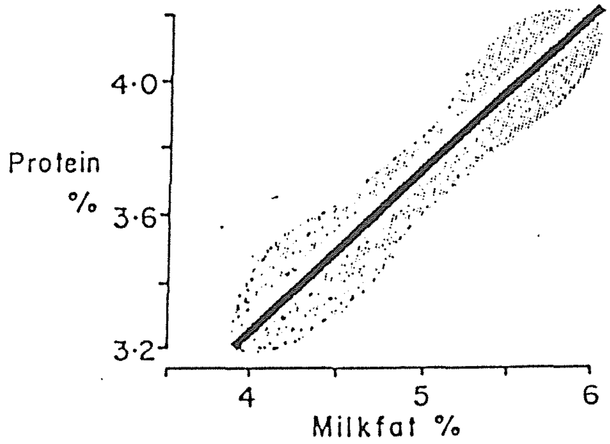


Table 6.2.2 The effect of two systems of milk payment on returns to the farmer

Production*	Producer 1	Producer 2	Producer 3
Fat Test	4.4	4.4	4.4
Protein Test	3.2	3.4	3.6
Prot/Fat Ratio	0.73	0.77	0.82
Fat (kg)	15400	15400	15400
Protein (kg)	11200	11900	12600
Milk (kg)	350000	350000	350000

* Assumes 100 cows producing 3500 kg milk/cow/year

Case 1. $6.8515 / kg milkfat			
$ Total =	105514	105514	105514
Case 2. $2.9947 / kg milkfat			
$4.9912 / kg protein			
$ Total =	102020	105514	109008
Difference (2-1) =	-3494	0	+3494

* Assumes Case 1. Prot/Milkfat Ratio = 0.773

Producers 1-3 all supply the same quantity of milkfat to the factory in their milk but differing quantities of protein. Under payment for fat only, all would receive the same returns despite the obvious differences in processing capacity of their respective milks. When separate payments for milkfat and protein are included, each producer will still receive the same returns for milkfat but the revenue from protein will necessarily be different. Thus producer 1 with the lowest protein/fat ratio would receive $3494 less for his annual milk supply while producer 3 with the highest protein/fat ratio would benefit by $3494 through providing milk of greater value to the factory.

The cost of milk volume

The volume charge incorporated into the A+B-C system reflects the cost of collecting and processing large quantities of milk to obtain the yields of valued milk components. Its identification as an additional payment issue is, similar to protein, a measure of the changing emphasis being placed on the qualities of milk required for processing.

The importance of milk volume to the New Zealand dairy industry is in determining the required processing capacity to cope with the seasonal pattern of milk supply. The seasonal nature of feed supply and currently recommended management practices to best utilize the available feed see factory supply dairy farmers across the country calving and reaching peak milk flows at roughly the same time each year. In effect, this means while factories must purchase and maintain enough processing capabilities to cope with the flushmilk period, as milk supply dwindles during the remainder of the season, they are operating at less than full capacity. Therefore flushmilk volumes are responsible for the high levels of overheads incurred by companies in catering for their suppliers milk. This explains the inclusion of volume charges in a payment system as a means of discouraging greater production of low testing milk. In this way those suppliers who provide the greatest value of milk components per unit of milk processed will be rewarded for their contribution to reducing company overheads (Paul, 1985).

An important feature determining milk composition is the genetic relationship between yields of milk solids and milk ($r=0.68$ to 0.82) (Ahlborn and Dempfle, 1992) (see Table 6.2.3). This implies that selection and breeding for increased herd production of milk solids will very likely result in concurrent increases in milk volume. Perhaps of greater importance is the negative genetic relationship observed between milk and milk solids content. High producing cows of the future may have greater yields of milk, milkfat and protein but milk will be less concentrated due to lower fat and protein percentages. However current methods of selection in New Zealand account for the disadvantages of milk volume by assigning it a negative value in the selection index. The extent to which this will protect against large increases in milk volume remains to be seen.

Table 6.2.3 Estimated genetic and phenotypic correlations between milk and milk solids (Ahlborn and Dempfle, 1992)

Trait	r_{milk}^{*}	
	Genetic	Phenotypic
Milkfat (kg)	0.68	0.82
Protein (kg)	0.82	0.91
Milkfat %	-0.43	-0.27
Protein %	-0.40	-0.31

* r = correlation coefficient

Effect on farmer income

The A+B-C system has no effect on the amount of money available for distribution by the companies. Rather it ensures the returns from sale of milk products are more accurately divided between suppliers according to the value of their individual contribution.

Bryant et.al (1988) have estimated the expected changes in income for suppliers of the New Zealand Co-operative Dairy Company (NZCDC) under their new Milk Price system. These are shown in Table 6.2.4.

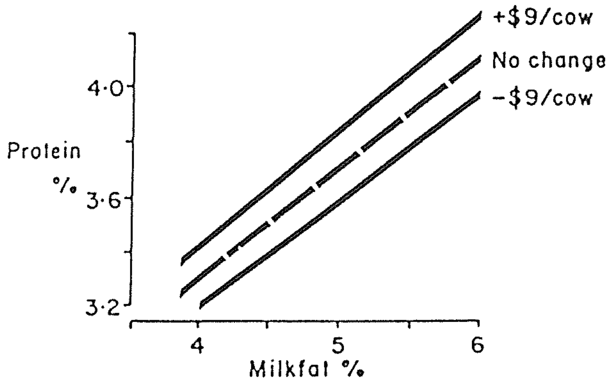
Table 6.2.4 Changes in farmer income under an A+B-C milk payment system

Change in Income (%)	% of Suppliers
-2 or greater	8.7
-1	22.9
0	34.2
+1	23.3
+2	10.9

For most suppliers the effect is small with 80% experiencing less than 2% change in returns from milk. However at the extremes 9% of suppliers will suffer losses greater than 2% while 11% will benefit by greater than 2%. Assuming average herd production of 20,000 kg milkfat and a milkfat price of $5.50/kg, this 2% change represents a figure of ±$2200 per year.

In an attempt to identify the characteristics of farms where income was increased or decreased by \$8 to \$10 per cow under the new payment system, Bryant et.al (1988) found no factors of great influence other than the relationship between milkfat and protein percentages in milk. Those suppliers who had lower than average protein tests for a given fat content had the greatest decreases while those above the mid value for a given fat content made the gains (see Figure 6.2.2)

Figure 6.2.2 The relationship between protein % and milkfat % of suppliers whose income changed by ±\$8-\$10 per cow under the A+B-C milk payment system (Bryant et.al, 1988)



7. THE DAIRY FARM MODEL

With the increasing price of milk protein relative to milkfat in payments to dairy farmers, there is growing interest in methods of producing more protein per hectare. Currently in New Zealand, genetic selection in dairy traits, both productive and non-productive, is carried out via indexing the respective merit of an animal for each characteristic based on individual, ancestry and progeny records, and weighting these values by the relative economic value of the trait (Wickham, 1988). The resulting index of overall genetic worth means emphasis is placed on those components of production which are worth the most to the industry. Based on the ranking of merit, only superior animals are selected to be the parents of the next generation, resulting in an annual genetic gain estimated at 1.4 to 1.5 fat BI units per year in the national herd (Wickham, 1988).

Due to the nature of current industry breeding structure in New Zealand, the national rate of genetic gain is controlled by the progress achieved in the 'nucleus' of superior animals with little chance of increase beyond this limit (Garrick, 1991). However the opportunity exists to introduce genetic material from outside this national framework (Rendel et.al, 1990). The use of foreign dairy sires which are superior to sires bred locally may rapidly increase this rate of gain, causing large 'jumps' in average genetic merit between generations. Increasing the size of the available gene pool also allows greater selection intensities to be practised with further benefits for genetic improvement. Boosting protein production in this way would allow New Zealand dairy farmers to take advantage of the greater payout for protein within a shorter time span than is currently being achieved by the national improvement programme.

Although the possible advantages from using foreign sires sound simple in theory, the practice may not yield such straight forward results. The balance lies in the efficiency with which such 'improved' animals perform under New Zealand pasture grazing conditions. If such increases in production of milk solids, particularly protein, are possible through the use of certain sires, what are the associated physiological changes which allow their offspring to achieve this? Certainly a change in production would require a corresponding change in energy requirement which in itself has important consequences for feed requirements and stocking rates in grassland farming. Changes in liveweight or size of animals could also influence maintenance requirements which in turn would affect the proportion of energy above maintenance available for milk production. Thus any change in the amount of inputs (feed) required to produce a unit of output (milk solids) will affect the efficiency of the genetically improved animals. Indeed such changes may only be deemed an improvement if the value of milk solids produced per unit of grass DM increases over and above that which could have been achieved using current New Zealand sires.

Evaluating the effect of changes in animal efficiency on profit per hectare can be carried out using a computer model which simulates a dairy system. By including only those components of the system which will be affected by genetic changes, entering the genetic characteristics of a sire into the model should produce the profit per hectare expected from his offspring. Between sire comparisons will then allow individual animals to be ranked in terms of profitability under similar environments. The inclusion of current New Zealand sires along with foreign sires of interest, provides the opportunity to examine how exploiting foreign gene pools may increase national dairy farm profitability. The disadvantage of modelling in this context is that it ignores the possible occurence of genotype by environment interactions in which a sires converted foreign proof may not accurately represent the performance of his offspring under New Zealand farming conditions. To avoid this problem all of the sires selected for the current study have actual New Zealand proofs.

7.1 OBJECTIVE OF THE MODEL

To examine the genetic influence of individual dairy sires on both productive and economic aspects of New Zealand dairy farming. These include:

* Milk yield and composition
* Cow liveweight
* Stocking rate
* Marginal profit per cow
* Marginal profit per hectare

7.2 BASIS OF THE MODEL

The proposed model is based on a 365 day production cycle for a New Zealand dairy farming system and therefore all production variables in the model are yearly totals.

Under many New Zealand farming systems, high stocking rates can mask the genetic potential of cows due to feeding level being below that required for potential maximum production. This strong environmental influence does not allow ease of comparison between individual sires and several assumptions must be made in devising a model to reach the required objective.

The influence of stocking rate on feeding levels and yields per cow can be removed by assuming all animals are being fed to meet their genetic potential. Milk and solids yield per hectare will then be the result of the number of producing cows per hectare able to be <u>fed to requirement</u> rather than a set number of animals competing for a limited amount of feed. Hence stocking rate becomes the consequence rather than the cause of feeding levels. In assuming that all daughters produce to their potential, the effect of genetic differences between sires on profitability per hectare should be expressed accurately. However this will be subject to the reliability of each sires genetic evaluation.

Given this major assumption, the framework of the model is also based on assumed values for:

* Average genetic merit of the base herd
* Average milk and solids yield per cow in the base herd
* Average liveweight per cow in the base herd
* Annual animal losses
* Annual replacement rate of cows in the base herd
* Energy requirements for maintenance, pregnancy, lactation and growth of cows and replacements
* Average pasture Dry Matter grown per hectare
* Average metabolizable energy content of pasture Dry Matter

The values above are fixed within the model and cannot be altered. The only variables which are required to be 'fed' into the model by the user are:

* The genetic characteristics of the proposed sire
* The economic value of outputs
* The economic cost of inputs

Using these fixed and input values, the following parameters are calculated by the model for each sire evaluated.

* Average liveweight and yields of milk and solids per cow in the herd
* The metabolizable energy and Dry Matter requirement per cow and per replacement
* The number of cows and replacements ie. the achievable stocking rate per hectare
* The marginal profit per cow and per hectare.

When the corresponding performance of the base herd for each of these parameters is subtracted, these figures represent the average changes expected after the first generation of a sires daughters has entered the milking herd and completed their first lactation. The change in milk yield and liveweight per cow in the herd as a result of using a particular sire will determine the marginal changes to profitability per cow. The associated changes in feed energy required to produce these changes, both per cow and per hectare, will determine the achievable stocking rate and hence marginal changes to profitability per hectare. Ranking potential sires according to their marginal profitability per hectare should therefore provide an estimate of their relative economic efficiency under New Zealand farming conditions.

7.3 DERIVATION OF THE MODEL

The main objective of the model is to examine profitability per hectare. Similar to previous studies (Dempfle, 1986), profit in this context can be simply evaluated as;

\$ Profit = \$ Output - \$ Input

\$ Profit / Hectare = \$ Profit / Cow x Stocking Rate

Saleable outputs will be milk solids, cull cows and calves, while inputs required to generate this production will be capital invested in land and plant, variable costs per cow and labour. However since profit per hectare is a direct result of profit per cow and stocking rate, only those costs which vary with cow numbers need be included for means of sire comparison.

7.3.1 OUTPUTS

Milk:

The economic value of milk is calculated using the **a+b-c** system currently being adopted in the New Zealand dairy industry.

$$\$ / Cow = (a \times kg\ milkfat) + (b \times kg\ protein) - (c \times litres\ milk)$$

where $a=$ \$/kg milkfat

$b=$ \$/kg protein

$c=$ \$/litre milk (volume charge)

* Note that for the purposes of this study it is assumed that 1 litre milk = 1 kg milk

Milk component prices used in the study are shown in Table 7.3.1.

Table 7.3.1 1991/92 Milk Component Prices received by the suppliers of Tui Milk Products

MILK COMPONENT	PRICE (\$/kg)
Fat	2.99
Protein	4.99
Volume	-0.04

<u>Cull Cows:</u>

The number of cows culled on a dairy farm each year is a function of the replacement policy and the animal losses incurred during the season. The carcass weights of these culled animals and the proportions within each payment classification will determine the final returns from the abattoir.

$$\$ / \textit{Cow in the herd} = (d - e) \times \$ / \textit{Carcass}$$

where $d =$ proportion of herd replaced per year
$e =$ proportion of cow losses per year

The price schedule used in the calculations involved the weight classifications and values shown in Table 7.3.2

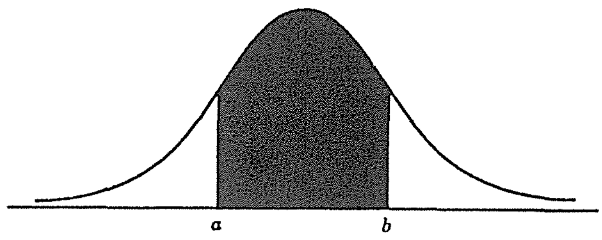
Table 7.3.2

PRICE SCHEDULE - CULL COWS*	
CARCASS WGT (kg)	**SCHEDULE ($/kg)**
< 154	1.81
154 to 175	2.02
175 to 196	2.06
196 to 218	2.08
218 to 240	2.08
240+	2.15

*** Average of AFFCO, Richmonds, Riverlands, Lowe Walker schedules**

Assuming an average herd liveweight and a population variance of 40kg (Ahlborn and Dempfle, 1992), the numbers of animals expected to fall into each carcass weight category can be calculated by use of standard normal distribution tables.

Figure 7.3.1 The Normal Distribution curve



The probability that a random variable, x, assumes values in an interval, say $a < x < b$, (see Figure 7.3.1) can be obtained by finding the area under the standardized normal curve between these points. The standard normal distribution table (see Figure 7.3.2) gives areas under the normal curve between the mean, μ, and a point any number of z standard deviations ($z\sigma$) from the mean. The total area under the curve is equal to 1 ie. 100% probability.

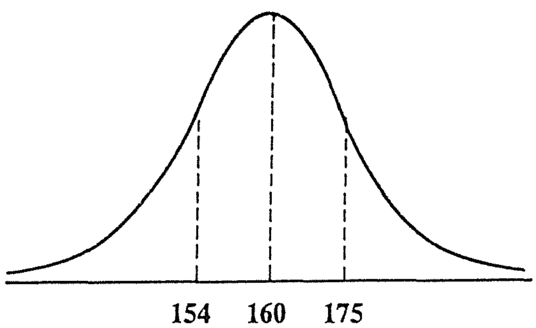
Figure 7.3.2 Example of a Standard Normal Distribution Table

z	0	1	2	3	4	5	6	7	8	9
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0754
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879

A simplified example involving only three carcass weight classifications is shown below:

Assuming average herd liveweight = 320kg (ie. 160kg carcass weight) and using weight classifications of <154 kg, 154 to 175 kg and 175+ kg (see Figure 7.3.3).

Figure 7.3.3 Normal Distribution curve with μ = 160 kg and σ = 40 kg



(*I*) z *value for* 154 *kg for* $N(160, 40) = \dfrac{154 - 160}{40} = -0.15$

From tables, $Pr(-0.15 < z < 0) = 0.0596$ *ie.* 5.96 %

(*II*) z *value for* 175 *kg for* $N(160, 40) = \dfrac{175 - 160}{40} = 0.38$

From tables, $Pr(0.38 > z > 0) = 0.1480$ *ie.* 14.8 %

(*III*) $Pr(z < -0.15)$ *ie. Proportion of herd with carcass weight* < 154 *kg* $= 0.5 - 0.0596$

$= 0.4404$

(*IV*) $Pr(-0.15 < z < 0.38)$ *ie. Proportion of herd with carcass weight* 154 *to* 175 *kg* $= 0.0596 + 0$[illegible]

$= 0.2076$

(*V*) $Pr(z > 0.38)$ *ie. Proportion of herd with carcass weight* > 175 *kg* $= 0.5 - 0.1480$

$= 0.3520$

Therefore:

Average liveweight of cows with carcass weight < 154 *kg* $= 160 + z \textit{ value } (0.4404 \times 0.5 + 0.0596) \times$

$= 160 + (-0.77) \times 40$

$= 129$ *kg*

Average liveweight of cows with carcass weight 154 *to* 175 *kg* $= 160 + z \textit{ value } (0.2076 \times 0.5) \times 40$

$= 160 + (0.26) \times 40$

$= 170$ *kg*

Average liveweight of cows with carcass weight > 175 *kg* $= 160 + z \textit{ value } (0.3520 \times 0.5 + 0.1480) \times$

$= 160 + (0.93) \times 40$

$= 197$ *kg*

Using the figures calculated in this example, the overall average dollar return per carcass expected for this particular herd can be calculated as shown in Table 7.3.3.

Table 7.3.3 Calculation of dollar return per carcass for herd with average liveweight = 320 kg

Weight Range	Average Carcass Weight (kg)	$/kg	Average $/Carcass	Percentage of the herd	
< 154 kg	129	1.81	233	44	103
154 to 175 kg	170	2.02	343	21	72
175+ kg	197	2.06	406	35	142
Av. $ / Carcass =					317

<u>Calves</u>:

The number of calves sold annually will depend on the proportion reared as replacements and the losses suffered through calving, empty cows and postpartum deaths. Birthweight and rate of gain, if any, after parturition will determine prices received per head.

$$\$ / Cow\ in\ the\ herd = (1 - y - i - j) \times \$ / carcass$$

where i= proportion of calf losses during birth

j= proportion of calf losses between birth and sale

y= proportion of replacements kept

The price schedule used in the calculations involved the weight classifications and values shown in Table 7.3.4.

Table 7.3.4

PRICE SCHEDULE - CALVES*	
CARCASS WGT (kg)	SCHEDULE ($/kg)
13 to 18	2.88
18+	3.77

* Otorohanga Bobby Calf pool

Returns per carcass can be calculated in a similar manner to those for cull cows by assuming an average calf weight, a population variance (in this case 5kg), and using standard normal distribution tables.

7.3.2 INPUTS

Animal costs included in the present study were;

* Labour (*k*)
* Animal Health (*l*)
* Artificial Breeding (*m*)
* Herd Testing (*n*)
* Shed costs (*o*)
* Electricity (*p*)
* Supplements (*q*)

Thus total inputs per cow can be expressed as;

$$\$\,Inputs\,/\,Cow = [\,k + l + m + n + o + p + q\,]$$

Input costs included in the model are only those which relate directly to cow numbers. In this way the influence of genetic improvement on profitability per hectare is expressed as a marginal change rather than an absolute figure. The cost values assumed are shown in Table 7.3.5.

Table 7.3.5

INPUT COSTS PER COW	
INPUT	**COSTS / COW ($)**
Labour	**59**
Animal Health	**28**
Artificial Breeding	**12**
Herd Testing	**10**
Shed Costs	**14**
Electricity	**19**
Supplements	**31**

*** Dairy Exporter - March 1991**

7.3.3 PROFIT PER COW AND PER HECTARE

The final equation for profit per cow can be written as;

$$\$PROFIT / COW = [(\ \$Milk + \$Cows + \$Calves\ ) - (\ \$Labour + \$Animal\ Health + \$AB + \$HT + \$Shed + \$Electricity + \$Supplements\ )]$$

The final equation for profit per hectare can be written as;

$$\$\ PROFIT / HA = Profit / Cow \times Stocking\ Rate$$

$$\$PROFIT / HA = [(\ a \times kgMF\ ) + (\ b \times kgProt\ ) + (\ c \times kgMilk\ ) + (\ d - e\ ) \times \$cow\ carcass + (\ 1 - y - i - j\ ) \times \$calf\ carcass - (\ k + l + m + n + o + p + q\ )] \times SR$$

7.3.4 ANIMAL PRODUCTION

To evaluate the influence of individual sires on production and profit, a base herd with hypothetical productive and genetic characteristics must first be assumed. These are shown as follows:

Average Fat / Cow	= 153kg	Average Fat BI	= 132
Average Protein / Cow	= 110kg	Average Protein BI	= 121
Average Milk / Cow	= 2700kg	Average Milk BI	= 119

These values are based on New Zealand Jersey cow averages (Dairy Statistics, 1992; Rendel, pers.comm,1992). With knowledge of both sire and dam genetic merit, the average genetic merit of replacement daughters can be estimated as;

$$Av.\ BI\ of\ daughter = \frac{1}{2}\ BI_{sire} + \frac{1}{2}\ BI_{dam}$$

The expected average lifetime production of these daughters can be estimated as the ratio of daughter BI over average herd BI multiplied by average base herd production.

$$Av.\ daughter\ production = \frac{daughter\ BI}{herd\ BI} \times Av.\ herd\ production$$

However a consequence of using immature animals as replacements is that mature production is not reached for several seasons after entering the herd. The relative yields of fat and protein averaged by different age groups in New Zealand Jersey herds is shown in Table 7.3.6.

