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Improved profitability and sustainability in asparagus production

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1 Executive summary

Asparagus yields in New Zealand are relatively low by world standards. To improve the industry's international competitiveness, the New Zealand Asparagus Council (NZAC) has set the goal of doubling the national average yield by 2010. If this can be achieved it would increase the value of the industry's output by about $15 million per annum. This three-year project was led by a group of progressive asparagus growers who wanted to take a leading role in achieving this goal by improving the productivity, profitability and sustainability of their businesses, and by using the project as a focus for technology transfer to other growers.

The group decided to focus on three objectives that were identified as key issues for productivity of asparagus crops in New Zealand:

1. maintaining plant population, particularly in establishing crops;
2. feasibility of increasing production by extending the usual harvest period; and
3. managing crops during the restorative fern growth period.

The project included a mixture of activities, including field trials, crop monitoring and technology transfer. In keeping with the intent of MAF Sustainable Farming Fund projects, there was strong emphasis on technology transfer to encourage involvement by growers and maximise the project's impact. During the three years, the project was featured at four field days and three research seminars (two national and one regional), nine items about it were published in *Spearhead* (the industry newsletter that is distributed to all asparagus growers in New Zealand), and results were published in two technical reports (including this final report) and a paper at an international conference.

As the project evolved, it emerged that the greatest value in terms of outcomes with worthwhile practical benefits was coming from work in the first objective. Therefore, following the preference of participating growers, more effort was put into this topic and less on the other two as the project progressed. The plant population topic was given high priority because the loss of plants from crops, especially during the early years, is a common reason for low asparagus yields in New Zealand. The project produced outcomes to help minimise plant losses during crop establishment that have been well publicised. Already these outcomes are being adopted by growers. They include: a simple procedure that growers can use to quantify plant losses from their crops; growers are now requiring high quality planting material (uniform, large crowns) from nurseries instead of accepting inferior crowns that result in poor crop establishment; and growers understand the need not to harvest crops during the first establishment year because of the high risk of causing early plant losses.

Extending the usual harvest period in established crops can allow growers to produce higher yields. Furthermore, the additional production could be obtained at the time of year when asparagus prices are usually highest. The project demonstrated that this is feasible provided the harvest extension is managed to minimise the risk of adversely affecting the long-term viability of crops. The main outcome is that growers have been challenged to get away from the traditional calendar-based close-up time, and to base the decision about when to stop harvesting on several factors. These include the condition of the crop, market opportunities at the time and the need to ensure the long-term sustainability of crops.

Most costs for crop management inputs are incurred during the restorative fern growth period when root system resources needed to produce yield in the following season are generated. Growers can influence fern growth mainly by managing nutrient and water availability and controlling foliar diseases such as *Stemphylium*. Higher yields and/or reduced costs could result from better management during this period. The project focused on availability of nutrients, particularly nitrogen (N) and boron (B), because N and B fertilisers are commonly applied to asparagus despite uncertainty about whether they produce any benefit. The outcome was that growers are rethinking their N and B fertiliser management, with the prospect of reducing costs, because no yield benefit was found from applying either nutrient.

2 *Introduction*

Early in 2002 a group of asparagus growers, one from each of the four main production regions, applied successfully for a grant from the MAF Sustainable Farming Fund (SFF) to conduct a three-year project. The four members of the Progressive Asparagus Growers' Group were Bryan Elliott (Waikato), Paul Smith (Hawke's Bay), Peter Wallis (South-west North Island) and Geoff Dillon (Canterbury). Derek Wilson and Sarah Sinton (Crop & Food Research) and the Executive Officer of the New Zealand Asparagus Council (NZAC; initially Kate Ward and, later, Helen Barnes) were also included in the project group.

Asparagus yields in New Zealand are relatively low by world standards. To improve its international competitiveness, the industry has set the goal of doubling the national average yield by 2010. If this can be achieved it would increase the value of the industry's output by about $15 million per annum. The project was proposed by a group of growers who wanted to take a leading role towards achieving the industry's target by improving production, profitability and sustainability in their own crops. They also wanted to use the project as a focus for technology transfer to other growers.