Table 7.3.6 Production Averages by Age (Jersey)

Age Group	Percent of Herd in each age group	Fat (kg/cow)	%*	Protein (kg/cow)	%*
2	15.3	128	79	88	75
3	14.3	148	91	105	89
4	13.4	161	99	115	97
5	13.4	162	100	116	100
6	12.1	163	100	118	100
7	10.6	163	100	119	100
8	8.1	161	100	118	100
9	5.2	156	96	115	98
10+	7.5	146	90	109	93

*** (Yield at given age/Av. Yield of 5 to 7 yr) x 100**
(From Dairy Statistics-LIC, 1990/91)

Assuming a herd age structure and adjusting the expected yield of each class by these values allows phenotypic estimates of average herd production to be calculated (see Table 7.3.7).

Table 7.3.7 Calculating Average Herd Production

Age Group	Proportion of herd in each age group	Potential Yield (kg protein/cow)	Age Effect	Actual Yield (kg protein/cow)
2	0.25	127	0.75	95
3	0.22	124	0.89	110
4	0.18	121	0.97	117
5	0.12	118	100	118
6	0.09	115	100	115
7	0.07	111	100	111
8	0.04	107	100	107
9	0.03	103	98	101
10+	0.02	96	93	89

Av. Herd Protein per Cow (kg) = $\sum$(Proportion of Herd x Potential Yield x Age Effect) = 110 kg

In Table 7.3.7, potential yield represents the average genotype (genetic value) of each age group while actual yield represents the average phenotype (genetic value plus environmental effects). It can be noted that for age groups where there are no age effects, genotype equals phenotype; a highly unlikely situation. However under the assumptions of the model (see section 7.2), major environmental effects, such as feeding level, have been removed to allow genetic differences between sires to be expressed accurately.

7.3.5 CALCULATION OF STOCKING RATE

Profit per cow can only be converted to profit per hectare if stocking rate is known. Rather than assign an economic cost to the growth and utilization of pasture feed, its marginal input value can be expressed as the number of cows able to be fed to requirement per unit of land. Assumptions made in the calculation of stocking rate are:

* an annual pasture production of 14,000 kgDM per ha with 90% utilization
* an average energy content of 11 megajoules of metabolizable energy per kgDM (MJ ME/kgDM)
* all replacements are grazed on the farm and enter the herd as two year olds.

Energy Requirements for Cows:

Maintenance:

$$MJ\ ME_{maint} / cow = (LWT^{0.75} \times MJ\ ME_{(during\ lactation)} / kg\ LWT^{0.75} / day) \times 270\ days + (LWT^{0.75} \times MJ\ ME_{(during\ dry\ period)} / kg\ LWT^{0.75} / day) \times 95\ days$$

where MJ ME_{maint} = Megajoules of Metabolizable Energy required for maintenance
= 0.65 for lactating cows and 0.55 for dry cows (Holmes and Wilson et.al, 1984)
LWT = Liveweight (kg)

Lactation:

Derived from an equation by Tyrell and Reid (1965)

$$MJ\ ME_{lact} = \frac{[(38.3 \times kg\ Fat) + (22.2 \times kg\ Protein) + (0.89 \times litres\ Milk)]}{k_{lact}}$$

where k_{lact} = Efficiency of ME use for lactation
= 0.65 (Holmes and Wilson et.al, 1984)

Pregnancy:

An expression for the exponential requirements of cows nurturing a growing foetus was sourced from ARC(1980).

$$MJ\ ME_{preg} = [\ 10^{(151.665\ -\ 151.64\ \times\ e^{(-0.0000576\ t)})}\ ] \times [\ 0.0201 \times e^{(-0.0000576\ t)}\ ]$$

This gives the daily MJ ME requirement of the dam at day t of gestation, carrying a calf of 40kg final birthweight. Integrating this function over 282 days rendered the more workable form of;

$$MJ\ ME_{preg} = \frac{292.68 \times BWT\ /\ 40}{k_{preg}}$$

where k_{preg} = Efficiency of ME use for pregnancy
= 0.133 (ARC, 1980)
BWT = Birthweight (kg)

This modified equation expresses requirements for calves of any birthweight by calculating them as a ratio of those for a 40kg calf.

Weight Gain and Tissue Mobilisation:

It was assumed that any increases in animal weight between lactations was simply the result of cows regaining condition ie. replacing body reserves used to support the energy requirements of the previous lactation. Hence the loss and gain of body tissue was regarded as a more or less antagonistic process in lactating cows with the additional dietary energy required for body gain being 'saved' later on by the mobilization of this stored energy ie.

$$Additional\ energy\ required\ for\ Weight\ Gain = MJ\ ME_{gain} - MJ\ ME_{mobil} = 0$$

where: MJ ME_{gain} = Megajoules of Metabolizable energy required for liveweight gain
MJ ME_{mobil} = Megajoules of Metabolizable energy mobilized from body reserves

<u>**Energy Requirements for Replacement Animals**</u>

Calves require an average of 0.11 kg of milk/kg of birthweight/day to gain 0.5 kg/day up until weaning at 9 weeks (60 days) (Holmes and Wilson <u>et.al</u>, 1984). Therefore:

$$Kg\ Milk\ /\ Repl.\ Calf\ to\ weaning = BWT \times 0.1095 \times 60 \times proportion\ of\ repl.\ /\ cow$$

Milk used to feed calves must be deducted from total yields per cow before financial returns from milk sales are calculated. In this way:

$$Actual\ Milk\ sold\ /\ Cow\ (kg) = Total\ Milk - (\ Milk\ /\ Calf \times proportion\ of\ Repl.\ Calves\ )$$

$$Actual\ Fat\ sold\ /\ Cow\ (kg) = Total\ Fat - (\ Milk\ /\ Calf \times Fat\ content \times proportion\ of\ Repl.\ Calves\ )$$

$$Actual\ Prot\ sold\ /\ Cow\ (kg) = Total\ Prot - (\ Milk\ /\ Calf \times Prot\ content \times proportion\ of\ Repl.\ Calves\ )$$

For maintenance and liveweight gains in growing heifers:

$$MJ\ ME_{maint} = \int_0^{730} [\ LWT \times (\ BWT/LWT + (\frac{BWT/LWT}{730}) \times t\ ]\,dt \times MJ\ ME_{maint}/day$$

where LWT = Mature Liveweight (kg)
BWT = Birthweight (kg)

This expression was proposed by Dempfle (1986) to calculate daily maintenance requirements at day t of age. Integration over the period 0 to 365 days and 365 to 730 days ie. from birth to one year and one year to parturition, will give the total compounded maintenance requirements as a result of increasing animal size. This assumes that replacements entering the milking herd have reached their mature liveweight. However account must be taken of calf weight gains prior to weaning and the equation has been modified to calculate requirements from weaning onwards.

Integration leads to the following expressions for the maintenance energy requirements of Rising one and two year old heifers.

$$R2yr\ MJ\ ME_{maint}\ /\ year = [\,(\,LWT \times 298\,) + (\,BWT + 30\,) \times 67\,]^{0.75} \times MJ\ ME_{maint} / kg^{0.75} / day$$

$$R1yr\ MJ\ ME_{maint}\ /\ year = [\,(\,LWT \times 97\,) + (\,BWT + 30\,) \times 208\,]^{0.75} \times MJ\ ME_{maint} / kg^{0.75} / day$$

where R2yr MJ ME_{maint} = Maintenance energy requirements per year for Rising two year old heifers

R1yr MJ ME_{maint} = Maintenance energy requirements per year for Rising one year old heifers

MJ ME/$kg^{0.75}$/day for R2yr = 0.45 (ARC, 1980)

MJ ME/$kg^{0.75}$/day for R1yr = 0.35 (ARC, 1980)

The part of the equation in square brackets calculates the compounded increase in liveweight over the respective period to account for the increased maintenance requirement of additional body tissue.

Similar expressions to calculate the total feed energy required for liveweight gain from birth to first parturition are:

$$R2yr\ MJ\ ME_{gain}\ /\ year = [\ LWT \times (\frac{(\,1 - (\,BWT + 30\,))\ /\ LWT}{670}) \times 365\ ] \times MJ\ ME_{gain}\ /\ kg\ gain$$

$$R1yr\ MJ\ ME_{gain}\ /\ year = [\ LWT \times (\frac{(\,1 - (\,BWT + 30\,))\ /\ LWT}{670}) \times 305\ ] \times MJ\ ME_{gain}\ /\ kg\ gain$$

where MJ ME / kg gain = 27 (Holmes and Wilson et.al, 1984)

In this case, the part of the equation in square brackets calculates the total gain required, based on average birthweight, to achieve mature liveweight at first parturition. This assumes replacement animals calve at 730 days of age ie. exactly two years after they are born. Energy requirements for pregnancy in Rising two year old heifers are calculated using the same expression as for mature cows.

Total Energy Requirement per Cow

Expressing replacements as a proportion of mature cow requirements allows the total energy required per cow per year to be calculated. These 'cow equivalent' values avoid the complications of using animals of differing maturity in estimating the achievable stocking rate.

In each year the relative number of animals on the farm will be:

* N milking cows

* x pregnant two year heifers

* y one year heifers

Obviously more replacement animals must be retained than are actually required to allow for stock losses over the two years between birth and first parturition. Therefore:

$$x = \frac{Replacement\ Rate}{(\ 1\ -\ \%R1yr\ losses\ )}$$

where Replacement Rate = 25%

$$y = \frac{x}{(\ 1\ -\ (\ \%R1yr\ losses\ +\ \%Calf\ losses\ +\ \%R2yr\ not\ preg\ ))}$$

* All losses assumed to be 5%

Total energy per cow equivalent (TER) will be a function of requirements for each class of animal weighted by their respective proportion of total animals on the farm.

$$\begin{aligned} TER\ (\ MJ\ ME\ /\ cow\ /\ year\ ) = {} & 1 \times [\ Maintenance + Lactation + Pregnancy + (\ Gain - Mobilization\ )] + \\ & x \times [\ Maintenance + Growth + Pregnancy] + \\ & y \times [\ Maintenance + Growth\ ] \end{aligned}$$

This energy requirement can be converted to the Total Pasture Dry Matter (TDM) requirement per cow per year by dividing by the average expected energy content of pasture over a season. This was assumed to be 11 MJ ME per kilogram of DM.

$$TDM\ (\ kgDM\ /\ cow\ /\ year\ ) = \frac{TER\ (\ MJ\ ME\ /\ cow\ /\ year\ )}{MJ\ ME\ /\ kgDM}$$

Stocking Rate

The number of animals and hence achievable stocking rate (SR) can then be calculated by assuming an annual DM production per hectare and the degree of feed utilization

$$No.\ of\ Cows = \left[\frac{kgDM\ /\ ha\ /\ year\ \times\ \%\ Utilization}{TDM} \right] \times \frac{1}{1 + x + y}$$

$$No.\ of\ R2yr = \left[\frac{kgDM\ /\ ha\ /\ year\ \times\ \%\ Utilization}{TDM} \right] \times \frac{x}{1 + x + y}$$

$$No.\ of\ R1yr = \left[\frac{kgDM\ /\ ha\ /\ year\ \times\ \%\ Utilization}{TDM} \right] \times \frac{y}{1 + x + y}$$

7.4 TESTING THE MODEL

Comparing practical findings and predicted results is probably the best method of determining the accuracy of a model. For this exercise the production and economic data from a Jersey/Frieisan comparison trial (Ahlborn and Bryant, 1992) were used.

Profit per hectare could not be strictly compared due to the differing definitions of stocking rate between studies. However by assuming the same prices, yields, liveweights, birthweights and replacement rates in the model it was possible to compare profit per cow. Table 7.4.1 shows the actual and predicted values of profit per cow.

Table 7.4.1 Comparison of actual profit (Ahlborn and Bryant, 1992) and predicted profit per Jersey cow

Actual parameter values assumed in the model prediction

Fat/cow (kg) †	**201**	**Liveweight/cow (kg)**	**341**
Protein/cow (kg) †	**139**	**Birthweight/cow (kg)**	**27**
Milk/cow (kg) †	**3306**	**Costs per cow ($)**	**169**

Actual and predicted parameter values	**Actual**	**Predicted**
Net Energy in Milk (MJ)	**13580**	**13727**
$Income from Culls/cow[†]	**65**	**68**
$Income from Calves/cow[†]	**31**	**30**
$Income from Milk/cow[*]	**876**	**876**
$Profit/cow	**803**	**805**

*** $/kgMF=2.21, $/kgProt=4.00, $/kgMilk=-0.0375**

† Culling=20%, Killing out=50%, Calves sold=77%

As shown the model predicts final profit per cow very accurately, hence supporting its use in the current study. The small discrepancies which do occur are principally due to the different methods used for calculating the returns from cull cows and calves. Whereas Ahlborn and Bryant (1992) used a flat rate per kg of carcass weight of $1.95/kg for Jerseys, a range of carcass classifications were used in the current study to calculate an average price per carcass. For classes between 154 and 196 kg carcass weight the average price was $1.96. Carcass classifications were also used in the model for calves, with calves less than 18kg receiving $2.88/kg and calves 18kg+ receiving $3.77/kg. Ahlborn and Bryant (1992) used values of $3/kg for calves.

8. METHODOLOGY

The dairy farm model will be used to meet the objectives outlined in section 7.1, with the results being extended and discussed to include an industry-wide perspective. Although the mathematical framework of the model is based on proven management, nutritional and genetic principles, the end result will be an analysis of the marginal consequences of marginal changes in animal genetic merit and is not an economic evaluation of the total farming system. Rather it describes the effect of a specific change to the system and as such includes only those costs and benefits associated with the change. The practical uses of the model are limited to predicting the productive and economic influence of dairy sires with proven genetic characteristics on the 'average' New Zealand dairy herd. The theoretical extension of this practical approach is to use a range of sire characteristics, not necessarily representing actual bulls, to establish the relationships between genetic merit and associated parts of the farming system. In the current study the model was used for:

(i) Predicting the effect of selected sires on farm production and profit

A selected group of high protein BI Jersey sires ('the selected sires') were evaluated using the model described in section 7.3. The sires used in the study were put forward by the New Zealand Jersey Cattle Breeders Association (NZJCBA) and are listed in Table 8.1. Knowledge of their proofs for yield traits as well as daughter liveweight information made it possible to estimate their respective effects on milk composition and liveweight of average herd cows, stocking rate, marginal profit per cow and marginal profit per hectare. The list of bulls includes 10 New Zealand (NZL) Jersey sires, all with widespread proof evaluations and 4 United States (US) Jersey sires with either a widespread or a limited (less than 20 two year old daughters, Payment BI reliability less than 50%, daughters spread over less than 6 herds) New Zealand evaluation (Sire Survey Register, 1991/92). Two sources of average daughter liveweight for the selected sires were made available. These were:

* Records from the Traits Other Than Production (TOP) scheme (Reynolds, pers.comm, 1992)
* Actual weighing of sire progeny across several herds (NZJCBA, 1993)

Whereas TOP records are based on subjective scoring of sire progeny, the weighing exercise provided objective measurements. Both sets of data were adjusted for numbers of records and herds and set to a base herd mean of 320 kg. Numbers of animals involved in the weighing exercise ranged from 31 daughters over 7 herds to 1 daughter in 1 herd, therefore these estimates differ widely in accuracy. In addition not all of the sires with TOP records had daughters included in the weighing exercise and therefore objective estimates are not available for these bulls (see Table 10.2.1). The numbers of daughters used in the TOP estimates range from 14 up to 2128, giving them a far higher degree of reliability. The US sires had the smallest of records per bull, with OPPORTUNITY (27 daughters) and SILVER SAINT (14 daughters) in particular not yet qualifying for a widespread evaluation. To avoid confusion and possible inaccuracies, the more reliable TOP liveweight figures were used in calculating stocking rate, profit per cow and profit per hectare estimates for each bull.

Table 8.1 Selected high protein BI Jersey sires used in the study

Name	Country	Fat BI	Protein BI	Milk BI
JS Quicksilver Royal	USA	155	148	154
A-9 Top Brass	USA	157	147	160
Fairweather Opportunity*	USA	162	146	168
Kaimua Goliath	NZL	154	140	136
GR Burghams Penny	NZL	158	138	139
Merivale Senator	NZL	146	136	137
Rocky Hill Silver Saint*	USA	146	134	146
RR Tregarden Ponsonby	NZL	150	131	132
Merivale Bromley	NZL	151	131	132
SJ3 Barthows Parsley	NZL	147	130	124
Lawnmuir Elton	NZL	151	130	128
Sproslea Dan Fernando ET	NZL	143	130	128
Kencrest Red Jasper	NZL	147	122	114
Owharoa Ferns Challenge	NZL	135	121	119

*** Limited evaluation only**

<u>(ii) Predicting the effect of a range of sire BI's and daughter liveweights on farm profit</u>

For proven Jersey sires which have not been included in the present study or even for potential sires of the future, a system has been devised whereby these animals can also be evaluated in terms of their potential profitability. This was achieved by predicting the marginal profitability per hectare using a range of possible sire BI's in the model. However for individual sires average daughter liveweight is often not accurately known. A lack of such information can be overcome by assuming a range of liveweight values, each of which will represent a measure of the possible contribution each sire makes to carcass returns and maintenance feed requirements. The resulting 'Look-up' Tables (see Appendix I) can be used to evaluate a potential sire when daughter information becomes available. Figures are presented as marginal profit per hectare (ie. the additional profit generated by use of a sire above the original base herd) so as to give a comparative measure of differences both between sires and of the potential benefits from using parent animals of high genetic merit.

Implications for the New Zealand Dairy Industry

Although large increases in yields of milk components can be expected in the coming years, future trends in the relative quantities of each component supplied to processing companies is uncertain. Undoubtedly this will be strongly influenced by future demand for milk products as well as changing methods of farming and feeding dairy cows. However it is also likely that the results of selection decisions made today will still be evident in 20 to 30 years time, indicating the lasting impact of genetic improvement on per cow production. In addition to genetic progress made by local breeders, the influence of foreign selection policies can be felt through the increasing numbers of proven dairy sires sourced from overseas. This section discusses the possible implications of greater use of North American genetics in the New Zealand dairy industry, with particular reference to future trends in milk composition. The issue of payment for milk components is also discussed in this context.

9. RESULTS

Model evaluations of the selected Jersey bulls are presented in this section along with summaries of the expected influence of each individual on the productive and economic characteristics of the base herd.

Table 9.1 lists the productive and economic attributes of both the base herd and individual sires. The expected nutritional requirements, milk and solids yields, liveweight and profit per cow in the herd generated by each sire as well as overall profit per hectare are detailed below the relevant animal. The same parameters calculated for the 'unimproved' base herd are included as a means of comparison. The results in this table reflect the average effect of each sire on a benchmark herd after his daughters have completed their first lactation.

Table 9.2 summarizes the influence of each selected sire on average yields of fat, protein and milk per cow in the 'improved' herd by expressing their performance as a deviation from the average yields per cow in the base herd. The accuracy of these predictions will be partially determined by the degree to which the proven BI of a sire reflects his true genetic ranking among his peers. Expected changes to milk composition as based on the calculated yield effects are included to provide an indication of the relative trends in total herd yields of milk solids relative to milk. The expected changes in yields of protein relative to fat produced in herd milk are also given. The slow rate of change in the compositional traits combined with the short time frame of the study mean that the calculated sire effects after one generation are so small as to be negligible. However the sign of the change (ie. '+' or '-') should demonstrate future trends in herd milk composition.

Table 9.3 summarizes cow liveweight and stocking rate effects, as well as the economic consequences of the changes made to herd performance by respective sires. Similar to Table 9.2, the effects of each bull are expressed as a deviation from base herd profitability. These figures are based on 1991/92 season prices for milk and meat and may not reflect actual results if there are future changes in the relative returns from these products.

Tables 9.4 to 9.6 detail the influence that changing prices for milk components could have on the marginal profitability calculated for each sire. The assumed price changes are in the order of $\pm$10% and $\pm$25% and therefore cover a wide range of possible scenarios. Also given are the relative rankings of the sires between 1 and 14 (ie. 14 sires) to show how changing economic emphasis on different milk components may alter the marginal profitability of each bull. Table 9.7 gives the expected changes to sire ranking and marginal profit per hectare for different prices per kg of carcass weight. This includes revenue earned for both cull cows and calves.

Table 9.8 is an example of the 'Lookup' tables described in section 8 to be used for predicting the profit per hectare generated by bulls not included in the current study. This particular table can be used for bulls with fat and milk BI's of 152 and 143 respectively. The remainder are displayed in Appendix I and cover a range of sire fat and milk BI's. The sire BI's for fat and milk used in Table 9.8 represent the average values for the 1991/92 Dairy Board Premier Jersey Sire Team. These tables are calculated using the same base herd characteristics as assumed in the evaluation of the selected bulls (see Table 9.1). The values in the table represent the additional profit per hectare generated above the base herd to which a sire is mated after his first generation daughters have completed their first lactation. For example, a sire with fat, protein and milk BI's of 152, 138, and 134 respectively and an average daughter liveweight of 320 kg would be expected to produce an extra $29 per hectare in the year his daughters are first milked in the herd. More detailed examples of the use of these tables are provided in section 10.5 and Appendix I.

Table 9.1 (Contd.)

VARIABLE	BASE HERD	R.R.T Ponsonby	Merivale Bromley	SJ3 Barthows Parsley	Lawnmuir Elton	S. Dan Fernando	Kencrest Red Jasper	O. Ferns Challenge
Breed	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY
Fat BI	132	150	151	147	151	143	147	135
Protein BI	121	131	131	130	130	130	122	121
Milk BI	119	126	132	124	128	128	114	119
Daughter LWT (kg)	320	315	319	320	330	319	326	311
METABOLIZABLE ENERGY REQUIRED (MJ/cow/year)								
Maintenance	16210	16162	16201	16210	16305	16201	16267	16124
Lactation	16440	16702	16730	16670	16713	16654	16609	16534
Pregnancy	1540	1516	1539	1540	1589	1536	1548	1497
R2yr Heifer	3631	3621	3629	3631	3652	3629	3644	3613
R1yr Heifer	2020	2014	2019	2020	2032	2019	2027	2009
Total MJ/cow/year	36694	36880	36972	36924	37119	36892	36933	36650
Total DM/cow/year	3336	3353	3361	3357	3374	3354	3358	3332
STOCKING RATE								
No. Cows	142	142	141	141	141	142	141	143
No. R2yr Heifers	37	37	37	37	37	37	37	38
No. R1yr Heifers	47	47	46	47	46	47	47	47
Cows/Hectare	2.372	2.360	2.355	2.358	2.345	2.360	2.357	2.375
PRODUCTION (kg/cow)								
Protein	110	111.3	111.3	111.2	111.2	111.2	110.4	110.3
Fat	153	155.7	155.8	155.3	155.8	154.8	155.3	153.8
Milk	2700	2723	2738	2718	2728	2728	2694	2706
Liveweight	320	318.8	319.8	320.0	322.5	319.8	321.5	317.8
Birthweight	28	27.6	28.0	28.0	28.9	27.9	28.1	27.2
PROFIT								
$Profit/Cow	785	800	800	799	802	797	797	790
$Profit/Hectare	1862	1888	1885	1884	1880	1882	1877	1876

Table 9.1 The effect of selected high protein BI Jersey sires on farm production and profitability after first generation daughters have completed one lactation in a base herd

VARIABLE	BASE HERD	JS Quicksilver Royal	A9 Top Brass	F. Opportunity	Kaimua Goliath	GR Burghams Penny	Merivale Senator	R.H Silver Saint
Breed	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY	JERSEY
Fat BI	132	155	157	162	154	158	146	146
Protein BI	121	148	147	146	140	138	136	134
Milk BI	119	154	160	168	136	139	137	146
Daughter LWT (kg)	320	328	315	314	321	322	328	319
METABOLIZABLE ENERGY REQUIRED (MJ/cow/year)								
Maintenance	16210	16286	16162	16153	16220	16229	16286	16201
Lactation	16440	16891	16923	16984	16796	16829	16727	16750
Pregnancy	1540	1579	1516	1512	1545	1550	1579	1536
R2yr Heifer	3631	3648	3621	3619	3633	3635	3648	3629
R1yr Heifer	2020	2030	2014	2013	2021	2022	2030	2019
Total MJ/cow/year	36694	37267	37100	37146	37065	37113	37102	36989
Total DM/cow/year	3336	3388	3373	3377	3370	3374	3373	3363
STOCKING RATE								
No. Cows	142	140	141	141	141	141	141	141
No. R2yr Heifers	37	37	37	37	37	37	37	37
No. R1yr Heifers	47	46	46	46	46	46	46	46
Cows/Hectare	2.372	2.336	2.346	2.344	2.349	2.346	2.346	2.354
PRODUCTION (kg/cow)								
Protein	110	113.0	112.9	112.8	112.2	112.0	111.8	111.6
Fat	153	156.3	156.6	157.2	156.2	156.7	155.2	155.2
Milk	2700	2792	2807	2827	2748	2755	2750	2773
Liveweight	320	322.0	318.8	318.5	320.3	320.5	322.0	319.8
Birthweight	28	28.7	27.6	27.5	28.1	28.2	28.7	27.9
PROFIT								
$Profit/Cow	785	809	808	808	806	806	802	799
$Profit/Hectare	1862	1891	1895	1894	1892	1891	1881	1880

Table 9.2 The effect of selected high protein Jersey sires on milk yield and composition per cow in the herd after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

Name	Country	Fat (kg/cow)	Protein (kg/cow)	Milk (kg/cow)	Protein%	Fat%	Protein:Fat
JS Quicksilver Royal	USA	+3.3	+3.0	+92	-0.03	-0.07	+0.004
A-9 Top Brass	USA	+3.6	+2.9	+107	-0.05	-0.09	+0.002
Fairweather Opportunity ET	USA	+4.2	+2.8	+127	-0.04	-0.11	-0.001
Kaimua Goliath	NZL	+3.2	+2.2	+48	+0.01	+0.02	-0.001
GR Burghams Penny	NZL	+3.7	+2.0	+55	-0.01	+0.02	-0.004
Merivale Senator	NZL	+2.2	+1.8	+50	-0.01	-0.02	+0.001
Rocky Hill Silver Saint	USA	+2.2	+1.6	+73	-0.05	-0.07	+0.0001
RR Tregarden Ponsonby	NZL	+2.7	+1.3	+23	+0.01	+0.05	-0.004
Merivale Bromley	NZL	+2.8	+1.3	+38	-0.01	+0.02	-0.005
SJ3 Barthows Parsley	NZL	+2.3	+1.2	+18	+0.02	+0.05	-0.003
Lawnmuir Elton	NZL	+2.8	+1.2	+28	+0.002	+0.04	-0.005
Sproslea Dan Fernando ET	NZL	+1.8	+1.2	+28	+0.002	+0.01	-0.001
Kencrest Red Jasper	NZL	+2.3	+0.4	-6	+0.02	+0.10	-0.008
Owharoa Ferns Challenge	NZL	+0.8	+0.3	+6	+0.002	+0.02	-0.002
Average :	USA	+3.3	+2.6	+100	-0.04	-0.09	+0.001
	NZL	+2.5	+1.29	+29	+0.004	+0.03	-0.003

* Ranked according to Protein BI

Table 9.3 The effect of selected high protein Jersey sires on stocking rate, liveweight per cow and marginal profit per cow and per hectare after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

Name	Country	Liveweight (kg/cow)	Feed Requirements (kgDM/Cow/Year)	Stocking Rate (Cows/Ha)	Marginal Profit ($/Cow)	Marginal Profit ($/Ha)
JS Quicksilver Royal	USA	+2.0	+52	-0.04	+24	+29
A-9 Top Brass	USA	-1.2	+37	-0.03	+23	+33
Fairweather Opportunity ET	USA	-1.5	+41	-0.03	+23	+32
Kaimua Goliath	NZL	+0.3	+34	-0.02	+21	+30
GR Burghams Penny	NZL	+0.5	+38	-0.03	+21	+29
Merivale Senator	NZL	+2.0	+37	-0.03	+17	+19
Rocky Hill Silver Saint	USA	-0.2	+27	-0.02	+14	+18
RR Tregarden Ponsonby	NZL	-1.2	+17	-0.01	+15	+26
Merivale Bromley	NZL	-0.2	+25	-0.02	+15	+23
SJ3 Barthows Parsley	NZL	0	+21	-0.01	+14	+22
Lawnmuir Elton	NZL	+2.5	+38	-0.03	+17	+18
Sproslea Dan Fernando ET	NZL	-0.2	+18	-0.01	+12	+20
Kencrest Red Jasper	NZL	+1.5	+22	-0.02	+12	+15
Owharoa Ferns Challenge	NZL	-2.2	-4	-0.00	+5	+14
Average :	USA	-0.2	+39	-0.03	+21	+28
	NZL	+0.3	+25	-0.02	+15	+22

* Ranked according to Protein BI

Table 9.4 The effect of changing milkfat prices on marginal profit per hectare generated by selected high protein BI Jersey sires after first generation daughters have completed one lactation in a base herd

Name	Country	% Change in Fat Price ($/kg)				
		+25%	+10%	+0%	-10%	-25%
JS Quicksilver Royal	USA	+31	+29	+29	+28	+27
Rank		5	5	5	4	4
A-9 Top Brass	USA	+37	+34	+33	+31	+29
Rank		1	1	1	1	1
Fairweather Opportunity ET	USA	+37	+34	+32	+31	+27
Rank		1	1	2	2	2
Kaimua Goliath	NZL	+34	+32	+30	+29	+27
Rank		3	3	3	3	2
GR Burghams Penny	NZL	+33	+30	+29	+27	+25
Rank		4	4	4	5	5
Merivale Senator	NZL	+20	+19	+19	+18	+17
Rank		11	10	10	10	10
Rocky Hill Silver Saint	USA	+21	+19	+18	+17	+16
Rank		10	10	11	11	12
RR Tregarden Ponsonby	NZL	+30	+28	+26	+25	+22
Rank		6	6	6	6	6
Merivale Bromley	NZL	+26	+24	+23	+21	+19
Rank		7	7	7	7	7
SJ3 Barthows Parsley	NZL	+25	+23	+22	+21	+19
Rank		8	8	8	8	7
Lawnmuir Elton	NZL	+20	+19	+18	+17	+17
Rank		11	10	11	11	10
Sproslea Dan Fernando ET	NZL	+22	+20	+20	+18	+13
Rank		9	9	9	9	12
Kencrest Red Jasper	NZL	+18	+16	+15	+14	+11
Rank		13	13	13	13	13
Owharoa Ferns Challenge	NZL	+16	+15	+14	+13	+5
Rank		14	14	14	14	14
Average :	USA	+32	+29	+28	+27	+25
	NZL	+24	+23	+22	+20	+18

Table 9.5 The effect of changing protein prices on marginal profit per hectare generated by selected high protein BI Jersey sires after first generation daughters have completed one lactation in a base herd

Name	Country	% Change in Protein Price ($/kg)				
		+25%	+10%	+0%	-10%	-25%
JS Quicksilver Royal	USA	+33	+30	+29	+27	+24
Rank		4	4	4	4	5
A-9 Top Brass	USA	+39	+35	+33	+30	+27
Rank		1	1	1	1	1
Fairweather Opportunity ET	USA	+38	+34	+32	+30	+26
Rank		2	2	2	1	2
Kaimua Goliath	NZL	+34	+32	+30	+29	+26
Rank		3	3	3	3	2
GR Burghams Penny	NZL	+32	+30	+29	+27	+26
Rank		5	4	4	4	2
Merivale Senator	NZL	+21	+20	+19	+18	+16
Rank		11	9	10	9	11
Rocky Hill Silver Saint	USA	+22	+20	+18	+17	+15
Rank		9	9	11	12	12
RR Tregarden Ponsonby	NZL	+29	+27	+26	+25	+23
Rank		6	6	6	6	6
Merivale Bromley	NZL	+25	+23	+23	+22	+20
Rank		7	7	7	7	7
SJ3 Barthows Parsley	NZL	+25	+23	+22	+21	+20
Rank		7	7	8	8	7
Lawnmuir Elton	NZL	+18	+18	+18	+18	+17
Rank		12	12	11	9	9
Sproslea Dan Fernando ET	NZL	+22	+20	+20	+18	+17
Rank		9	9	9	9	9
Kencrest Red Jasper	NZL	+15	+15	+15	+15	+15
Rank		14	13	13	13	12
Owharoa Ferns Challenge	NZL	+16	+15	+14	+13	+11
Rank		13	13	14	14	14
Average :	USA	+33	+30	+28	+26	+23
	NZL	+24	+22	+22	+21	+19

Table 9.6 The effect of changing milk volume charges on marginal profit per hectare generated by selected high protein BI Jersey sires after first generation daughters have completed one lactation in a base herd

Name	Country	% Change in Volume Charge ($/ltr)				
		+25%	+10%	+0%	-10%	-25%
JS Quicksilver Royal	USA	+27	+28	+29	+29	+30
Rank		5	4	4	4	4
A-9 Top Brass	USA	+31	+32	+33	+34	+35
Rank		1	1	1	1	1
Fairweather Opportunity ET	USA	+30	+31	+32	+33	+34
Rank		2	2	2	1	2
Kaimua Goliath	NZL	+30	+30	+30	+31	+31
Rank		2	3	3	3	3
GR Burghams Penny	NZL	+28	+28	+29	+29	+29
Rank		4	4	4	4	5
Merivale Senator	NZL	+18	+19	+19	+19	+19
Rank		10	9	10	9	11
Rocky Hill Silver Saint	USA	+17	+18	+18	+19	+20
Rank		12	11	11	9	9
RR Tregarden Ponsonby	NZL	+26	+26	+26	+26	+26
Rank		6	6	6	6	6
Merivale Bromley	NZL	+22	+22	+23	+23	+23
Rank		7	7	7	7	7
SJ3 Barthows Parsley	NZL	+22	+22	+22	+22	+22
Rank		7	7	8	8	8
Lawnmuir Elton	NZL	+18	+18	+18	+18	+18
Rank		10	11	11	12	12
Sproslea Dan Fernando ET	NZL	+19	+19	+20	+19	+20
Rank		9	9	9	9	9
Kencrest Red Jasper	NZL	+16	+16	+15	+15	+15
Rank		13	13	13	13	13
Owharoa Ferns Challenge	NZL	+14	+14	+14	+14	+14
Rank		14	14	14	14	14
Average :	USA	+26	+27	+28	+29	+30
	NZL	+21	+21	+22	+22	+22

Table 9.7 The effect of changing carcass prices on marginal profit per hectare generated by selected high protein BI Jersey sires after first generation daughters have completed one lactation in a base herd

Name	Country	% Change in Carcass Prices ($/kg)				
		+25%	+10%	+0%	-10%	-25%
JS Quicksilver Royal	USA	+29	+29	+29	+29	+28
Rank		4	4	4	4	5
A-9 Top Brass	USA	+32	+32	+33	+33	+34
Rank		1	1	1	1	1
Fairweather Opportunity ET	USA	+31	+31	+32	+33	+33
Rank		2	2	2	1	2
Kaimua Goliath	NZL	+30	+30	+30	+30	+31
Rank		2	3	3	3	3
GR Burghams Penny	NZL	+28	+28	+29	+29	+29
Rank		5	5	4	4	4
Merivale Senator	NZL	+19	+19	+19	+19	+18
Rank		9	9	10	10	11
Rocky Hill Silver Saint	USA	+18	+18	+18	+19	+19
Rank		11	11	11	10	10
RR Tregarden Ponsonby	NZL	+25	+26	+26	+26	+27
Rank		6	6	6	6	6
Merivale Bromley	NZL	+22	+22	+23	+23	+23
Rank		7	7	7	7	7
SJ3 Barthows Parsley	NZL	+22	+22	+22	+22	+22
Rank		7	7	8	8	8
Lawnmuir Elton	NZL	+18	+18	+18	+17	+17
Rank		11	11	11	12	12
Sproslea Dan Fernando ET	NZL	+19	+19	+20	+20	+20
Rank		9	9	9	9	9
Kencrest Red Jasper	NZL	+15	+15	+15	+15	+15
Rank		13	13	13	13	13
Owharoa Ferns Challenge	NZL	+13	+13	+14	+14	+15
Rank		14	14	14	14	13
Average :	USA	+28	+28	+28	+29	+29
	NZL	+21	+21	+22	+22	+22

Table 9.8 Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 152
Sire Milk BI = 134

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	47	41	36	31	26	21	16	12	7	3	-2
132	49	43	38	33	28	23	18	14	9	5	0
134	51	45	40	35	30	25	20	16	11	7	2
136	53	47	42	37	32	27	22	18	13	9	4
138	55	49	44	39	34	29	24	19	15	10	6
140	57	51	46	41	36	31	26	21	17	12	8
142	59	53	48	43	38	33	28	23	19	14	10
144	61	55	50	45	40	35	30	25	21	16	12

10. DISCUSSION

From the definition of profit per hectare (see section 7.3) increasing average herd protein production by the use of high protein BI sires can influence the marginal change in profit per hectare in two ways;

* The effect on stocking rate
* The effect on profit per cow

These in turn will be influenced by the changes in milk solids yield and liveweight per cow in the herd, and the associated changes in annual feed requirement per cow.

As seen by Tables 9.2 and 9.3, the differences between the performance of the 'improved herd' and the base herd have been used as an indicator of the productive and economic benefit of each sire. The use of these marginal figures in addition to the absolute values given in Table 9.1 provides a quick reference to the potential ranking of sires as well as detailing the actual extent of improvement over the 'unimproved' herd.

When interpreting the results in section 9, it must be remembered that the calculated changes in yields, liveweight, stocking rate, profit per cow and profit per hectare due to a sire are only for the case where his daughters are completing their first lactation ie. all replacements in a given year are his daughters. Presenting data for the case where his genes have been assimilated into the whole herd is unnecessary for two reasons;

* In practice, sires are not often used in a given herd for more than several consecutive years.
* Unless sire BI or average daughter liveweight changes drastically, continued use of a sire will not change his ranking in terms of profitability per hectare.

Thus although reported changes are often only small they will adequately represent the average effect of a sire on herd characteristics.

Projected trends in yields of milk and milk solids per cow have been calculated for different scenarios involving both genetic gains in the New Zealand dairy industry and the potential influence of foreign sires. The implications of these changes for milk payments received by farmers and the processing industry are discussed.

10.1 EFFECT OF SELECTED JERSEY SIRES ON MILK YIELD AND COMPOSITION

The primary motivation behind the use of high BI sires is to produce replacement animals which are genetically superior to the average cow in the herd. This gradual means of improvement will increase the average genetic merit of the herd and hence boost the average yield of milk and milk solids per cow in the future. The extent and direction of changes to milk composition will depend on;

* The BI of the sire for each trait
* The average BI of the herd for each trait

This stems directly from the equation given in section 7.3.4 where the parent animals are each expected to contribute half of the genetic makeup of their offspring. The average BI of the herd is used based on the assumption that the sire is mated to cows at random within the herd.

The average BI of cows used in the model were 132, 121 and 119 for fat, protein and milk respectively and are based on national averages for Jersey cattle over the last 15 years (Rendel, pers.comm, 1990). Average yields for each milk trait per cow were assumed to be 153kg, 110kg and 2700 ltr for fat, protein and milk respectively also based on national Jersey averages (Dairy Statistics, 1990/91).

The BI's for fat, protein and milk can be observed to vary widely between sires (Sire Survey Register, 1990/91) hence their respective influences on average herd milk composition can be expected to differ depending on their relative merit for each trait.

From Tables 9.1 and 9.2, which summarize the effect of the selected sires on yield and composition traits, several general trends can be established. Figures 10.1.1 and 10.1.2 plot the general relationship between sire protein BI and his corresponding influence on average yields of fat and milk per cow in the herd. The simple regression line shown in each graph displays the general trend while The R^2 value is a measure of the proportion of variation in the data explained by the regression.

Although these sires are relatively few in number and not representative of the population as a whole (ie. not selected at random) the clear positive relationships between sire protein merit and other dairy traits correspond well with the previously measured genetic and phenotypic correlations between these traits (Van Der Werf, et.al, 1989; Ahlborn and Dempfle, 1992).

The sires in Table 9.2 are ranked in descending order according to protein yield. Of note is the clustering of US sires in the top half of the table, suggesting their greater propensity to produce daughters of high protein

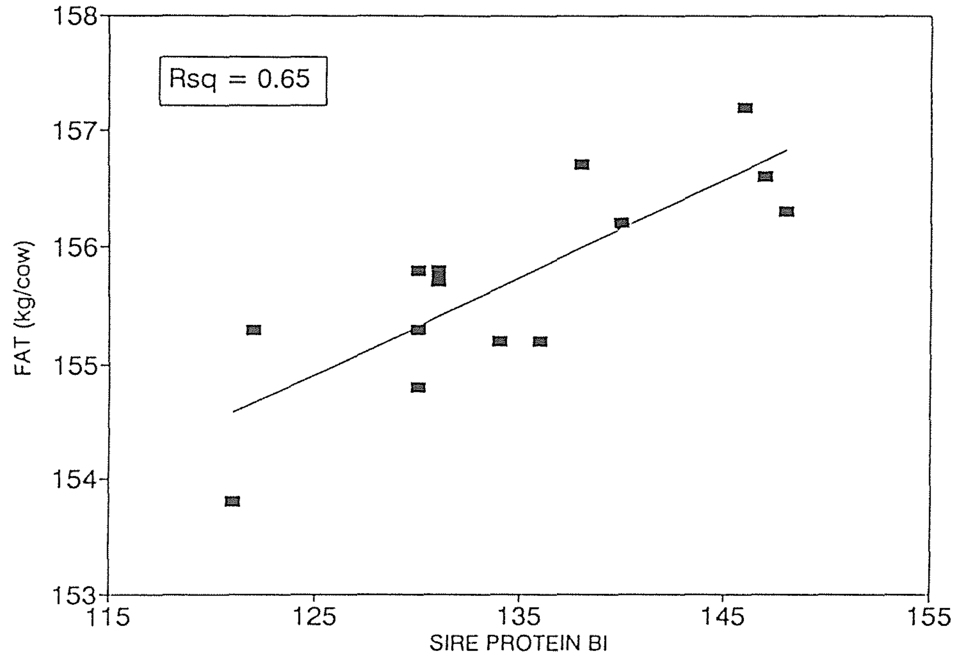


Figure 10.1.1 Relationship between selected sire protein BI and fat yield per cow in the herd after daughters have completed their first lactation

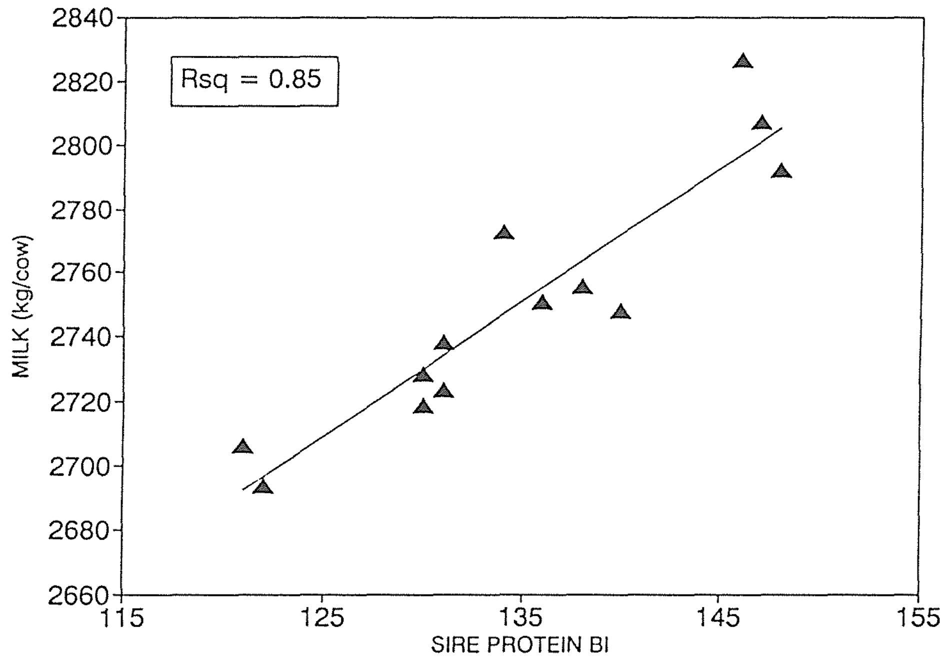


Figure 10.1.2 Relationship between selected sire protein BI and milk yield per cow in the herd after daughters have completed their first lactation

yielding potential. Although these bulls may not be representative of the population of US Jersey sires, their New Zealand proofs in comparison with New Zealand's top Jersey sires implies differing genetic levels for milk and solids production between the two countries. The average changes to yields per cow in the herd generated by the four US sires are +3.3kg (+2.4%), +2.6kg (+2.6%) and +100kg (+3.7%), while those for their New Zealand counterparts are +2.5kg (+1.8%), +1.3kg (+1.4%) and +29kg (+1.1%) for fat, protein and milk yields respectively.