This report describes the project, which ran from July 2002 to June 2005.

3 Financial

The project was co-funded by the SFF and the NZAC, and it was managed by the NZAC. Financial details for the project are provided in Appendix I.

4 Project planning and objectives

The project group held a planning meeting in June 2002. Project objectives, management procedures and allocation of responsibilities were discussed and agreed. The group decided to focus on three objectives about crop management topics that were identified as key issues.

1. **Maintaining plant population.** A common reason for low asparagus yields in New Zealand is the loss of plants from crops, especially during the early years. Therefore, ***the first objective*** was to find ways to minimise plant losses during crop establishment.

2. **Length of harvest.** Higher yields can sometimes be achieved by extending the harvest period in established asparagus crops, often at the time of year when prices are highest. Therefore, ***the second objective*** was to determine when harvests can be extended without too much risk of adversely affecting the long-term viability of crops and to develop guidelines for deciding when to stop harvesting.

3. **Management during fern growth.** Higher yields could result from better management during fern growth because root system resources needed to produce yield in the following season are generated during this period. Therefore, ***the third objective*** was to determine the effects on fern growth and subsequent yield of the availability of nutrients, particularly nitrogen (N) and boron (B). Both are thought to be key elements of fertiliser management for asparagus crops but, in both cases, there is considerable uncertainty about the need for them.

The project was designed to include a mixture of activities on each topic, including field trials, crop monitoring and technology transfer, and the group aimed to involve as many growers as possible in the activities. As the project evolved during the three years, it emerged that the greatest value in terms of practical benefits was coming from work in the first objective. Therefore, following the preference expressed by participating growers, more effort was put into this topic and less on the other two as the project progressed.

5 Maintaining plant population

5.1 Introduction

Sustainable production of high yielding asparagus crops depends on establishing and maintaining a population of vigorous, productive plants. However, good planting material is not always available and there is often pressure to start harvesting early to recoup costs and begin making a profit. As a result, plant loss from establishing crops is common in New Zealand, and it causes irreversible long-term loss of potential yield. Once plants have been lost, the remaining adjacent plants are unable to compensate by producing extra yield. Lost plants leave gaps, and gaps don't produce yield.

Most crops in New Zealand are established by planting one-year old crowns and then harvesting during the establishment years. This contrasts with standard practice in highly productive European asparagus systems where crops are established by planting large (>70 g fresh weight), uniform crowns and not harvesting them during the first establishment year. The result is that plant losses are low in European crops and high in New Zealand ones.

The project group hypothesised that there are two main causes of plant death in New Zealand crops:

- ***small and/or variable planting material.*** Asparagus is usually established by planting crowns grown from seed in a nursery, and their size and vigour can vary considerably. This can lead to a few large, vigorous plants quickly dominating weaker ones in the population. Small crowns have small buds and limited root resources, and they produce fewer, smaller ferns. They take longer to establish and are more likely to die in the first year, especially under adverse conditions such as drought and weed infestation.
- ***over-harvesting in the early years****.* Crops are usually harvested for short periods to obtain some income in the establishment years. However, this could penalise the developing plants and, especially, aggravate the problem of competition between strong and weak plants.

The objective of this part of the project was improve long-term crop performance by finding ways to minimise plant losses, especially in the early years and, thereby, maintain most of the initial plant population without sacrificing too much yield. Two field trials were established, one each in Waikato and Canterbury, to determine whether plant losses could be reduced and yields increased by establishing crops with large, uniform crowns, and not harvesting them in the establishment years. Treatments consisted of grading crowns into various sizes before planting and varying harvest management in the first two years.

As well as the trials, plants were monitored in young commercial crops by working with other growers in each region. This involved observing crops in different situations to quantify plant survival and death.