Despite the advantage of the US sires in yields of milk solids per cow in the herd, the proportional increase in milk per cow far exceeds that of changes induced by New Zealand-bred sires. A significant effect of these changes is that whereas the New Zealand sires generally boost milk solids concentration, the US sires cause large decreases in milk percentages of fat and protein, hence an overall move towards less concentrated milk.

10.2 EFFECT OF SELECTED JERSEY SIRES ON COW LIVEWEIGHT

The effect of high protein sires on milk composition (see section 10.1) are important not only in terms of increased milk solids yield but also because of the observed correlations between dairy traits and body size in New Zealand dairy cattle (Ahlborn and Dempfle, 1992). Thus changes in milk composition may be associated with changes in animal liveweight, depending on the relationship between sire BI and the size of his daughters.

Increasing cow liveweight has a two-fold influence on farm productivity. It can:

* Increase carcass returns per cow in the herd
* Increase maintenance feed requirement per cow in the herd

(Wickham et.al, 1992)

While the first effect will determine changes to profit per cow, the latter will determine changes to profit per hectare through its influence on achievable stocking rate.

Similar to the case with milk composition, the change in average cow liveweight as a result of using a certain sire will depend on the size of his daughters relative to cows in the base herd and the proportion of animals replaced each year. The average liveweight of base cows was assumed to be 320kg.

The large discrepancies between the TOP and weighed average daughter liveweights (see Table 10.2.1) for many of these sires makes it difficult to obtain conclusive results. The TOP data is probably the more reliable, being based on a greater number of daughters spread over more herds. The nature of the relationship between sire protein BI and average daughter liveweight can be shown in Figure 10.2.1.

The apparent lack of correlation between these two traits could be due to two reasons;

* There is no genetic correlation between the traits
* The sample size is not large enough to show the true relationship

The implication of a zero correlation between sire protein BI and daughter liveweight is that daughter size differs at random between sires. Listing the sires in descending order of TOP liveweight as in Table 10.2.1 suggests that the average daughter liveweight of the US sires is no different from that of the New Zealand sires.

Although the number of sires used in these analyses are only small, based on available information the conclusion must be drawn that differences in sire protein BI are not associated with differences in daughter

Table 10.2.1 Estimated daughter liveweights of selected sires using TOP records and weighed records

Name	Country	Average Daughter Liveweight (kg)	
		TOP	Weighed
Lawnmuir Elton	NZL	330	314*
JS Quicksilver Royal	USA	328	323
Merivale Senator	NZL	328	347**
Kencrest Red Jasper	NZL	326	332
GR Burghams Penny	NZL	322	-
Kaimua Goliath	NZL	321	-
SJ3 Barthows Parsley	NZL	320	332
Rocky Hill Silver Saint	USA	319	316*
Merivale Bromley	NZL	319	317**
Sproslea Dan Fernando	NZL	319	328
A-9 Top Brass	USA	315	313
RR Tregarden Ponsonby	NZL	315	313
Fairweather Opportunity	USA	314	-
Owharoa Ferns Challenge	NZL	311	282**
Average :	USA	319	317
	NZL	321	321

* Records in two herds
** Records in one herd

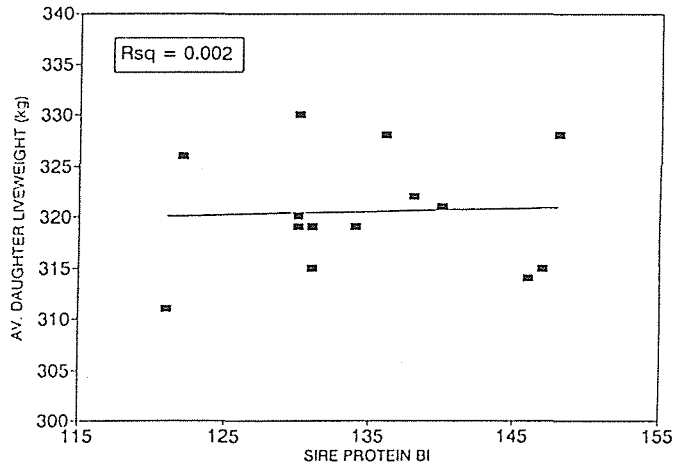


Figure 10.2.1 Relationship between selected sire protein BI and average daughter liveweight

liveweight to any great extent, at least within this particular group of bulls. The relationships between average daughter liveweights and sire BI's for fat and milk were investigated with no definite trends emerging between these variables. These results conflict with the positive correlations previously observed between liveweight and yield traits (Harville and Henderson, 1966; Hooven et.al, 1968; Ahlborn and Dempfle, 1992).

The magnitude of changes to average liveweight of cows in the herd from using the selected sires were only small, being in the order of -2.2 to +2.5 kg. Table 9.3 lists these effects for individual sires. On average, the New Zealand sires had a positive influence on average liveweight per cow in the herd while the US sires tended to decrease cow liveweight. This is perhaps contrary to the expected result as the larger reputed size of US cows does not appear to have been carried over in the New Zealand daughters of the US sires. The possibility does exist that these particular US sires were originally proven in New Zealand because of their smaller bodysize. However the suggestion is that it is largely differences in systems of management which influence the relative size of animals between countries rather than genetic differences. The strong environmental component of liveweight is supported by the findings of Peterson (1988).

10.3 EFFECT OF SELECTED JERSEY SIRES ON STOCKING RATE

Achievable stocking rate in the context of this study refers to the number of animals farmed per hectare while ensuring that all cows are fed to their requirement for a given level of production and all available pasture is eaten. This is an idealized situation but demonstrates the influence of increasing yield and size per cow, and the associated change in feed requirements, on total milk and meat production per unit of pasture eaten.

The relatively small changes in average milk composition and liveweight per cow in the herd as the result of one years mating to proven sires (see Tables 9.2 and 9.3) mean only marginal increases in annual feed requirement per cow. The magnitude of these changes for each sire (see sections 10.1 and 10.2) based on the assumed yields and liveweights of the base herd can be shown in Table 9.3. Figures include requirements for replacement animals per cow in the herd.

These changes do not differ greatly between sires, ranging between -4 and +52 kgDM per cow in the herd per year (ie. in the order of 1 or 2% of the average annual intake per cow). The influence of the US sires on greater yields of milk and milk solids per cow is reflected in the greater increase in per cow feed requirement relative to New Zealand sires. The 'cost' of this additional feed requirement is reflected in the lower achievable stocking rate at which these animals can yield this level of production ie. profit per hectare does not increase to the same extent as profit per cow. In this way, rather than assigning an economic value to each additional kg of feed DM eaten per cow, the marginal cost of the production lost through carrying less cows per hectare will be included in the calculation of marginal profit per hectare.

As average cow yield and possibly size increases with successive generations of 'improved' progeny entering the herd, the magnitude of stocking rate differences between sires relative to the base herd will increase. Thus although increasing the genetic merit of a herd is not usually substantial enough to warrant practical stocking rate changes between two successive years, continuous genetic improvement over a number of years will result in a cumulative increase in feed requirement per hectare. When considering the effects of individual bulls it will therefore be the relative differences between animals rather than the absolute size of differences which is of interest. Table 9.3 lists the changes in stocking rate as a result of using certain sires. The negative values illustrate the effect of daughter liveweight and greater milk yields on changing feed requirement per cow in the herd.

Using Quicksilver Royal, a quick example of the influence of genetic improvement on stocking rate and cow numbers can be given.

Assuming: Farm area = 60 hectares
Cows milked = 200
Stocking Rate = 3.33 cows/ha

From Table 9.3, Quicksilver Royal will decrease achievable stocking rate by 0.04 cows per hectare in the year his daughters are first milked in the herd.

$$\begin{aligned} \textit{Achievable Stocking Rate} &= 3.33 \textit{ cows / ha} - 0.04 \textit{ cows / ha} \\ &= 3.29 \textit{ cows / ha} \\ &= 197 \textit{ cows / 60 hectares} \end{aligned}$$

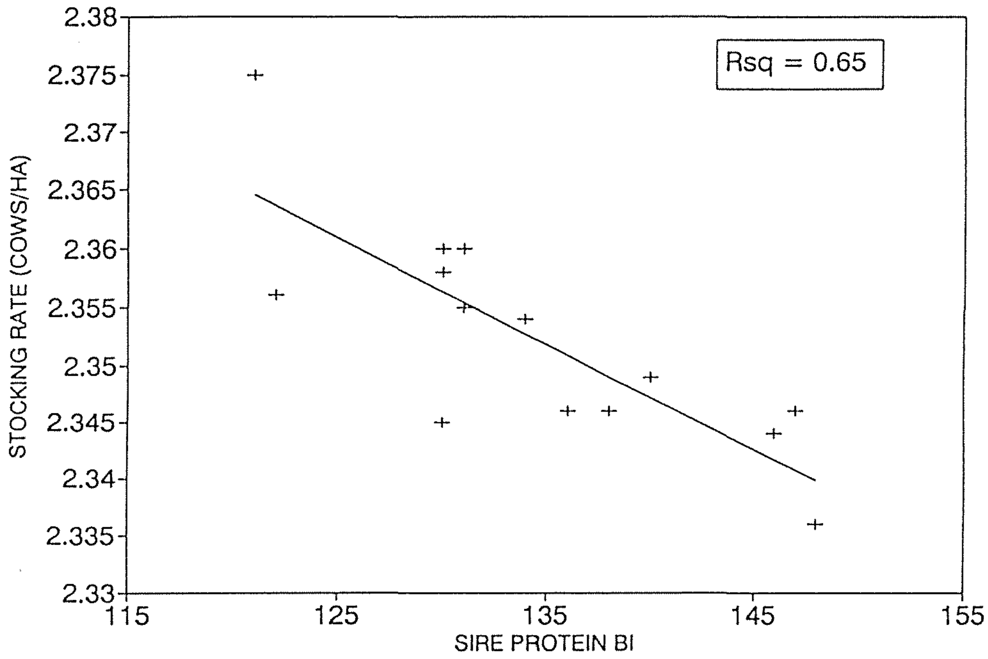
This result suggests that in order for remaining cows to be fed according to their average level of production, cow numbers must be dropped by approximately three at the end of the three years it will take from conception to first lactation of a sires daughters. In other words, the extra feed required to support the additional yields of high genetic merit replacements sired by this bull will be the equivalent of the annual requirement of three cows producing at the level of the unimproved herd. This illustrates how the choice of sire can significantly affect farm profit per hectare through the influence of his daughters on both milk solids output per cow and achievable stocking rate. This is discussed further in section 10.5.

Given that genetic progress in New Zealand dairy cattle has seen significant changes in the production and merit of the average cow since the 1960's (Carter, 1964; Wickham, 1978; Davey et.al, 1983) and that stocking rates since this time have increased by 50% (Holmes, 1989) it could be argued that the influence of genetic improvement on the number of cows farmed per hectare could become increasingly important in future years. The observation that grassland DM production has not significantly increased over the past 30 years in New Zealand (Hodgson, 1989) further suggests that future developments in improved dairy systems could see a move back towards lower stocking rates.

Graphing the relationship between sire protein BI and stocking rate for the selected Jersey bulls shows the following trends (see Figure 10.3.1).

Generally, any increase in production and hence annual feed requirement per cow will reduce the achievable stocking rate. In this case, the lower achievable stocking rate with increasing sire protein BI corresponds not only with greater protein yield per cow but also with the associated increases in milk and fat observed in section 10.1. The wide variations about the regression line are presumably generated by the lack of relationship between the protein BI's of the selected sires and daughter liveweight as shown in section 10.2.

Figure 10.3.1 Relationship between selected sire protein BI and stocking rate



10.4 EFFECT OF SELECTED JERSEY SIRES ON MARGINAL PROFIT PER COW

Annual income per cow in the herd is generated by its individual output of saleable milk solids and a proportion of the carcass returns from culled cows and calves. In this manner, the genetic contribution of a proven sire to profit per cow is not only through the transmission of its superior dairy genes but also in the liveweight of the progeny it leaves behind. This beneficial effect of increased weight conflicts with the adverse effects of increasing liveweight on per cow feed requirement and achievable stocking rate (see section 10.3). The genetic component of liveweight (0.16 to 0.24) (Ahlborn and Dempfle, 1992) and the variability of offspring size between sires has been recently acknowledged in New Zealand by the inclusion of a liveweight and stature score in the economic breeding index (Sire Survey Register, 1992). Assuming costs of production are fixed per animal, increasing both milk solids yield and liveweight would be expected to increase average profitability per cow.

The relationship between sire protein BI and marginal profit per cow is shown in Figure 10.4.1. Clearly, increasing sire protein BI generates a greater marginal profit per cow in the herd. However, given that no relationship was observed to exist between selected sire BI and the average liveweight of his daughters (see section 10.2) the greater profits must be mainly due to differences in per cow yields of milk and milk solids.

Indeed, even if there was a relationship between BI and liveweight it is unlikely that it would greatly influence overall profit per cow because of liveweight only contributing a small proportion of the total profit per cow. Milk earnings account for approximately 90% of total profit per cow with the value of meat from cull cows and calves only contributing the remaining 10%.

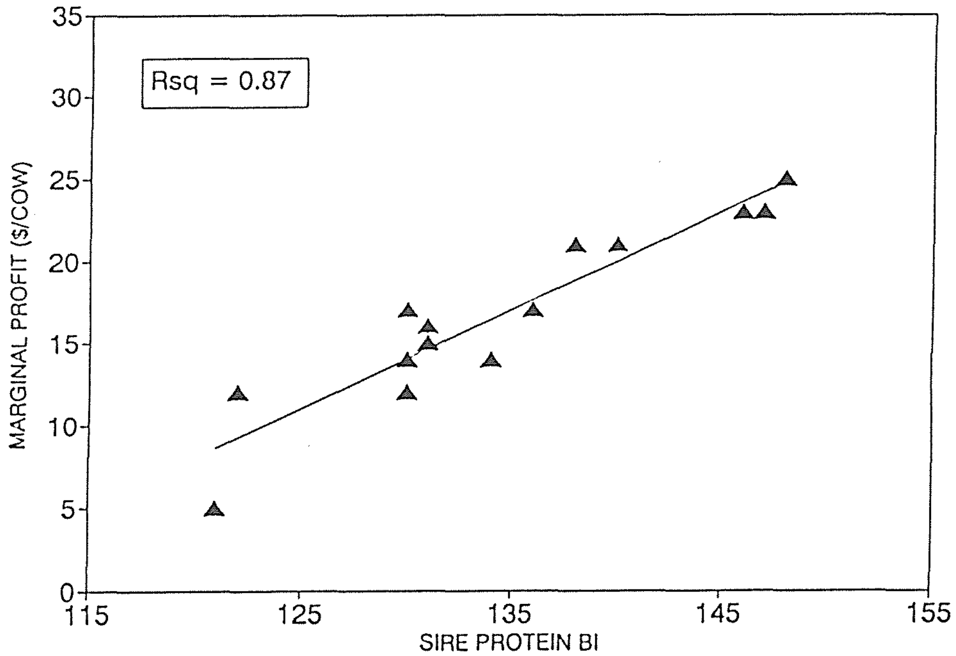


Figure 10.4.1 Relationship between selected sire protein BI and marginal profit per cow in the herd

Table 9.3 summarizes the effect of selected sires on marginal changes to profit per cow relative to cows in the base herd. The US sires again tended to be among the top bulls, producing on average $6 greater profit per cow in the herd than their New Zealand counterparts.

Predicting the effect of a sire on marginal profit per cow in the herd

The average effect of changes to sire fat, protein and milk BI's, and also daughter liveweight on marginal profit per cow can be evaluated using theoretical values in the model (see Table 10.4.1).

Table 10.4.1 The influence of sire BI and daughter liveweight on marginal profit per cow in the herd ($/Cow)

Trait	Δ Sire BI	Δ Marginal Profit per Cow
Fat BI	**+ 5 BI**	**+ $1.80 / cow in the herd**
Protein BI	**+ 5 BI**	**+ $2.40 / cow in the herd**
Milk BI	**+ 5 BI**	**- $0.40 / cow in the herd**
Cow Liveweight	**+ 10 kg**	**+ $1.20 / cow in the herd***

*** Assumes average cow liveweight between 300 and 330kg**

The higher value of protein relative to other dairy traits is expressed in the greater unit change in profit per cow expected per unit change in sire protein BI. These figures imply that given two sires with the following characteristics:

Sire 1:	Fat BI	= 155	Sire 2:	Fat BI	= 145
	Protein BI	= 145		Protein BI	= 130
	Milk BI	= 150		Milk BI	= 130
	Liveweight	= 320 kg		Liveweight	= 300 kg

Sire 1 will generate $11.60 greater profit per cow in the herd than will sire 2. Another way of approaching this is to say that in order for two sires which differ by 5 protein BI units to achieve equal profitability per cow, the lower sire must be either 7 fat BI units higher, 32 milk BI units lower or have daughters weighing an average of 20 kg more.

10.5 EFFECT OF SELECTED JERSEY SIRES ON MARGINAL PROFIT PER HECTARE

High profit per hectare will be achieved by efficient conversion of pasture into revenue. In general, cows with high yields will be efficient converters of feed into milk, but their overall economic efficiency will also be influenced by their size. Thus in order for profit per hectare to increase with the use of a certain sire, the greater potential yields of milk and meat from his daughters must outweigh the loss in production from a potentially lower stocking rate. In this way high profit per cow may not always lead to high profit per hectare.

Table 9.3 shows the marginal changes in profit per hectare caused by the first lactation daughters of the selected high protein Jersey sires. Herd BI's and yields are the same as those assumed in section 10.1. The relationship between sire protein BI and marginal profit per hectare is shown in Figure 10.5.1.

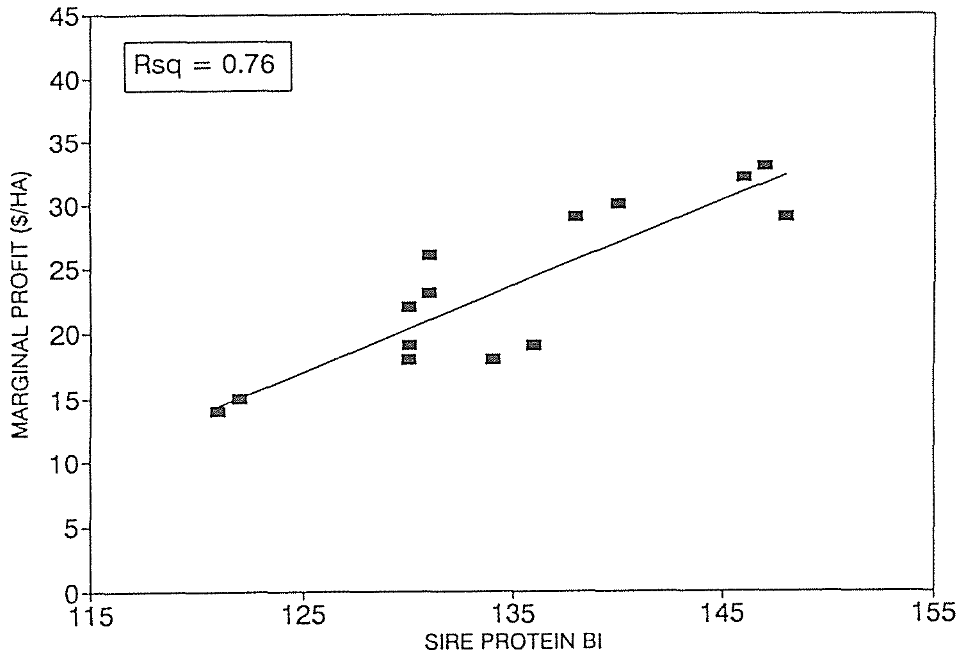


Figure 10.5.1 Relationship between selected sire protein BI and marginal profit per hectare

The US sires again proved to be among the top bulls for generating marginal changes to profitability per hectare. This is due to the high solids producing ability of their daughters relative to the selected New Zealand sires. The average differences in marginal profit per hectare as a result of including these foreign genes into the herd was an additional $6 per hectare over that of New Zealand sired herds.

<u>Predicting the effect of a sire on marginal profit per hectare</u>

Using Table 9.8 as an example, the additional profit per hectare expected from different values of sire protein BI and daughter liveweight can be identified. This assumes average herd BI's and production as stated previously (see section 10.1) as well as sire BI's for fat and milk of 152 and 134 respectively. These latter figures are the average values for the 1992 Premier Sire Bull Team (LIC Premier Sires, 1992).

Given a sire with the following characteristics:

*	Fat BI	= 152
*	Protein BI	= 140
*	Milk BI	= 134
*	Daughter LWT	= 320kg

Table 9.8 shows that the marginal profit per hectare generated by this sire will be $31 above that of the base herd to which he was mated by the time his first daughters have completed one lactation. If the same bulls daughters weighed an average of 350 kg, marginal profit per hectare would be $19. Figure 10.5.2 displays the data in Table 9.8 as a series of iso-profit lines to illustrate the relationship between the genetic merit of a sire, the average liveweight of his daughters and marginal profit per hectare.

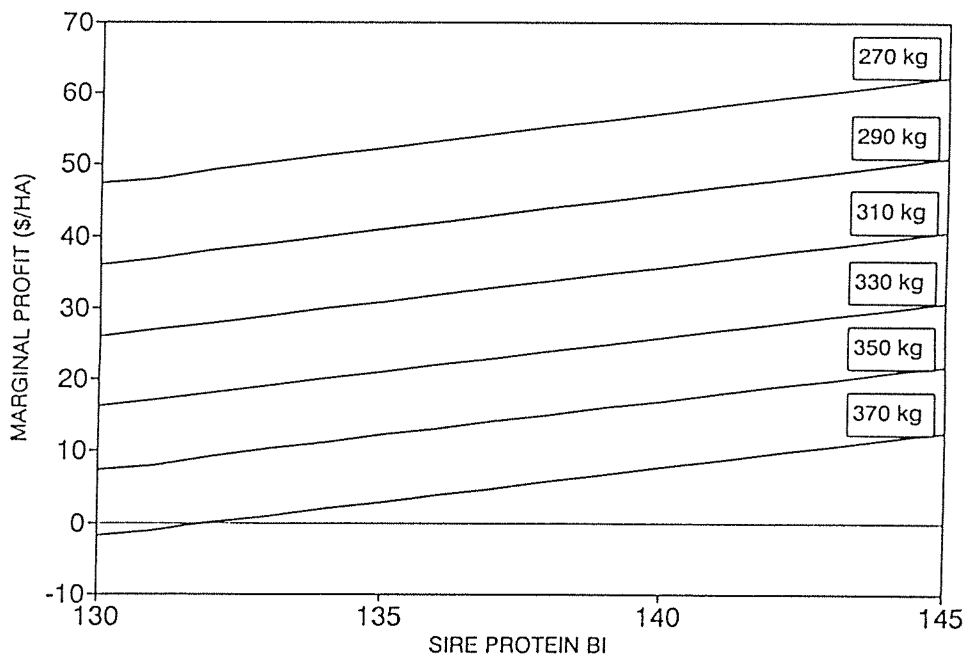


Figure 10.5.2 The relationship between sire protein BI, average daughter liveweight and marginal profit per hectare

Figure 10.5.2 shows how, assuming per hectare yields of fat and milk stay the same, increasing daughter liveweight will reduce the marginal profit per hectare for a given sire protein BI. This is because the additional revenue from heavier carcass weights and calves is not enough to replace the income lost when increased feed requirement per cow reduces the achievable stocking rate. Also shown is how a sire with protein BI less than 132 or average daughter liveweight greater than 370kg may actually decrease marginal profit per hectare below that generated by the base herd to which he was first mated.