5.2 Population and harvesting trials

5.2.1 Methods

Similar trials were set up on two growers' properties in Waikato and Canterbury during spring 2002. Four treatments were established by planting crowns with different sizes and degrees of uniformity. The crowns for each treatment were obtained by grading from mixed populations provided by the host growers. The cultivars were Apollo and JWC1 in Waikato and Canterbury respectively. First the size distribution of each population was determined by individually weighing about 500 randomly selected crowns and plotting their distributions. The results showed that crown size was very variable in both populations, with the majority of crowns between about 6 and 46 g in both cases (Fig. 1).

The four crown size treatments were defined on the basis of the results in Figure 1: small (6-16 g), medium (20-30 g), large (36-46 g) and variable. The latter treatment was established by planting small, medium and large crowns systematically along the rows. A total of 4500 crowns, about 1500 of each size, was planted in each trial. Crowns from 17 to 19 g and 31 to 35 g were discarded to give a clear distinction between the small, medium and large grades.

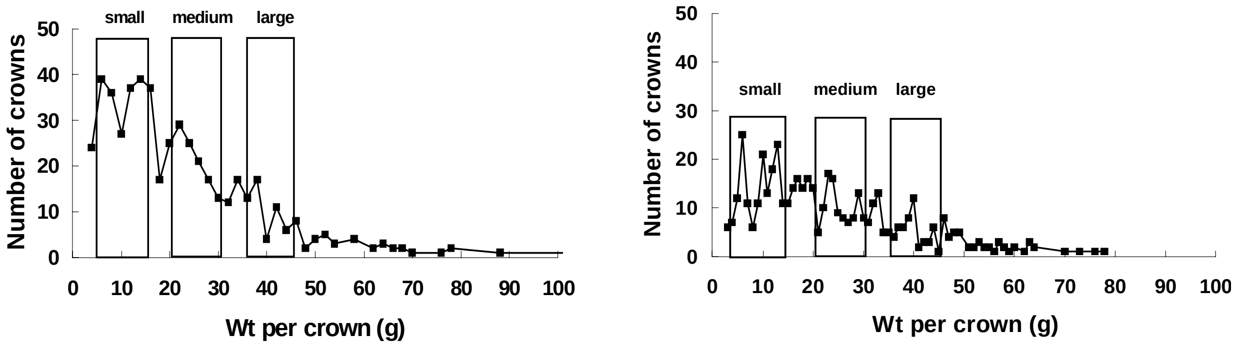

Figure 1: Weight distributions of about 550 Apollo crowns in the Waikato trial (left) and about 500 JWC1 crowns in the Canterbury trial (right). The vertical columns indicate the size ranges that were defined for the small, medium and large crown size treatments.

Each crown size treatment was subjected to three harvest duration treatments to apply different degrees of stress to the establishing plants during the first two years:

- **Treatment 1:** Differed between the trials. In the Waikato trial there was no harvest in the first year and a 12-week harvest in the second year. In the Canterbury trial there was no harvest in both years. These corresponded with common practice by growers in each region;
- **Treatment 2:** Short harvests of 3 and 8 weeks in years one and two respectively;
- **Treatment 3:** Longer harvests of 6 and 12 weeks in years one and two respectively.

The Waikato trial was a randomised complete block design with three replicates. The trial in Canterbury was a factorial row-column design, so the analysis of results accounted for the effects of an adjacent belt of deciduous trees. There were 36 plots in each trial. Each plot consisted of three 11 m rows. Spacings were 1.5 m between rows and 0.3 m between plants within rows, giving a population equivalent to 22 000 plants/ha. Results from the trial in Waikato were analysed by ANOVA, and results from the trial in Canterbury were analysed with a mixed model analysis fitted with REML (restricted maximum likelihood) as implemented in GenStat. Apart from the crown size and harvest treatments, the trial crops were managed by the host growers using standard best practices for establishing asparagus crops.

Every plant in each plot (a total of about 9000) was assessed during fern growth in the autumn of 2003, 2004 and 2005 (i.e. 6, 18 and 30 months after planting). Each time, each plant was either recorded as missing or given a vigour rating. Within each plot, vigour was scored as low (1), medium (2) or high (3), based on a visual assessment of fern number and relative fern size within the plot. Low vigour plants had less than 4 small ferns per plant, medium had an average fern size with between 4 and 6 ferns, and high vigour plants had more than 6 large ferns per plant. In addition to the within-plot scores, in 2004 and 2005 each plot was given an overall vigour rating by identifying the weakest and most vigorous plots and rating them 1 and 5 respectively. The addition of these scores to form a scale from 1 to 8 allowed plant vigour to be compared among plots.