With knowledge of a sires respective trait BI's and his average daughter liveweight, Tables such as 9.8 and those in Appendix I can be used to provide an estimate of his economic performance relative to other sires. Such estimates provide an additional aid to making the most profitable breeding decisions.

The average effect on marginal profit per hectare of changing BI's for fat, protein and milk, as well as daughter liveweight are given in Table 10.5.1.

Table 10.5.1 The influence of sire BI and daughter liveweight on marginal profit per hectare

Trait	Δ Sire BI	Δ Marginal Profit per Hectare ($/Ha)
Fat BI	**+ 5 BI**	**+ $2.40 / Ha**
Protein BI	**+ 5 BI**	**+ $4.90 / Ha**
Milk BI	**+ 5 BI**	**- $1.80 / Ha**
Liveweight	**+ 10 kg**	**- $4.90 / Ha**

The figures in Table 10.5.1 can be used to estimate the relative changes in overall profit per hectare for different sires by summing the effects for each respective trait. These figures imply that given two sires with the following characteristics:

Sire 1:	Fat BI	= 155	Sire 2:	Fat BI	= 145
	Protein BI	= 145		Protein BI	= 130
	Milk BI	= 150		Milk BI	= 130
	Payment BI	= 147		Payment BI	= 135
	Liveweight	= 320		Liveweight	= 300 kg

Sire 1 will generate $2.50 greater profit per hectare than will sire 2. Equivalently, for two sires which differ by 5 protein BI units to achieve equal profitability per hectare, the lower sire must be either 10 fat BI units higher, 14 milk BI units lower or have daughters weighing an average of 10 kg less.

This shows how sires differing greatly in total Payment BI may actually be very similar in terms of marginal changes to profit per hectare simply through the influences of their respective daughter liveweights on achievable stocking rate.

Wickham et.al (1992) calculated the net effect of an increase in cow liveweight (in Jerseys) as a profit reduction of $0.31 per kg. This slightly underestimates the figure in Table 10.5.1 which predicts a $0.49 reduction in profit per kg increase in liveweight. Current prices for milk are higher while prices for meat are slightly lower than those used in the previous study. When the earlier prices were used in the model, the reduction in profit became $0.23 per kg. The exercise serves to illustrate the influence of the relative prices for milk and meat on the changing value of liveweight to the dairyfarmer.

10.6 THE EFFECT OF ARTIFICIAL INSEMINATION COSTS ON SIRE PROFITABILITY

The results presented in Table 9.3 are model predictions of sire profitability using a base herd with assumed production characteristics as a means of comparison. This also assumes that all costs associated with production are the same for each sire used over the herd. A characteristic of these results is that the cost per straw of semen was set to an average of $12 to avoid the genetic influence of a sire on economic performance of the herd becoming confounded with widely varying costs of insemination between bulls. This section uses the actual cost per straw of semen for each of the selected Jersey sires to calculate their 'real' influence on marginal profit per cow and per hectare.

The formula used in the model to calculate the costs of artificial insemination is shown as follows:

$ Cost / Cow in the herd = Replacement Rate x $ / Straw x 2.8

The replacement rate is multiplied by 2.8 to establish the number of straws of semen required to achieve this number of first lactation A.I daughters. This figure is probably very low compared with the actual straw numbers per replacement achieved in practice. However in the context of this study it will not affect the relative rankings of sires. This figure assumes:

* All replacements are daughters of A.I matings
* Conception rate to A.I is 70%
* Losses between conception and daughter lactation are 10%
* Half of the progeny are heifers

In this way, paying $12 per straw for a bull to be used over a herd which requires a 25% replacement rate will generate an average cost of $8.40 per cow in the herd. Other costs associated with mating are assumed to be included in the average figure of $12 per cow given in Table 7.3.5.

Table 10.6.1 lists the marginal profitability per hectare calculated using both a fixed straw price ($12/straw) and the actual straw price for the selected Jersey bulls used in the previous sections (see Table 8.1).

Table 10.6.1 Profitability per hectare of selected Jersey sires using fixed and actual semen prices

Name	Country	$ / Straw	$Marginal Profit / Ha ($12/straw)	(Actual $/straw)
JS Quicksilver Royal	USA	35	+25	-1
A-9 Top Brass	USA	100	+29	-103
Fairweather Opportunity	USA	25	+28	+19
Kaimua Goliath	NZL	14	+26	+35
GR Burghams Penny	NZL	9	+25	+42
Merivale Senator	NZL	9	+15	+32
Rocky Hill Silver Saint	USA	12	+14	+26
RR Tregarden Ponsonby	NZL	9	+22	+39
Merivale Bromley	NZL	12	+18	+31
SJ3 Barthows Parsley	NZL	12	+18	+30
Lawnmuir Elton	NZL	10	+14	+29
Sproslea Dan Fernando	NZL	13	+15	+26
Kencrest Red Jasper	NZL	9	+11	+28
Owharoa Ferns Challenge	NZL	10	+10	+25
Average:	USA	43	+24	-15
	NZL	11	+17	+32

As may be expected, the price of imported US semen is far more expensive than that of New Zealand born sires. A feature of these results is that whereas in Table 9.3 the US sires were among the most profitable bulls in the group, Table 10.6.1 shows them to be generally less profitable than even the lowest New Zealand sire. A limitation of the model in this respect is that it does not take account of the potential income from the sale or lease of high value offspring for use as parent animals. Table 10.6.1 shows that using a bull such as A-9 Top Brass in a commercial herd purely for boosting the average genetic merit of grade cows will be very unprofitable relative to the price paid for his semen. However where the same bull is mated to a superior dam and generates a son which is itself used in an A.I scheme, the financial returns may justify the initial cost. For these reasons the results presented in this section should be interpreted with caution.

10.7 SENSITIVITY OF THE MODEL

A characteristic of any modelling exercise is that the results obtained are a direct reflection of the assumptions made about the system under study. In developing the present model, assumptions were made about product prices, the production and genetic merit of the base herd, the energy contained in each unit of product and the efficiency with which feed energy was utilized (see section 7.3). Estimates of these parameters are available from previous research but in many cases these values vary between author and experiment. Thus the limitations of the model are effectively set by the limitations of current scientific knowledge. However the modelling approach taken here is one of comparing between animals using a base herd as a common point of reference. This necessarily requires the characteristics of this base herd to be the same for each sire evaluated, effectively removing any outside variation which may 'cloud' the final results.

The metabolic and genetic assumptions made about the base herd will not influence the simulated differences between sires and can be excluded from any analyses of model sensitivity. On the other hand, graded systems of payment will contribute to economic differences between the offspring of respective sires. The milk and meat prices used in this study are those being paid to dairy farmers for the current season (1992/93) (see section 7.3). The fluctuating prices over recent years and the uncertain future makes it difficult to put forward representative values for either source of income. However, as reflected by changing methods of milk payment, it seems likely the value of milk protein relative to milk fat will continue to increase in coming years as world demand and markets for protein expand (Marshall,1992).

Milk Component Prices

With a milk component system based purely on fat yield a change in price, although affecting the magnitude of marginal profit achieved per hectare, does not affect the relative ranking of individual sires. This is analogous to the situation where the protein:fat ratio does not differ between herds. However as bulls with different milk, fat and protein BI's leave daughters with differing milk composition, the adoption of the A+B-C payment system will greatly influence the profitability of individual animals. As such, changing the relative values of milk components can have a significant effect on the ranking of sires.

Tables 9.4 - 9.6 show the effect of changing milk component values on the marginal profit per hectare generated by the 14 selected Jersey sires listed in section 8. A ranking out of fourteen is given to the figures calculated for each bull to allow the influence of price changes on the relative performance of the sires to be evaluated.

As would be expected, changes to the value of the protein component have the greatest influence on marginal profit per hectare and the relative ranking of sires. Some sires changed ranking by up to three places for the full range of variation in milk component prices. The average margin of profit per hectare for the 4 US sires also remains ahead of the New Zealand sires for all the assumed price changes. However the difference between the two groups is strongly reduced by both a decrease in the value of milk protein and/or a greater processing charge for the volume of milk produced. This indicates the advantage of the 4 US sires in terms of boosting yields of protein and milk per cow relative to the New Zealand sires.

Carcass Prices

Table 9.7 presents the changes to marginal profit per hectare generated by each sire and their relative ranking under assumed changes to the prices paid per kg of carcass weight. These estimates include prices for both cull cows and calves.

The relatively small influence of carcass prices on marginal profit per hectare is indicated by the stability of calculated values for each sire across a wide range of price changes. The ranking of sires is also relatively unaffected by such changes.

The Efficiency of Milk Synthesis

The efficiency with which the metabolizable energy absorbed by the mammary gland is converted to the net energy in milk is represented by K_l. An aspect of K_l which could be deemed inappropriate in the present context is that it represents the overall efficiency of milk energy synthesis rather than the partial efficiencies of fat, protein and lactose synthesis as separate energy containing components of milk. When considering milks of varying composition ie. the yielding potential of the daughters of different sires, it seems logical that differing concentrations of fat, protein and lactose will mean some animals produce milk containing a greater amount of net energy than others. Estimates of the partial efficiencies of fat, protein and lactation synthesis are shown in Table 10.7.1.

The important point to be noted from this is that the estimated efficiency by which protein is synthesised is lower than that of the other milk components. This implies that animals yielding milk high in protein may be less efficient converters of feed energy into milk energy than others. However, interpretation of the K value for protein synthesis is difficult as the rapid turnover of protein in the animal body can contribute to the apparently high energy cost of protein deposition. (Annison, 1976). Whether this holds for milk protein, which is not subject to turnover but instead is removed from the body, is currently unknown.

Table 10.7.1 Estimated partial efficiencies of milk component synthesis

Component	Source	Efficiency of Synthesis (K)*
Fat	Chwaliborg (1991)	0.8
	Holmes et.al (1984)	0.75 - 0.8
		0.97 (From body tissue)
Protein	Chwaliborg (1991)	0.5
	Buttery and Boorman (1976)	0.51
	Oldham (1981)	0.42 - 0.51
	Van Es (1980)	0.55 - 0.65
Lactose	Van Es (1980)	0.75
	Holmes et.al (1984)	0.65 - 0.80

*** Net Energy produced in milk component / Metabolizable energy absorbed by the mammary gland**

Incorporating the values in Table 10.7.1 into Tyrell and Reids (1965) equation for calculating the metabolizable energy content of milk (see section 7.3) gives the following derivation:

$$MJ\ ME_{Milk} = \frac{(38.3 \times kgMF)}{K_{Fat}} + \frac{(22.2 \times kgProt)}{K_{Prot}} + \frac{(0.89 \times kgMilk)}{K_{Lact}}$$

where K_{Fat} = Partial efficiency of fat synthesis

K_{Prot} = Partial efficiency of protein synthesis

K_{Lact} = Partial efficiency of lactose synthesis

Table 10.7.2 gives the estimated metabolizable energy content of three milks differing in protein:fat ratio using the equation in section 7.3 and the derivation above.

Under these assumptions the two methods of calculating the metabolizable energy required to synthesize milk show small differences over a range of milk compositions. The overall conclusion is that the assumptions used in the present model will cause only very small overestimates in the efficiency and profitability of high protein sires.

Table 10.7.2 The calculated net energy content of milk using two different methods

Component		Milk 1	Milk 2	Milk 3
Fat (kg)		160	160	160
Protein (kg)		112	120	128
Lactose (kg)		175	175	175
Protein:Fat Ratio		0.70	0.75	0.80
A.	$K_l = 0.70$	16756 MJ	17010 MJ	17264 MJ
B.	$K_{Fat} = 0.8$ }			
	$K_{Prot} = 0.5$ }	16786 MJ	17141 MJ	17497 MJ
	$K_{Lact} = 0.75$ }			
A - B		30 MJ	131 MJ	233 MJ
% Difference		0.2%	0.8%	1.3%

* MJ = Megajoules of metabolizable energy

10.8 TRENDS IN MILK YIELD AND COMPOSITION PER COW

Comprising a major part of the countrys manufacturing sector, the New Zealand dairy industry is inextricably linked to its supply of milk as a raw material and to the farms which produce it. The relative yields of fat, protein and milk received annually by dairy companies determine both the quantities of product able to be made and the cost of making them. Therefore knowledge of current changes to farming systems are important for ensuring that the planned development of the industry keeps pace with future trends in milk composition.

Although milk composition can be altered temporarily by factors such as feeding and management (Bryant, 1979; Thomson, 1988), aside from choice of breed, permanent changes can only be brought about in the long term by genetic selection. The national herd improvement scheme seeks to influence yields of milk components by selecting future parent animals based on their genetic merit for yields of milk, fat and protein. However any changes to the relative yields of milk and milk solids over time may also bring about associated changes to average milk composition. Weighting the respective yields by their relative economic values ensures that emphasis is placed on those traits which are most valuable to the industry.

The difficulty of achieving this latter objective in practice is due to the fact that breeding decisions implemented today will not yield results for the 10 years taken until the daughters of proven bulls enter their first lactation (Garrick and Rendel, 1992). Formulating selection objectives for this planning horizon requires extreme foresight, particularly with regard to future market trends. In ten years time the demand for specific milk products may have changed. This may reduce the value of any intermediary changes to national milk composition.

The use of foreign dairy sires in New Zealand represents one aspect of changing milk composition which has the potential to expand greatly in future. The relatively small numbers of these sires currently in use in the industry makes it difficult to predict the contribution of their genes to greater yields of fat, protein and milk in the coming years. Predicting the extent of their influence on future trends in industry milk composition requires knowledge of the relative genetic levels between countries and the respective rates of genetic gain for each trait.

Annual genetic gain in the New Zealand dairy industry

The rate of genetic gain within any population under selection is a function of how well animals are evaluated (ie. reliability of prediction), the amount of selection (selection intensity), the rate at which younger animals replace their parents (generation interval) and the genetic diversity existing in a population (genetic standard deviation) (Van Vleck et.al, 1987). These first three factors are at least partly under the control of the breeder and thus any difference between countries in industry breeding structure can contribute to differences in rates of gain. The genetic standard deviation within a closed population, although able to be changed over the generations, is at any one time essentially fixed (Johansson,1969).

With knowledge of current New Zealand industry breeding structure and the genetic and phenotypic parameters which exist in the national herd (Ahlborn and Dempfle, 1992), the annual rate of genetic gain under present selection policies can be calculated. This assumes a closed population ie. selection and mating is carried out only on those animals born under the national herd improvement scheme. For a multiple trait index based on individual and progeny test records for milk and solids yields and cow liveweight, the expected correlated increases in fat, protein, milk and live weight per Jersey cow per year are shown in Table 7.8.1 (see Appendix II). These figures represent the average genetic gains per cow across all Jersey herds involved in the national improvement scheme. The relative economic values (REV) or weightings currently used in the industry (Sire Survey Register, 1990/91) are given along with the expected annual genetic gains in each trait. Note projected changes are due to genetic improvement only.

Table 10.8.1 Calculated annual genetic gains in yield and liveweight traits for New Zealand Jersey cattle (see Appendix II)

Trait	REV	Annual Genetic Gain	%
Fat	0.1087	2.04 kg/yr	1.3
Protein	1	1.51 kg/yr	1.4
Milk	-0.0074	33 kg/yr	1.2
Liveweight	-0.1358	0.13 kg/yr	0.04

Total Increase = 1.5 Payment BI / year

*** Percentage of average annual yields per Jersey cow, assumed to be 153kg fat, 110kg protein, 2700kg milk (Dairy Statistics, 1990/91)**

Both liveweight and milk have negative REV's in the index indicating that a negative selection pressure is applied to them rather than a positive pressure as is the case for fat and protein yields. Despite this, increases in these traits are still made due to their strong positive genetic correlations (Ahlborn and Dempfle, 1992) with yields of milk solids and the high REV for milk protein.

The influence of foreign sires on future milk composition

The natural forces of selection imposed by particular environments and the past selection objectives of improvement schemes can all act to alter the mean production within a closed population and so create genetic differences between countries. These factors and the way in which they change over time will determine the actual genetic divergence between populations at any point in the future.

Previous discussion has been based on calculated genetic gains in milk and solids per cow within a closed New Zealand dairy industry. The reality of increases in the use of foreign genestock may make these estimates invalid due to the differing genetic parameters they contribute and the greater selection intensities which may be practised with more potential parent animals to choose from. Thus using foreign sires may alter the trends in milk composition compared with what would otherwise have been expected from using solely New Zealand bulls. The extent and rate of this divergence will depend on the degree of genetic difference between the national and foreign herds, the comparative rates of gain and probably most importantly, the frequency with which foreign sires are used among New Zealand herds.

At present no accurate information exists as to the actual genetic differences between the US and New Zealand Jersey populations, therefore to avoid confusion it will be assumed that the average genetic merit of cows in both countries are the same. Actual rates of genetic gain in the US Jersey population were obtained from data showing annual breeding value averages for all cows and sires over the last 35 years (Wiggans, pers.comm, 1993). Graphing these trends (see Figure 10.8.1) revealed that consistent lag periods between sire and dam groups have only been achieved since 1975 and hence yearly changes were calculated from this time on. Table 10.8.2 lists the average genetic gain per annum for milk components.

Table 10.8.2 Average genetic gain per year achieved in the US Jersey cow population since 1975

Trait	Δ Genetic Gain (% / yr)*
Fat	1.39 %
Protein	1.05 %
Milk	1.55 %

*** Linear regression on average cow breeding values between 1975 and 1993.**

Comparing these figures with those in Table 10.8.1, the greater emphasis which has been placed on milk production in the US is evident. The slower rate of gain in the protein trait is particularly noteworthy in the context of this study.

Although the use of foreign sires could influence milk composition to a large extent at the individual herd level, the effect on the industry will be largely determined by the relative proportions of New Zealand and foreign bred sires in use and the changing patterns of farmer acceptance over the coming years. Positive results from using foreign sires in these current 'experimental' years could be expected to generate an upsurge in demand over subsequent years. However predicting farmer attitudes is not always an easy or reliable process.

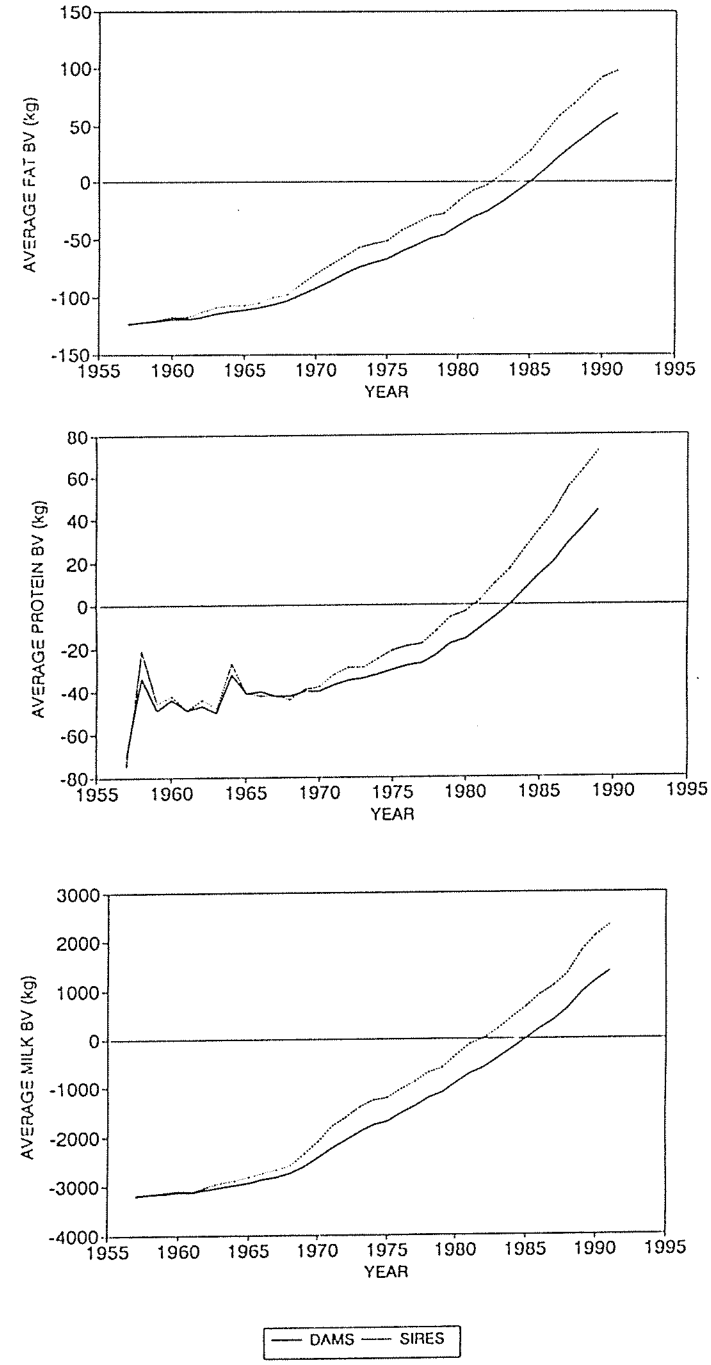


Figure 10.8.1 Genetic trends in yields of fat, protein and milk in US Jersey cattle (from data by Wiggans, 1993)

Possible trends in New Zealand Jersey milk composition

Projected trends in milk composition per cow for the coming years have been established by assuming the following conditions:

* The average genetic merit of cows in New Zealand and the USA are equal
* The estimated genetic gains in milk and milk solids yields for the New Zealand and US Jersey populations shown in Tables 10.8.1 and 10.8.2

Two scenarios are assumed:

* Mating and selection in the New Zealand dairy industry using New Zealand sires only
* Mating and selection in the New Zealand dairy industry using USA sires only

The first scenario is equivalent to the case where the New Zealand dairy industry is assumed to be a closed population and genetic gain is achieved using native animals only. The second case, although unlikely, provides an estimate of the potential extremes to which New Zealand milk composition can be altered by incorporating genetics from an industry which is currently developing at different rates of genetic gain. For both scenarios, rather than referring to individual animals in particular, it is the average genetic trends in the respective populations which are the means of comparison. Tables 10.8.3 and 10.8.4 give a summary of the predicted changes to milk yield and composition under both scenarios for the next 30 years.

Based on the calculated genetic gains in the New Zealand dairy industries, future yields of fat, protein and milk per cow can be expected to increase considerably under current New Zealand selection objectives. Fat and protein percentages of milk will increase slightly over this time with greater gains in protein percentage relative to fat. This leads to a similarly marginal change in the protein to fat ratio. The overall trend is for greater emphasis on protein and a general move towards more concentrated milk. The total percentage increases presented in Tables 10.8.3 and 10.8.4 refer to an additive increase in yield per year, not a compound increase.

The most obvious changes to the production of New Zealand Jersey cows brought about by assuming US rates of genetic gain in the industry are the dramatic increase in milk yield per cow and the decrease in protein yield per cow relative to that predicted under New Zealand rates of genetic gain (see Figure 10.8.2). Differences in fat yield per cow under the respective rates of genetic gain are only small. In 30 years time the faster genetic improvement in the US milk trait could result in a 270kg advantage in average milk yield per cow if New Zealand Jersey farmers were to adopt the sole use of US sires over their herds.

Table 10.8.3 Predicted change in annual yields of fat, protein, milk and milk solids concentration for the average Jersey cow under current New Zealand rates of genetic gain

Year	Fat (kg)	Prot (kg)	Milk (kg)	Fat %	Prot %	P/F*
1992	153	110	2700	5.67	4.07	0.719
1997	163.2	117.6	2865	5.70	4.10	0.720
2002	173.4	125.1	3030	5.72	4.13	0.721
2007	183.6	132.7	3195	5.75	4.15	0.722
2012	193.8	140.2	3360	5.77	4.17	0.723
2017	204.0	147.8	3525	5.79	4.19	0.724
2022	214.2	155.3	3690	5.80	4.21	0.725
Total Δ	+61.2	+45.3	+990	+0.14	+0.14	+0.006
% Δ	+40%	+41%	+37%	+2.3%	+3.4%	+0.83%

* Protein to Fat ratio

Table 10.8.4 Predicted change in annual yields of fat, protein, milk and milk solids concentration for the average Jersey cow under past US rates of genetic gain

Year	Fat (kg)	Prot (kg)	Milk (kg)	Fat %	Prot %	P/F
1992	153	110	2700	5.67	4.07	0.719
1997	163.7	115.8	2910	5.62	3.98	0.708
2002	174.3	121.6	3120	5.59	3.90	0.698
2007	185.0	127.4	3330	5.55	3.83	0.689
2012	195.6	133.2	3540	5.53	3.76	0.681
2017	206.3	139.0	3750	5.50	3.71	0.674
2022	216.9	144.8	3960	5.48	3.66	0.668
Total Δ	+63.9	+34.8	+1260	-0.19	-0.41	-0.051
% Δ	+42%	+32%	+47%	-3.4%	-10.1%	-7.1%

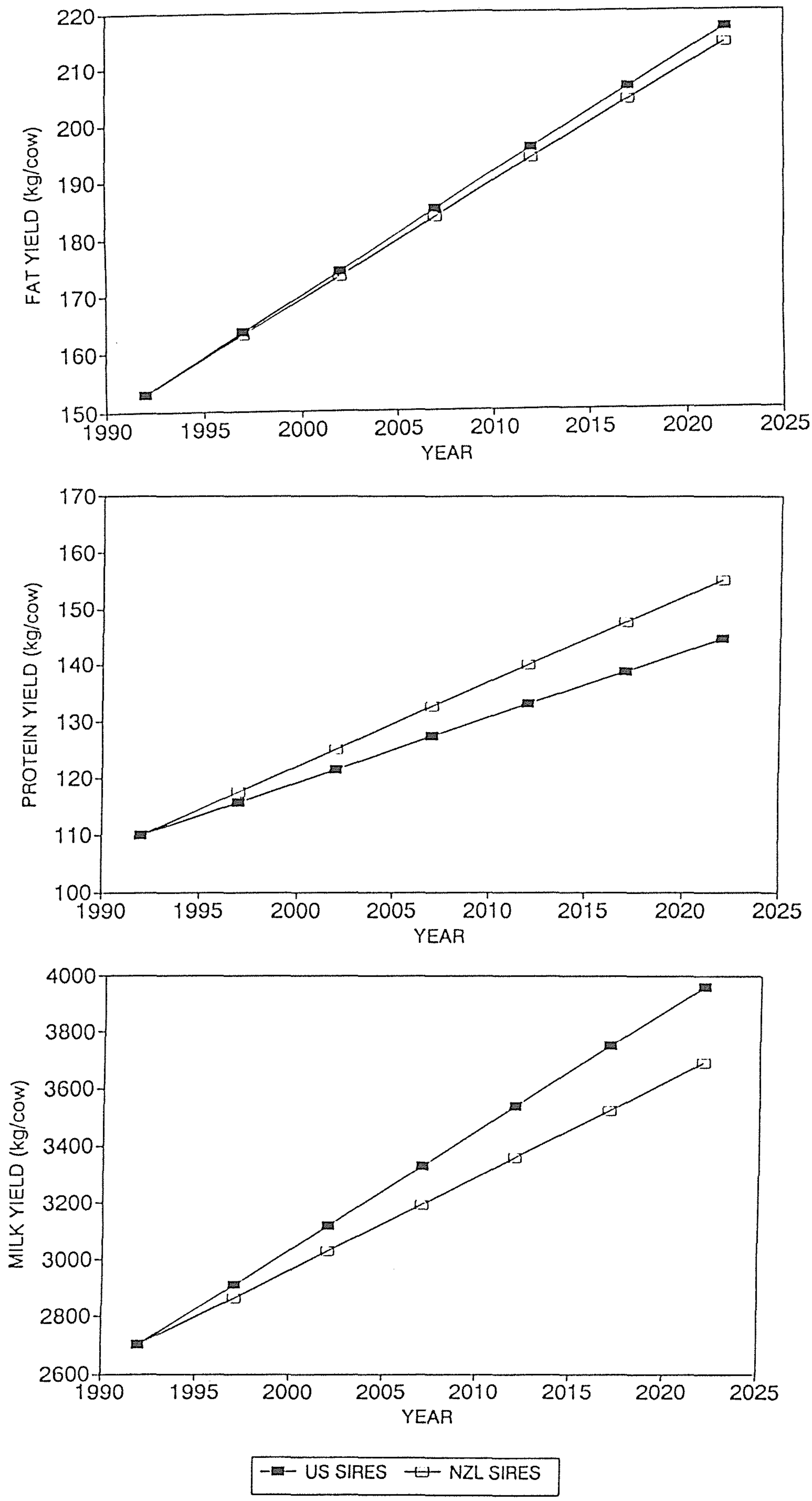


Figure 7.8.2 Predicted trends in yields of milk and milk solids per cow using New Zealand or U.S sires

The 10kg advantage of New Zealand sires in terms of protein per cow after 30 years is at odds with the greater protein BI's and per cow yields generated by the 4 selected US sires used in the earlier study (see Table 9.2). However the slow rate of increase in the U.S protein trait over past years (see Table 10.8.2) suggests that the current rate of genetic improvement in the New Zealand Jersey population should result in national average protein yields per cow eventually surpassing the benefits of using US sires. This assumes that past differences in selection emphasis between the two countries do not alter much in the future. The large domestic milk market in the US has probably resulted in greater importance in the past being placed on genetic gains in total milk yield rather than yields of milk solids as in New Zealand. The larger correlated gains in protein yield relative to fat with direct selection for milk (Kennedy, 1982) could mean that US Jerseys currently do have higher genetic potential for protein production. However the recent inclusion of protein in the New Zealand selection index, along with its heavy economic weighting, has probably contributed to the greater annual gains currently being predicted in this trait relative to that in the US. From these results it becomes obvious that the future direction of US selection objectives may have a large impact on the relative genetic trends between countries. Any increase in the emphasis placed on protein by the US may result in the genetic gain in this trait 'catching up' to that of the New Zealand industry, thereby creating or maintaining a genetic advantage.

A significant result of the greater milk yields per cow generated by using US sires are the decreases in milk solids concentration and the general move towards less concentrated milk. Figure 10.8.3 shows the widely diverging trends in future milk composition under the two scenarios. These amount to a total difference after 30 years of approximately 0.3 and 0.5 of a percent for fat and protein percentages respectively, relative to the values under New Zealand rates of genetic gain.

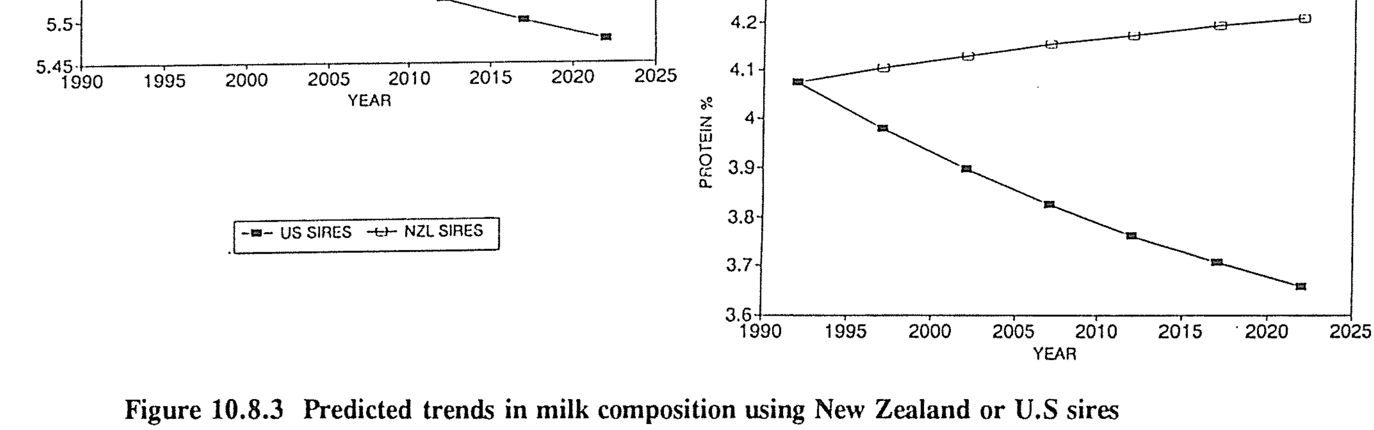


Figure 10.8.3 Predicted trends in milk composition using New Zealand or U.S sires

Whereas the New Zealand sires have an almost negligible effect on the ratio of protein:fat produced per cow over 30 years, the US sires could cause nearly a 7% decrease in protein:fat ratio relative to current values over this time. Wiles (1988) estimated that selection solely on the basis of milkfat yield in the New Zealand dairy cow population was causing average protein:fat ratios to decrease by 0.0027 per annum. Wickham (1985) had earlier suggested that the REV's used in sire selection indexes would have to favour protein by 4 to 1 for the trend in protein:fat ratio to become positive. Market trends in recent years have seen this become a reality with REV's for fat and protein currently standing at 0.1087 and 1 respectively in the national selection index (Sire Survey Register, 1992). From Table 10.8.3 the calculated increase in protein:fat ratio at +0.0002 per annum, although a negligible change overall, shows that greater selection emphasis on protein has probably halted the downwards trend in kg protein produced per kg fat.

Implications of predicted trends in milk yield and composition for on-farm changes

Using the projected changes to average Jersey cow milk composition under the two scenarios and the correlated gains in cow liveweight from genetic improvement (see Table 10.8.1), the farm model was used to quantify the on-farm implications of these changes for achievable stocking rate, profit per cow and profit per hectare. This assumed the following production figures per cow in the base year of 1992:

* Average kg fat per cow = 153
* Average kg protein per cow = 110
* Average ltr milk per cow = 2700
* Average liveweight per cow = 320

Economic figures are based on todays milk and meat prices (see section 7.3) and do not take account of future market trends or inflation/interest rates. Predicted trends in these variables for the next 30 years under New Zealand rates of genetic gain are given in Table 10.8.5.

The expected increases in per cow yields of milk and liveweight from using only New Zealand sires should boost profitability per cow in the herd by 47% over the next 30 years. However the increases in producing ability per cow have caused large increases in the annual feed requirements per cow, with a consequent 15% decrease in achievable stocking rate over the same time period. This results in only a 25% increase in profit per hectare. However the fact that profit per hectare is still increasing despite the downward trend in stocking rate reflects the ability of improved cows to dilute their maintenance requirements across a greater volume of milk and the reduction in animal costs per hectare. The small expected increases in average cow liveweight, in the order of 3 to 4 kg over the next 30 years, should have little influence on the change in average maintenance requirements per cow.

Table 10.8.5 The effect of predicted changes in average Jersey cow milk composition under New Zealand rates of genetic gain on achievable stocking rate, profit per cow and profit per hectare.

Year	Stocking Rate	Δ Profit / Cow	Δ Profit / Ha
1992	2.371	0	0
1997	2.303	+ $62	+ $87
2002	2.238	+ $123	+ $169
2007	2.178	+ $185	+ $247
2012	2.120	+ $247	+ $321
2017	2.066	+ $309	+ $390
2022	2.014	+ $370	+ $456
Total Δ	-0.357	+ $370	+ $456
% Δ	-15%	+ 47%	+ 25%

Table 10.8.6 The effect of predicted changes in average Jersey cow milk composition under US rates of genetic gain on achievable stocking rate, profit per cow and profit per hectare.

Year	Stocking Rate	Δ Profit / Cow	Δ Profit / Ha
1992	2.371	0	0
1997	2.301	+ $53	+ $65
2002	2.235	+ $105	+ $127
2007	2.173	+ $157	+ $185
2012	2.114	+ $210	+ $240
2017	2.059	+ $262	+ $293
2022	2.006	+ $315	+ $343
Total Δ	-0.365	+ $315	+ $343
% Δ	-15%	+ 40%	+ 18%

Assuming US rates of genetic gain in the New Zealand Jersey population, predicted trends in farm profitability are given in Table 10.8.6. Due to a lack of information to the contrary, similar correlated increases in cow liveweight are assumed as those calculated for the closed New Zealand industry (see Table 10.8.1). Figure 10.8.4 graphs the relative changes to farm profitability and stocking rate under U.S or New Zealand rates of genetic gain.

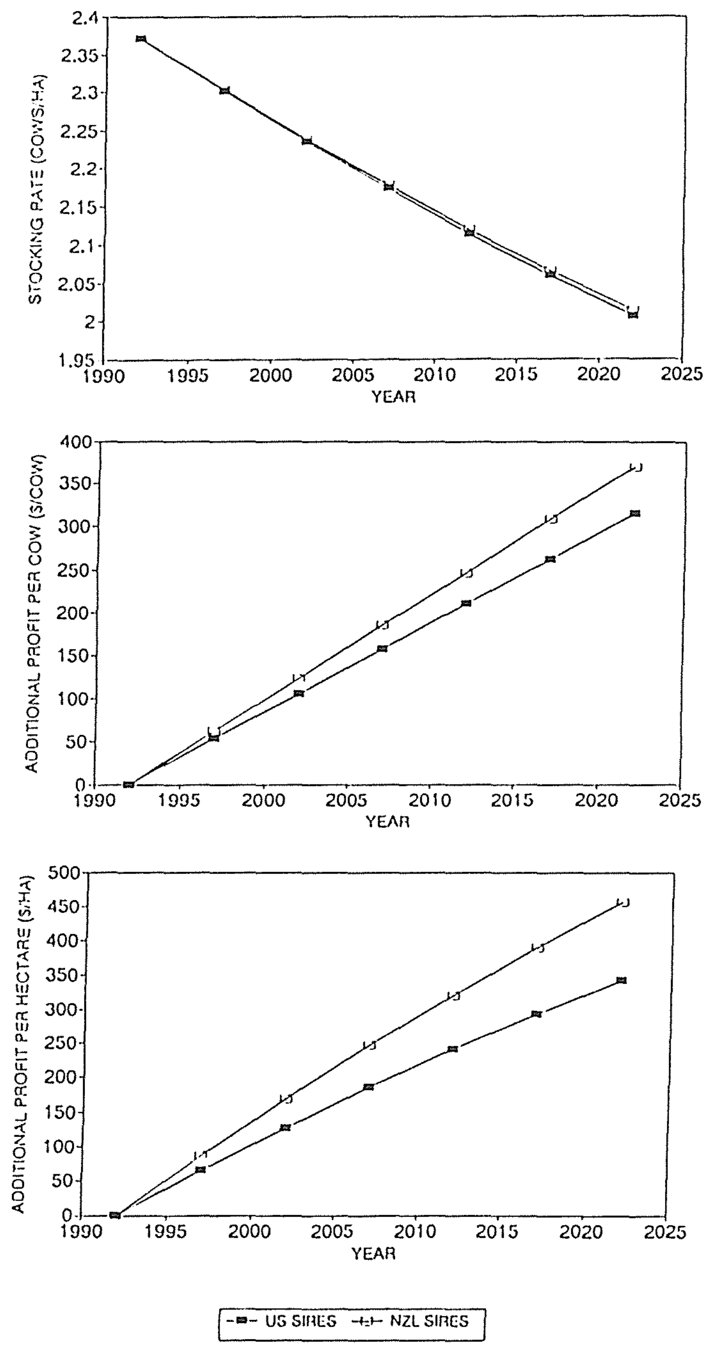


Figure 10.8.4 Predicted trends in stocking rate and profitability using New Zealand or U.S sires

Stocking rate effects are similar for the two rates of genetic gain, with both scenarios creating roughly a 15% decrease in achievable stocking rate after 30 years. Profit generated per cow shows an increasingly wider difference between the two scenarios in favour of the New Zealand sires. Although the U.S sires produce larger increases in fat yield per cow, the advantage of the New Zealand sires in terms of the higher priced protein component and lower milk volumes per cow results in greater overall milk solids returns.

These results imply that in years to come, using an 'average' New Zealand Jersey sire over a given herd should provide an increasing economic advantage over an 'average' U.S sire. However it must be noted that when considering individual sires from both countries, the comparative profitability of such animals will depend entirely on their relative genetic merit.

10.9 TRENDS IN MILK SUPPLY AND COMPOSITION WITHIN THE INDUSTRY

From the industry's point of view, increasing quantities of milk and milk solids produced per cow represent gross changes in the supply of raw materials for processing. The relative quantities of each milk component supplied will determine the mix of products which can be made, the market returns per kg of milk and ultimately the returns to the farmer.

Changes to per cow milk composition are determined at the individual herd level by the breeding and culling decisions of the farmer. A simple estimate of annual changes on an industry scale would therefore involve the average compositional change per industry cow multiplied by the number of cows in the national herd. For the two scenarios presented in the previous section, the changes to yields of milk and milk solids per cow from using purely New Zealand or US Jersey sires can be extrapolated to predict future supply trends for milk components from the New Zealand population of Jersey cattle.

Tables 10.9.1 and 10.9.2 present a summary of the predicted changes in annual supply of milk components from the total New Zealand population of Jersey cows under both scenarios. This assumes that all Jersey herds are involved in the national improvement scheme and share in the annual genetic gains made within the industry. Assuming that the total area of New Zealand on which Jersey cows are milked remains fixed over the years, the increase in annual feed requirement per cow caused by increasing genetic merit can be accounted for by decreasing total cow numbers. The decrease in achievable stocking rate under the two scenarios was earlier calculated as being in the order of 15% over a period of 30 years (see Tables 10.8.5 and 10.8.6). This rate of decrease was also assumed in Tables 10.9.1 and 10.9.2.

Trends in future milk composition from using only New Zealand Jersey sires could see the supply of milk components from the Jersey population increasing by 19%, 20% and 16% for yields of fat, protein and milk respectively over the next 30 years. The concentration of milk solids in milk produced will increase slightly.

For the case where only U.S sires are used, the large predicted increase in overall milk volume and the associated decreases in milk concentration have important implications for the future development of the processing industry. Compared with New Zealand sires, supply increases generated by US genetics may provide a further 1.4 million kg of fat and 143 million kg milk, while protein would be 5.5 million kg less after 30 years of genetic improvement.

Table 10.9.1 Predicted changes in total yields of milk components, milk solids concentration and protein : fat ratio in the New Zealand Jersey population under New Zealand rates of genetic gain.

Year	No. Cows*	Yields (million kg)			Fat %	Protein %	Protein:Fat
		Fat	Protein	Milk			
1992	624,558	95.6	68.7	1686	5.67	4.07	0.719
1997	608,944	99.4	71.6	1745	5.70	4.10	0.720
2002	593,330	102.9	74.2	1798	5.72	4.13	0.721
2007	577,716	106.1	76.7	1846	5.75	4.15	0.722
2012	562,102	108.9	78.8	1889	5.77	4.17	0.723
2017	546,488	111.5	80.8	1926	5.79	4.19	0.724
2022	530,874	113.7	82.4	1959	5.80	4.21	0.725
Total Δ		+18.1	+13.7	+273	+0.13	+0.14	+0.006
% Δ		+19%	+20%	+16%	+2.3%	+3.4%	+0.83%

* Assumes decrease in achievable stocking rate of 15% over 30 years (see Table 10.8.5)

Table 10.9.2 Predicted changes in total yields of milk components, milk solids concentration and protein : fat ratio in the New Zealand Jersey population under US rates of genetic gain.

Year	No. Cows*	Yields (million kg)			Fat %	Protein %	Protein:Fat
		Fat	Protein	Milk			
1992	624,558	95.6	68.7	1686	5.67	4.07	0.719
1997	608,944	99.7	70.5	1772	5.62	3.98	0.708
2002	593,330	103.4	72.1	1851	5.59	3.90	0.698
2007	577,716	106.9	73.6	1924	5.55	3.83	0.689
2012	562,102	109.9	74.9	1990	5.53	3.76	0.681
2017	546,488	112.7	76.0	2049	5.50	3.71	0.674
2022	530,874	115.1	76.9	2102	5.48	3.66	0.668
Total Δ		+19.5	+8.2	+416	-0.19	-0.42	-0.051
% Δ		+20%	+12%	+25%	-3.3%	-10.2%	-7.1%

* Assumes decrease in achievable stocking rate of 15% over 30 years (see Table 10.8.6)

With regard to the interpretation of Tables 10.8.3 to 10.9.2, the two scenarios represent the extreme cases for rates of genetic gain within the New Zealand Jersey population from using US genetics. In particular, genetic improvement in the US Jersey population is based on retrospective data and therefore does not necessarily reflect current changes in that industry. Depending on the proportion of foreign sires used in herd AI programs and the proportion of total herds which actually use these sires at all, expected trends in milk composition per cow and the industry could vary anywhere within these two extremes.

Implications of predicted trends in milk yield and composition for the dairy industry

The issue of increasing milk volumes in relation to dairy industry efficiency has been discussed frequently in the past (Cooper,1979; Bay,1983; Bryant,1988; Paul,1985). However the problem lies not so much with volume per se as with the pattern in which milk is supplied to factories during the year. A factory which receives a higher than 'average' milkflow before or after the spring flush has a higher level of sustained throughput so allowing costs per kg of processed milk solids to be reduced (Paul, 1985). The pattern of national milkfat supply to dairy factories over the 3 seasons prior to 1992 are shown in Figure 10.9.1.

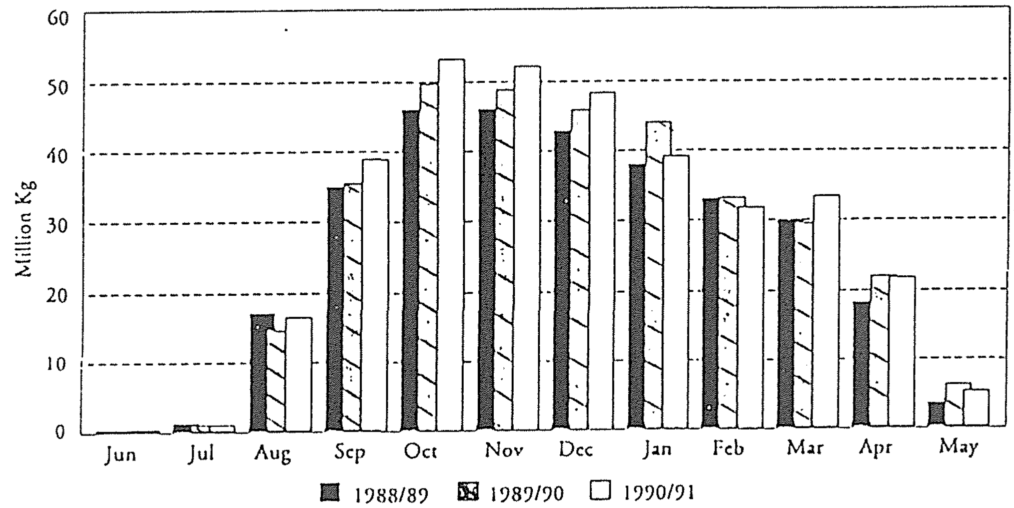


Figure 10.9.1 Total milkfat processed per month by New Zealand dairy factories (1988-1990 seasons) (Dairy Statistics, 1991)

This figure illustrates the large volumes of raw product supplied to factories from October through to December in relation to the remainder of the season. Annual supply is characterized by a steep increase in August/September and a slow decrease from October onwards.

Dairy companies must have the processing capacity to accommodate peak milk flows over the months from October to December, therefore any reduction below these peak levels, as occurs before and after this time, results in an inefficient use of available resources. Peak milk volume is a function of both the supply curve and the total supply volume in each season. In the present context, genetic improvement is not likely to have much influence on the seasonal pattern of milk supply but will certainly reflect on total milk supply through the greater average yields per cow. Given these concerns, the impact of genetic improvement on the cost of milk volume to the industry will be determined by the changing annual supply of total milk and milk solids and the future capacity of the dairy companies to process these raw materials.

Assuming that industry processing capacity is currently running at a maximum during the normal period of peak milk flows (October-December) and that the Jersey breed accounts for approximately 26% of the national herd (Dairy Statistics, 1990/91), Tables 10.9.1 and 10.9.2 can be used to draw several conclusions. It must be noted that all figures refer solely to genetic improvement in the New Zealand Jersey breed. They ignore changes in farming practice, total cow numbers and genetic progress made in other New Zealand dairy breeds.

Using only New Zealand Jersey sires in the industry will increase total milk supplied to dairy companies by approximately 273 million kg (16%) over the next 30 years of genetic improvement (see Table 10.9.1). This will require an expansion of 9 million kg (0.5%) in total industry processing capacity per year. For the case where it is assumed only U.S sires are used in the industry, milk volume will increase by 416 million kg (25%) over the next 30 years, requiring capacity increases in the order of 14 million kg (0.8%) per year (see Table 10.9.2). Assuming that the seasonal pattern of milk supply has not altered over this time, the extra 157 million kg of milk generated by the future daughters of US sires translates directly into an additional volume cost over and above that caused from using solely New Zealand sires. The 'marginal' cost of US genetics will therefore involve not only the reduced profit per cow and per hectare under the current payment system (see Tables 10.8.5 and 10.8.6), but also the larger investment by dairy companies in additional processing capacity. This latter cost will inevitably be transferred back to the farmer through lower milk payouts in the future.

The fluctuating nature of past trends in national milk supply (Dairy Statistics, 1990/91) may make these predicted annual rates of processing expansion difficult to justify, particularly in the case of a poor season where investment in additional capacity remains unutilized. However the converse argument also applies in that industry capacity should stay ahead of expected milk supply trends in the event of a better than average season occurring. This 'catch 22' situation represents the conflict for companies which must maintain processing responsibilities to its suppliers while attempting to run an efficient system with maximum utilization of existing facilities.

The solids concentration of milk determines the processing cost of retrieving a kg of milk fat or protein ie. milk of higher concentration yields a greater quantity of saleable milk solids per unit of volume than milk of lower concentration. The ratio of protein to fat in milk supplied determines the relative value of the total milk solids able to be extracted from a unit of milk ie. milk with a larger protein:fat ratio can be processed into product with a higher marginal value than milk with a lower ratio.

Table 10.9.1 shows that while New Zealand sires will generate increases in overall milk volume, the greater proportional increases in fat and protein will result in a gradual increase in milk solids percentage over the coming years. Although as shown above, annual growth in industry processing capacity is required to meet these changes, the marginal returns on this additional investment should also be increasing due to the larger yields of fat and protein per unit of milk processed. The negligible change in industry protein:fat ratio for New Zealand sires indicates little change in dairy company returns through the mix of protein and fat products able to be manufactured.

The reductions in fat and protein concentrations of milk brought about by the use of U.S sires represents a potentially major cost to the New Zealand dairy industry. Larger volumes of milk supplied per annum would require additional investment by dairy companies in collection, storage and processing facilities as well as aggravating the flush milk problem. A likely result of this would be either a greater penalty for milk volume in the payout and/or a greater emphasis being placed on the production of out-of-season milk. The latter solution would have significant flow-on effects for the development of alternative farming systems and structuring of the industry as a whole.

The decrease in the protein:fat ratio from using U.S sires would alter the range of products which could be made by factories. This in turn would reduce the ability of dairy companies, and subsequently farmers, to take advantage of the high prices of protein relative to fat. This illustrates how the use of foreign genes, although potentially beneficial to herd improvement in the short term, could effectively remove genetic progress from New Zealands long term market realities.

Case Study : New Zealand Dairy Group of Companies

The potential increases in annual production of milk and solids due to genetic improvement over the coming years has been demonstrated in the previous sections. The impact of such changing supply patterns on the processing sector of the dairy industry will depend to a large extent on the planning and decisions made by dairy companies today. The object of this section is to provide an indication of the possible effects of future genetic improvement on the annual throughput of an individual dairy company.

The New Zealand Dairy Group of Companies (NZDGC) is one of New Zealands largest commercial enterprises. In the last four years its annual turnover has doubled from $933 million to $1883 million, aided by the recent incorporation of the former Waikato Valley Dairy Company into its already impressive list of corporate resources. Now the NZDGC processes nearly half of the total volume of milk produced by New Zealand dairy farmers with almost 90% of its products being exported around the world through the New Zealand Dairy Board. In return, these exports generate over 10% of the countries total annual export revenue.

Table 10.9.3 lists the production history of the NZDGC for the past 10 years, excluding the years following the 1990/91 season when figures become distorted by the merger with Waikato Valley. Average annual changes to each production variable over the years since the 1979/80 season are given beneath the respective column.

Since this study deals primarily with genetic improvement in the Jersey breed, an assumption must be made about the breed mix among cows which supply the NZDGC. However since it is unlikely that genetic improvement will be made solely by the Jersey breed, any calculated yield increases based on only a proportion of the total cows milked will be rather meaningless. This is a major limitation of the industry supply trends predicted earlier in this section. For this reason it will be assumed that all cows supplying the NZDGC are Jersey and thus the effect of genetic improvement will be expressed in terms of total milk and solids processed per year by the company.

Using the values in Tables 10.8.1 and 10.8.2, the annual pattern of supply increases for the NZDGC can be predicted under the two scenarios described in previous sections. It is assumed that cow supply numbers remain static at the 1990/91 level. Table 10.9.4 shows these predicted changes for the next 30 years.

Similar to the figures in Tables 10.9.1 and 10.9.2, Table 10.9.4 illustrates the significant influence genetic improvement can be expected to have on the supply of milk to processing companies in the future. Assuming all cows supplying milk are Jerseys, the use of only New Zealand sires could be expected to boost supply by 47.7 million kg (39%), 38.5 million kg (42%) and 908 million kg (36%) for fat, protein and milk

Table 10.9.3 Production history of the New Zealand Dairy Group of Companies (1979-1990)

Season	Herds	Cows	Fat (kg/year)	Protein (kg/year)	Milk (kg/year)
1979/80	4485	622847	96132324		
1980/81	4393	620674	91413109		
1981/82	4439	640016	94696884		
1982/83	4256	620608	91903297		
1983/84	4424	677774	105021804		
1984/85	4364	694513	108470222	77016500	2151628907
1985/86	4497	726268	112743647	79375883	2358076833
1986/87	4466	727896	98426181	74419161	2067318129
1987/88	4621	755703	111916371	84834118	2327440765
1988/89	4659	766754	112517492	85070220	2376402505
1989/90	4703	795418	114117130	86864060	2412757612
1990/91	4765	804893	122235307	91649079	2521128805
Δ / year	33	18601	2450228	2483041	54533772
R^2	0.63	0.96	0.75	0.79	0.57

* R^2 is a measure of the reliability of the estimate, ranging between 0 and 1

respectively. Using only US sires would mean smaller gains in protein supply (28.9 million kg) but a much greater increase in milk volume (1172 million kg).

Unlike the values calculated for the industry as a whole (see Tables 10.9.1 and 10.9.2), a limitation of these figures is that they do not take account of changing cow numbers over the years. In fact, assuming that cow numbers remain static while per cow production increases requires the total area off which milk is produced to increase as a result of the greater annual feed requirements per cow. Since factory supply is a function of the number of cows milked as well as the average yield per cow, trends in cow numbers will play a significant role in determining future supply. Table 10.9.5 gives the predicted annual increase in supply for each milk component over the next 30 years under various scenarios. Annual increases in cow numbers are assumed to be the same as the figure shown in Table 10.9.3.

Table 10.9.4 Predicted increases in the supply of milk and milk solids to the NZDGC over the next 30 years of genetic improvement.

Year	Only New Zealand sires (kg/year)			Only US sires (kg/year)		
	Fat	Protein	Milk	Fat	Protein	Milk
1992	122.2	91.6	2521	122.2	91.6	2521
1997	130.2	98.1	2672	130.7	96.5	2717
2002	138.1	104.5	2824	139.2	101.3	2912
2007	146.1	110.9	2975	147.7	106.1	3107
2012	154.0	117.3	3126	156.2	110.9	3303
2017	162.0	123.7	3277	164.7	115.7	3498
2022	169.9	130.1	3429	173.2	120.5	3693
Total Δ	+47.7	+38.5	+908	+51	+28.9	+1172
% Δ	+39%	+42%	+36%	+42%	+32%	+46%

When assuming that cow numbers remain static over the coming years, the expected annual supply increases generated by genetic improvement are far less than the actual gains experienced to date. If past gains also represent the current annual increase in factory processing capacity, this would suggest that the NZDGC is presently developing at a sufficient rate to cope with future genetic improvement, regardless of how this is achieved. However the large annual increases in cow supply numbers in the past 12 years implies that much of the increased throughput is for this reason rather than solely changes to animal performance. Table 10.9.5 shows that similar increases in future cow numbers combined with predicted genetic gain will more closely match current supply increases. Points to note are that both US and NZL sires would be expected to boost annual fat supply beyond current rates of increase, while protein supply would increase at a lesser rate. NZL sires can be expected to decrease future gains in milk supply, while the US sires would cause annual volume to exceed present rates of gain. This latter observation is undoubtedly the most important difference between the two scenarios, particularly in relation to industry concerns about flush milk volumes. However since the assumption of using only US sires was chosen to represent the extreme case, it could be expected that future rates of gain in factory supply will in fact fall short of this estimate.

Table 10.9.5 Estimates of annual supply increases for the NZDGC under various scenarios

	Annual Supply Increase (million kg/yr)		
	Fat	Protein	Milk
Current Rate	2.45	2.48	54.5
No increase in cow numbers:			
Using NZL sires	1.59	1.28	30.3
Using US sires	1.70	0.96	39.1
Increase in cow no:			
Using NZL sires	2.69	2.17	51.3
Using US sires	2.88	1.63	66.2

10.10 PAYMENT FOR MILK

The composite nature of milk and the varying function and versatility of its component parts means that it can be processed into a wide range of saleable products, each commanding its own specific price in the market place. The combined returns from these products minus processing and running costs represents the profit pool available for distribution by dairy companies among suppliers. The problem then arises as to the fairest way to partition these profits given that the climatic, managerial and genetic factors acting on individual farms will generate milk varying widely in composition and hence final value to the manufacturer. It is this inherent variation which provides the challenge of finding a system of milk payment which fairly reflects the true market value of the different milks produced by farmers.

The inclusion of protein and volume in the milk payout marks a major step in the development of fairer payout systems, succeeding the direct payment for fat used in the past. This officially recognizes for the first time that different milks can vary in composition and provides the farmer not only with a more equitable system of payment but clear market indicators of the type of product desired by consumers. The increasing marginal value of protein relative to fat further emphasizes the importance of differentiating between the milks supplied by individual farmers in order to accurately reward those with higher yields of protein per unit of fat.

The volume charge incorporated into milk payment represents the relative cost of processing milks of varying solids concentrations. Logically the less money spent on obtaining saleable milk solids from a unit of milk, the greater the profit for the dairy company which in turn is redistributed to suppliers. The industry costs incurred by milk volume appear from the moment milk leaves the farm gate and include:

* Investment in tanker fleets
* Transportation costs
* Investment in vat and chiller capacity
* Milk chilling costs
* Initial and/or additional investment in milk processing machinery/technology
* Milk processing costs

(Wiles, 1988)

This mix of capital and running costs means that the effects of milk volume can differ markedly between companies, depending on such factors as the size of the collection area, annual pattern of supply, number of suppliers and the product mix involved. Understandably this makes calculation of the overall costs of volume to the industry very difficult, particularly in the case of predicting future supply and the additional investment required to cope with this.

The significant influence of market trends on the direction of genetic improvement in New Zealand is evident by the more or less simultaneous inclusion of the protein trait both in systems of milk payment and in the selection index used to rank animals in terms of their total economic merit. This link between milk component prices and the selection and breeding of animals for greater economic returns is essential for ensuring genetic progress anticipates future trends in consumer demand. The selection decisions made in the national herd improvement scheme should therefore be optimizing farmer returns under the current milk payment system.

Assuming that increasing total economic return is a common selection objective among dairy populations in other countries, it is logical that the emphasis placed on the various dairy traits differs markedly under local environmental and market conditions. In this way, genetic progress could be made in different areas or traits within respective dairy industries while still maximizing the total economic gain in each. The economic implications of transferring genetic material between breeding populations will therefore depend on the disparity between their respective systems of milk payment and selection objectives for genetic improvement.

For the case of using U.S Jersey sires in New Zealand herds as considered in this study, the differing selection objectives between the two countries are evident in the contrasting rates of genetic gain achieved in the fat, protein and milk yield traits (see Tables 10.8.1 and 10.8.2). Whereas the large U.S domestic milk market provides the motivation for increasing total milk volume, the dependence of the New Zealand dairy industry on international markets for processed dairy products has encouraged selection for greater yields of milk solids. The contrasting emphasis placed on milk concentration in the two countries creates a conflict for farmers wanting to exploit the higher genetic levels of U.S sires for milk solids yield while avoiding the potentially greater volume penalties incurred under the current a+b-c milk payment system.

Tables 10.8.5 and 10.8.6 illustrate the expected trends in profit per cow and per hectare for the two extreme scenarios, in which either the New Zealand Jersey population is assumed to be closed to outside genetic influences or only US sires are used in the industry. The past rates of genetic gain in both countries suggest that the future influence of US genes on average per cow yields in the New Zealand dairy industry will be to increase the yield of milk and decrease the yield of protein relative to the changes induced by New Zealand sires (see Tables 10.8.3 and 10.8.4). The high value of protein relative to fat and the penalty for milk volume in the a+b-c payment system means that these changes will not maximize the increase in marginal returns to farmers: a point clearly illustrated by the results in Tables 10.8.5 and 10.8.6. Thus although the superior genes of individual sires in the U.S Jersey population may be exploited to advantage at present, the contradictory nature of the selection objectives (more versus less concentrated milk) in each country may eventually reduce their worth to the New Zealand industry.

Despite these negative predictions, future market developments which see milk components such as lactose incorporated into the milk payout and/or a reduction in the value of protein relative to fat could see a favourable swing towards the greater milk yields of U.S animals. The limited markets for lactose at present mean that only certain dairy companies process this component, with the returns from lactose being included in the payments for fat and protein. The extent to which this lactose 'loading' is currently partitioned between the fat and protein prices could see significant changes in future selection emphasis if a separate payment for lactose is included in future. Milk yield is strongly linked to lactose synthesis and secretion which may result in increasing value being placed on cows which produce large volumes of milk and hence large yields of lactose. This latter point has major implications for future farming systems, cattle selection programs and breed choice.

The results presented in this study do not suggest that the future use of US Jersey sires is a pointless exercise. Rather, the point being made is that under the assumed rates of genetic gain in each country (see Tables 10.8.1 and 10.8.2), the 'average' US sire will probably become less profitable in the long term than the 'average' New Zealand sire with current systems of milk payment. Assuming that currently the US Jersey population has a small genetic advantage in per cow yields of milk solids and a large advantage in milk yield, it could be 'guesstimated' that milk and fat yields will continue to be led by the New Zealand daughters of such bulls due to the greater rate of genetic progress made by US Jerseys in these traits. However the negative value of milk volume and the low value of fat relative to protein under the current New Zealand milk pricing system makes this the disadvantage of using these sires. Based on the figures in Tables 10.8.3 and 10.8.4, and current prices of milk components, the respective influence of the 'average' New Zealand and US sires on gross milk returns per cow over the next 30 years can be predicted (see Table 10.10.1). Note these figures do not take account of future market trends or inflation/interest rates.

However given the genetic variation which exists in any breeding population, it should still be possible to identify individual US sires which have the appropriate genetic qualities to make them comparable with sires bred within the New Zealand industry. With this in mind, selection of US sires to be used in New Zealand herds should be done carefully, with emphasis being placed on increasing protein yields and decreasing the volume of milk produced per cow. The validity of the conclusions made here will be affected by any changes to the New Zealand milk payment system, US selection objectives and/or the relative prices of milk components. An important point demonstrated by these results is the potentially greater ability of the national herd improvement scheme to make selection decisions which will be beneficial to farmer returns under the environmental and market conditions in which the New Zealand dairy industry operates. Only through the use of locally bred sires can farmers be assured that genetic progress is made in line with New Zealand's future market expectations.

Table 10.10.1 Gross milk returns of the average New Zealand and US sired Jersey daughter over the next 30 years

Year	$/Daughter	
	NZ Sires	US Sires
1992	898	898
1997	962	961
2002	1020	1015
2007	1086	1070
2012	1144	1121
2017	1207	1171
2022	1266	1225

* Assumes $Fat=2.99, $Protein=4.99, $Milk=-0.04

11. CONCLUSIONS

The influence of the 14 selected Jersey sires on farm production and profitability revealed several important relationships between sire merit and changes to average performance per cow and per hectare. **In general,** increasing sire protein BI was associated with:

* greater yields of protein, fat and milk per cow in the herd
* lower achievable stocking rates
* greater marginal profit per cow
* greater marginal profit per hectare

No relationship was found between a sire's BI for fat, protein or milk and his influence on the average liveweight of cows in the base herd.

The positive relationships between sire protein BI and per cow yields of fat, protein and milk reflects the correlated changes to other milk traits which can be potentially achieved by selecting for one trait alone. Thus the influence of a particular sire on farm production and profit, regardless of his merit for protein production, will be the result of total changes to milk composition and not simply an increase in protein yield per cow. The way in which average daughter liveweight was observed to vary at random between the individual sires indicates that the changes they made to stocking rate and profit per cow and per hectare were mainly a result of changing milk composition rather than changing liveweight per cow in the herd.

On average, the four USA sires generated larger increases in yields of milk and milk solids per cow, lowered achievable stocking rates and increased profit per cow and per hectare relative to the 10 New Zealand sires. However since these animals may not be representative of their respective populations, it is unable to determine whether an actual genetic difference between USA and New Zealand Jerseys exist from the results of this study. Results from the sensitivity analysis showed that changing protein prices had the greatest influence on both marginal profit per hectare and the ranking of the 14 sires. The average marginal profit per hectare generated by the USA Jersey sires remained ahead of the New Zealand sires in all cases but the difference was reduced by both a decrease in protein price relative to the other milk components and/or an increase in the milk volume charge. Changing carcass prices had very little effect on either marginal profit per hectare or the ranking of individual sires.

In general, it was found that for two sires which differed by 5 protein BI units to achieve equal profit per cow in the herd, the lower sire must have either +7 fat BI units, -32 milk BI units or daughters weighing an average of 20kg more than the higher sire. Similarly, for two sires which differed by 5 protein BI units to achieve equal profit per hectare, the lower sire must have either +10 fat BI units, -14 milk BI units or daughters weighing an average of 10kg less than the higher sire. Thus sires differing greatly in Payment BI ie. relative merit for different milk components, may actually be very similar in terms of the marginal profit they generate per hectare. From these results the economic influence of a 1kg increase in the average liveweight of cows in the herd was estimated as a reduction of $0.49 in marginal profit per hectare.

Based on estimated rates of genetic improvement in the New Zealand and US Jersey populations, the significant influence of USA sires on decreasing milk concentration and protein:fat ratios per cow should lead to a decline in their long term worth to the New Zealand dairy industry compared with the use of New Zealand sires. Not only will the lower US rate of genetic gain in protein yield disadvantage farmers attempting to increase herd production of this valuable component but the greater milk volumes produced by the daughters of such sires will require a greater investment in additional processing capacity by dairy companies. The marginal cost of using USA Jersey genetics in the long term is therefore likely to be a reduction in the marginal profit per cow and per hectare relative to that achieved by New Zealand sires due to the lower economic returns per kg of milk solids produced as well as greater volume penalties incurred for processing milk.

The contrasting emphasis placed on milk concentration in the two countries creates a conflict for New Zealand farmers currently wanting to exploit the genetic merit of USA Jersey sires for milk solids yield while avoiding the potentially greater volume penalties incurred under the $a+b-c$ milk payment system. However future market developments which see milk components such as lactose incorporated into the milk payout and/or a reduction in the value of protein relative to fat could see a favourable swing towards the greater milk yields of USA Jerseys. Given the lower estimated profitability of the average USA Jersey sire compared with the average New Zealand sire in the future, it should still be possible to identify individual USA sires which have the appropriate genetic qualities to make them economically comparable with sires bred within the New Zealand industry. The major attributes to look for will be the similar to those presently encouraged in New Zealand dairy herds: high milk solids yield, particularly protein, and low milk volume. The advantages of using New Zealand bred Jersey sires in the long term illustrates the potentially greater ability of the national herd improvement scheme to make selection decisions which will be beneficial to farmer returns under the environmental and market conditions in which the New Zealand dairy industry operates.

SUMMARY

A computer model was developed to evaluate the changes to farm production and profitability which could be expected from using dairy sires with high genetic merit for protein yield. Fourteen proven Jersey sires were used in the model, including 10 New Zealand Jersey sires and 4 USA Jersey sires with New Zealand proofs.

Positive relationships were established between sire protein BI and his average effect on yields of fat, protein and milk per cow, achievable stocking rate, marginal profit per cow and marginal profit per hectare in an assumed base herd. No relationship was observed between sire protein BI and the average liveweight of his daughters.

On average, the four USA sires generated larger increases in yields of milk and milk solids per cow, decreased stocking rate and increased marginal profit per cow and per hectare compared with the 10 New Zealand sires. A sensitivity analysis using different prices for milk and meat revealed that the USA sires retained their economic advantage over a wide range of values. However this advantage could be reduced by decreasing protein prices and/or increasing milk volume charges.

Based on estimated rates of genetic gain for the New Zealand and US Jersey populations, using only USA sires in the New Zealand dairy industry could be expected to increase yields of fat and milk per cow and decrease yields of protein over the next 30 years, relative to the case where only New Zealand sires are used. Associated with these changes are a greater supply of fat and milk, and a lower supply of protein to the processing industry over this time compared with New Zealand sires. A major consequence of this is that using only USA sires could be expected to decrease both milk concentration and protein:fat ratios in the long term. This in turn reduces the value of the average USA sire to the industry relative to the changes induced by using only New Zealand bred sires.

However future market developments which see milk components such as lactose incorporated into the milk payout and/or a reduction in the value of protein relative to fat could see a favourable swing towards the greater milk yields of USA Jerseys. Given the lower estimated profitability of the 'average' USA Jersey sire in the future, it should still be possible to identify individual USA sires which have the appropriate genetic qualities to make them comparable with sires bred within the New Zealand industry.

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APPENDIX I - LOOKUP TABLES FOR PREDICTING THE MARGINAL PROFITABILITY PER HECTARE OF PROVEN SIRES

Tables IIa to IIp contained in this section can be used to predict the marginal profitability per hectare (improved herd - base herd) of a sire in the year that his daughters enter their first lactation. This assumes the following base herd characteristics:

* Average herd BI's = 132 Fat, 121 Protein, 119 Milk
* Average herd production = 153kg Fat, 110kg Protein, 2700kg Milk
* Average herd liveweight = 320kg
* Replacement rate = 25%

Each table contains predicted profitabilities for sires with protein BI ranging between 130 and 145, and average daughter liveweights ranging between 270 and 370kg. The tables cover a range of sire fat and milk BI's to provide profitability estimates for a cross-section of possible sire genotypes. The following summary table is a guide to which table will apply to a given sire.

		Fat BI			
		140	**145**	**150**	**155**
Milk BI	**130**	**IIa**	**IIb**	**IIc**	**IId**
	135	**IIe**	**IIf**	**IIg**	**IIh**
	140	**IIi**	**IIj**	**IIk**	**IIl**
	145	**IIm**	**IIn**	**IIo**	**IIp**

An example of using the Lookup Tables: Given a sire with the following characteristics -

* Fat BI = 150
* Protein BI = 145
* Milk BI = 140
* Daughter LWT = 340kg

The appropriate Lookup Table will be IIk. The additional profit per hectare expected from using this bull can be located by finding the row which has his protein BI and the column which has his average daughter liveweight. The value in the table at which the row and column intersect is 23. This sire would therefore be expected to generate an extra $23 per hectare in the year his daughters are first milked in the herd.

Table IIa Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 140
Sire Milk BI = 130

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	43	37	32	26	22	17	12	7	3	-1	-6
132	45	39	34	28	24	19	14	9	5	0	-4
134	47	41	36	30	26	21	16	11	7	2	-2
136	49	43	38	32	27	23	18	13	9	4	-0
138	51	45	40	34	29	25	20	15	11	6	2
140	53	47	42	36	31	26	22	17	13	8	4
142	56	50	45	39	34	29	24	20	16	11	6
144	57	51	46	40	35	30	25	21	17	12	7

Table IIb Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 145
Sire Milk BI = 130

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	45	40	34	29	24	19	14	10	5	1	-4
132	47	41	36	31	26	21	16	12	7	3	-2
134	49	43	38	33	28	23	18	14	9	5	0
136	51	45	40	35	30	25	20	16	11	7	2
138	53	47	42	37	32	27	22	18	13	9	4
140	55	49	44	39	34	29	24	19	15	10	6
142	57	51	46	41	36	31	26	21	17	12	8
144	59	53	48	43	38	33	28	23	19	14	10

Table IIc Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 150
Sire Milk BI = 130

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	48	42	37	31	26	22	17	12	8	3	-1
132	50	44	39	33	28	23	19	14	10	5	1
134	52	46	41	35	30	25	20	16	12	7	2
136	54	48	42	37	32	27	22	18	14	9	4
138	56	50	44	39	34	29	24	20	15	11	6
140	58	52	46	41	36	31	26	22	17	13	8
142	60	54	48	43	38	33	28	24	19	15	10
144	62	56	50	45	40	35	30	26	21	17	12

Table IId Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 155
Sire Milk BI = 130

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	50	44	39	34	29	24	19	15	10	6	1
132	52	46	41	36	31	26	21	17	12	7	3
134	54	48	43	38	33	28	23	18	14	9	5
136	56	50	45	40	35	30	25	20	16	11	7
138	58	52	47	42	37	32	27	22	18	13	9
140	60	54	49	43	39	34	29	24	20	15	10
142	62	56	51	45	40	36	31	26	22	17	12
144	64	58	53	47	42	37	32	28	24	19	14

Table IIe Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 140
Sire Milk BI = 135

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	41	35	30	25	20	15	10	6	1	-3	-8
132	43	37	32	27	22	17	12	8	3	-1	-6
134	45	39	34	29	24	19	14	10	5	1	-4
136	47	41	36	31	26	21	16	12	7	3	-2
138	49	43	38	33	28	23	18	13	9	4	-0
140	51	45	40	34	30	25	20	15	11	6	2
142	53	47	42	36	32	27	22	17	13	8	4
144	55	49	44	38	34	29	24	19	15	10	6

Table IIf Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 145
Sire Milk BI = 135

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	44	38	32	27	22	17	12	8	4	-1	-5
132	46	40	34	29	24	19	14	10	6	1	-3
134	47	42	36	31	26	21	16	12	8	3	-2
136	49	44	38	33	28	23	18	14	9	5	0
138	51	46	40	35	30	25	20	16	11	7	2
140	53	48	42	37	32	27	22	18	13	9	4
142	55	50	44	39	34	29	24	20	15	11	6
144	57	51	46	41	36	31	26	22	17	13	8

Table IIg Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 150
Sire Milk BI = 135

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	46	40	35	30	25	20	15	11	6	2	-3
132	48	42	37	31	27	22	17	12	8	3	-1
134	50	44	39	33	29	24	19	14	10	5	1
136	52	46	41	35	31	26	21	16	12	7	3
138	54	48	43	37	32	28	23	18	14	9	5
140	56	50	45	39	34	29	25	20	16	11	6
142	58	52	47	41	36	31	26	22	18	13	8
144	60	54	49	43	38	33	28	24	20	15	10

Table IIh Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base Herd)

For:
Sire Fat BI = 155
Sire Milk BI = 135

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	48	43	37	32	27	22	17	13	8	4	-1
132	50	45	39	34	29	24	19	15	10	6	1
134	52	46	41	36	31	26	21	17	12	8	3
136	54	48	43	38	33	28	23	19	14	10	5
138	56	50	45	40	35	30	25	21	16	12	7
140	58	52	47	42	37	32	27	22	18	13	9
142	60	54	49	44	39	34	29	24	20	15	11
144	62	56	51	46	41	36	31	26	22	17	13

Table IIi Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 140
Sire Milk BI = 140

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	39	33	28	23	18	13	8	4	-0	-5	-9
132	41	35	30	25	20	15	10	6	2	-3	-7
134	43	37	32	27	22	17	12	8	4	-1	-6
136	45	39	34	29	24	19	14	10	5	1	-4
138	47	41	36	31	26	21	16	12	7	3	-2
140	49	43	38	33	28	23	18	14	9	5	0
142	51	45	40	35	30	25	20	16	11	7	2
144	53	47	42	37	32	27	22	18	13	9	4

Table IIj Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 145
Sire Milk BI = 140

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	42	36	31	25	20	16	11	6	2	-3	-7
132	44	38	33	27	22	18	13	8	4	-1	-5
134	46	40	34	29	24	19	15	10	6	1	-3
136	48	42	36	31	26	21	17	12	8	3	-1
138	50	44	38	33	28	23	18	14	10	5	1
140	52	46	40	35	30	25	20	16	12	7	2
142	54	48	42	37	32	27	22	18	14	9	4
144	56	50	44	39	34	29	24	20	15	11	6

Table IIk Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 150
Sire Milk BI = 140

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	44	38	33	28	23	18	13	9	4	-0	-5
132	46	40	35	30	25	20	15	11	6	2	-3
134	48	42	37	32	27	22	17	13	8	4	-1
136	50	44	39	34	29	24	19	15	10	6	1
138	52	46	41	36	31	26	21	16	12	7	3
140	54	48	43	37	33	28	23	18	14	9	5
142	56	50	45	39	35	30	25	20	16	11	7
144	58	52	47	41	37	32	27	22	18	13	9

Table III Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 155
Sire Milk BI = 140

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	47	41	35	30	25	20	16	11	7	2	-2
132	49	43	37	32	27	22	17	13	9	4	-0
134	51	45	39	34	29	24	19	15	11	6	1
136	52	47	41	36	31	26	21	17	13	8	3
138	54	49	43	38	33	28	23	19	14	10	5
140	56	51	45	40	35	30	25	21	16	12	7
142	58	53	47	42	37	32	27	23	18	14	9
144	60	54	49	44	39	34	29	25	20	16	11

Table IIm Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 140
Sire Milk BI = 145

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	37	32	26	21	16	11	7	2	-2	-7	-11
132	39	34	28	23	18	13	9	4	-0	-5	-9
134	41	36	30	25	20	15	10	6	2	-3	-7
136	43	38	32	27	22	17	12	8	4	-1	-5
138	45	39	34	29	24	19	14	10	6	1	-3
140	47	41	36	31	26	21	16	12	8	3	-2
142	49	43	38	33	28	23	18	14	9	5	0
144	51	45	40	35	30	25	20	16	11	7	2

Table IIn Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 145
Sire Milk BI = 145

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	40	34	29	24	19	14	9	5	0	-4	-9
132	42	36	31	25	21	16	11	7	2	-2	-7
134	44	38	33	27	23	18	13	9	4	-0	-5
136	46	40	35	29	25	20	15	10	6	2	-3
138	48	42	37	31	27	22	17	12	8	3	-1
140	50	44	39	33	28	24	19	14	10	5	1
142	52	46	41	35	30	25	21	16	12	7	3
144	54	48	42	37	32	27	23	18	14	9	5

Table IIo Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 150
Sire Milk BI = 145

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	42	36	31	26	21	16	11	7	3	-2	-6
132	44	38	33	28	23	18	13	9	5	0	-4
134	46	40	35	30	25	20	15	11	7	2	-3
136	48	42	37	32	27	22	17	13	8	4	-1
138	50	44	39	34	29	24	19	15	10	6	1
140	52	46	41	36	31	26	21	17	12	8	3
142	54	48	43	38	33	28	23	19	14	10	5
144	56	50	45	40	35	30	25	21	16	11	7

Table IIp Marginal profit per hectare from using Jersey sires of different protein BI after first generation daughters have completed one lactation in a base herd (ie. Improved Herd - Base herd)

For:
Sire Fat BI = 155
Sire Milk BI = 145

AV. DAUGHTER LIVEWEIGHT (kg)

SIRE PROTEIN BI	270	280	290	300	310	320	330	340	350	360	370
130	45	39	34	28	24	19	14	9	5	1	-4
132	47	41	36	30	25	21	16	11	7	2	-2
134	49	43	38	32	27	23	18	13	9	4	-0
136	51	45	39	34	29	24	20	15	11	6	2
138	53	47	41	36	31	26	21	17	13	8	4
140	55	49	43	38	33	28	23	19	15	10	5
142	57	51	45	40	35	30	25	21	17	12	7
144	59	53	47	42	37	32	27	23	18	14	9

APPENDIX II - CALCULATION OF GENETIC GAIN IN THE NEW ZEALAND JERSEY POPULATION

Assuming a multiple trait selection index using four traits and selecting for Total Economic Value (TEV) ie.

$$TEV_{\alpha} = v_1 G_{\alpha 1} + v_2 G_{\alpha 2} + v_3 G_{\alpha 3} + v_4 G_{\alpha 4} \qquad [1]$$

where v_i = relative economic value (REV) of trait i

$G_{\alpha i}$ = additive genetic value of animal α for trait i

Traits of interest are:

* Fat yield
* Protein yield (Prot)
* Milk yield
* Cow liveweight (LWT)

The first step in evaluating TEV for animal α is to estimate the genetic value (G_{ij}) for each trait separately using available records ie.

$$G_{ij} = b_{1i} X_{1j} + b_{2i} X_{2j} + b_{3i} X_{3j} + b_{4i} X_{4j} \qquad [2]$$

where b_{ij} = weighting value of the ith trait for each jth trait being evaluated

X_{ij} = record on the ith trait being weighted for each jth trait being evaluated

Estimates for dams are based on single records for each trait while estimates for sires are based on single records for each trait measured on 55 daughters.

The weighting values (b_{ij}) of the ith trait for the jth trait being evaluated can be calculated as:

$$b = P^{-1} G$$

where b = weighting value

P^{-1} = inverse of Var-Cov matrix of information available (Phenotype)

G = Var-Cov matrix of traits being predicted (Genetic)

P and G matrices have the following format:

$$\begin{bmatrix} Var\ Fat & Cov\,(Fat, Prot) & Cov\,(Fat, Milk) & Cov\,(Fat, LWT) \\ & Var\ Prot & Cov\,(Prot, Milk) & Cov\,(Prot, LWT) \\ & & Var\ Milk & Cov\,(Milk, LWT) \\ & & & Var\ LWT \end{bmatrix}$$

* All matrices are symmetrical ie. numbers above the diagonal are the mirror image of those below the diagonal.

For dams, matrices used are:

$$P = \begin{bmatrix} 513.6 & 309.8 & 8010.9 & 16.3 \\ 309.8 & 230.8 & 5740.4 & 12.7 \\ 8010.9 & 5740.4 & 165091.0 & 307.8 \\ 16.3 & 12.7 & 307.8 & 14.4 \end{bmatrix}$$

$$G = \begin{bmatrix} 131.0 & 72.7 & 1832.5 & 5.8 \\ 72.7 & 55.9 & 1352.5 & 4.4 \\ 1832.5 & 1352.5 & 43231.0 & 90.5 \\ 5.8 & 4.4 & 90.5 & 2.3 \end{bmatrix}$$

For sires, matrices used are:

$$P = \begin{bmatrix} 41.9 & 23.4 & 593.0 & 1.7 \\ 23.4 & 17.7 & 434.6 & 1.3 \\ 593.0 & 434.6 & 13487.4 & 27.7 \\ 1.7 & 1.3 & 27.7 & 0.82 \end{bmatrix}$$

$$G = \begin{bmatrix} 65.5 & 36.4 & 916.3 & 2.9 \\ 36.4 & 28.0 & 676.2 & 2.1 \\ 916.3 & 676.2 & 21615.5 & 45.2 \\ 2.9 & 2.2 & 45.2 & 1.1 \end{bmatrix}$$

Using [1] gives the following vectors of weighting values for each trait for dams and sires respectively:

Dams:

		Trait evaluated			
		Fat	Protein	Milk	Liveweight
Trait Weighted	Fat	0.354487	-0.01859	-1.21098	0.003301
	Protein	-0.0759	0.297377	-3.70498	0.026754
	Milk	-0.00374	-0.00142	0.446912	-0.00082
	Liveweight	0.151347	0.093782	1.361199	0.146956

Sires:

		Trait evaluated			
		Fat	Protein	Milk	Liveweight
Trait Weighted	Fat	1.581554	-0.0427	-1.00022	0.002799
	Protein	-0.01383	1.687149	-4.76429	0.048135
	Milk	-0.00179	-0.00271	1.791324	-0.00106
	Liveweight	0.306549	0.177714	4.288251	1.331558

Substituting the genetic value of each trait (G_{ij}) as estimated in [2] into [1] and using the vector of REV's given below, the overall weighting (b) for each trait used in the index to estimate TEV are:

$$\text{Vector of REV's} = \begin{bmatrix} Fat \\ Prot \\ Milk \\ LWT \end{bmatrix} = \begin{bmatrix} 0.1087 \\ 1.0000 \\ -0.0074 \\ -0.1358 \end{bmatrix}$$

$$b\ (\ Dams\ ) = \begin{bmatrix} Fat \\ Prot \\ Milk \\ LWT \end{bmatrix} = \begin{bmatrix} 0.0289 \\ 0.3165 \\ -0.0051 \\ 0.0802 \end{bmatrix}$$

$$b\ (\ sires\ ) = \begin{bmatrix} Fat \\ Prot \\ Milk \\ LWT \end{bmatrix} = \begin{bmatrix} 0.1366 \\ 1.7209 \\ -0.0162 \\ -0.0015 \end{bmatrix}$$

The expected responses per year from selection for TEV can be estimated as:

$$\Delta\ TEV = \frac{\bar{i}\ \sigma_I}{L}$$

where $\bar{\imath}$ = selection intensity factor

σ_I = standard deviation of the linear function (selection index)

L = generation interval

The correlated genetic response per year for the individual traits included in the index can be found by the regression of G_{ij} on TEV (ie. the overall index) multiplied by the selection intensity factor ($\bar{\imath}$) and divided by the generation interval (L).

$$\Delta\ G_{ij} = \frac{Cov\ (\ G_{ij}\ ,\ TEV\ )}{\sigma_I} \times \frac{\bar{i}}{L} \qquad [3]$$

where ΔG_{ij} = expected correlated response in trait i per year from selection for TEV

σ_I = Standard deviation of overall index for TEV

In matrix form [3] becomes:

$$\Delta G_{ij} = \left[\frac{m' \; G \; b}{\sqrt{b' \; P \; b}} \right] \times \frac{\bar{i}}{L}$$

where m′ = transpose of a special vector composed of a 1 and zeros, the order of which determines the trait of interest ie. when m′ = [1 0 0 0] fat is the trait of interest.

Selection intensities ($\bar{i}$) and generation intervals (L) assumed for each pathway of selection are:

Selection Pathway	**$\bar{i}$**	**L**
Sires of bulls	**2.116**	**6 years**
Sires of cows	**1.435**	**7 years**
Dams of bulls	**2.484**	**4 years**
Dams of cows	**0.211**	**5 years**

The expected responses in each trait calculated using [3] are:

$$\Delta G_{Fat} = \frac{[(0.21 \times 4.94) + (2.48 \times 4.94) + (1.44 \times 8.86) + (2.12 \times 8.86)]}{5 + 4 + 7 + 6}$$

$$= 2.04 \; kg \; / \; year$$

$$\Delta G_{Prot} = \frac{[(0.21 \times 3.65) + (2.48 \times 3.65) + (1.44 \times 6.58) + (2.12 \times 6.58)]}{5 + 4 + 7 + 6}$$

$$= 1.51 \; kg \; / \; year$$

$$\Delta G_{Milk} = \frac{[(0.21 \times 73.6) + (2.48 \times 73.60) + (1.44 \times 146.75) + (2.12 \times 146.75)}{5 + 4 + 7 + 6}$$

$$= 32.7 \; kg \; / \; year$$

$$\Delta G_{LWT} = \frac{[(0.21 \times 0.35) + (2.48 \times 0.35) + (1.44 \times 0.54) + (2.12 \times 0.54)]}{5 + 4 + 7 + 6}$$

$$= 0.13 \; kg \; / \; year$$

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