Total spear yield in the harvest length treatments was measured during spring 2003 and 2004. It was estimated by counting spears regularly (daily in the Waikato trial and less frequently in the Canterbury trial where production was slower). These counts were used with results from counting and weighing spears every 10 days to calculate the yields.

5.2.2 Results

1. Plant losses

Initial plant establishment was good in all treatments. However, a significant number of plants had already been lost by the time the first observations were made in autumn 2003 (Table 1). In both trials the highest number of plants, about 7% of the planted population (equivalent to 1500 plants/ha), was lost from the plots with small crowns. Losses were smaller and similar in the other three treatments (about 2-4%). The overall loss of plants in the first year was less in the Canterbury trial. Most losses were from small crowns that failed to establish in the stressful conditions of a shorter growing season with a dry climate and a sandy river terrace soil. The greater loss in the Waikato trial was probably caused by substantial weed competition. This highlights the need for good weed control from the start to ensure good plant establishment.

By the third year (2005) about 8 and 4% of plants had been lost in plots established from large crowns in the Waikato and Canterbury trials respectively. Corresponding values were about 16 and 11% for small crowns. Losses were intermediate and similar in the treatments established with medium and variable crowns (about 11 and 8% in Waikato and Canterbury respectively).

Plant losses were higher in plots that were harvested in spring 2003 and 2004. In the worst case, 17 and 25% of plants were lost from plots that were established from small crowns and had long harvests in the Waikato and Canterbury trials respectively. In contrast, only about 3% of plants died in plots that were established from large crowns and not harvested during establishment.

Table 1: Missing plants (%) during the fern growth period in the autumn of each year.

	Waikato trial			Canterbury trial		
Treatment	*2003	2004	2005	*2003	2004	2005
Harvest:						
No	3.2	3.5	9.5	5.1	3.4	2.6
Short	5.9	5.9	12.2	1.5	4.5	5.1
Long	4.4	7.6	13.2	1.4	11.4	17.0
LSD (*P* = 0.05)	1.8	2.6	3.8	4.6	4.5	4.1
Crown size:						
Small	7.3	9.9	16.3	6.8	10.0	11.5
Medium	3.6	4.9	11.0	0.8	6.7	7.3
Large	3.3	3.3	7.7	1.3	2.7	4.3
Variable	3.8	4.6	11.7	1.8	6.3	9.7
LSD (*P* = 0.05)	2.1	3.5	4.4	5.5	6.1	5.2
H x CS Interaction	*	N.S.	N.S.	*	N.S.	N.S.

*No harvest in the first year.

2. Plant vigour

Plants grew more vigorously overall in the warmer Waikato climate. However, this difference is not reflected in the vigour scores in Table 2, which are independent for each trial. Despite the overall difference between trials, the responses to the treatments were similar.

Crown size and harvest treatment both affected plant vigour. In general, harvest length had more effect on vigour than crown size in both years, especially in the Canterbury trial. For all crown sizes, plant vigour was increasingly reduced by lengthening harvest duration, especially after the first harvest with the longest duration. This effect was less marked after the second harvest. In both trials vigour was greatest in plants that were grown from large crowns and not harvested in the first year, whereas plants grown from small crowns were less vigorous. Vigour was intermediate in plots established with crowns of medium or variable size. The effect of crown size on vigour was large in 2004 and had diminished by 2005, but by this time more plants had been lost from plots established from small crowns.

Table 2: Plant vigour during the fern growth period in the autumn of years 2 and 3. Vigour was scored from 1 to 8 with 1 = low vigour and 8 = high vigour. See text for details of vigour assessments.

	Waikato trial		Canterbury trial	
Treatment	2004	2005	2004	2005
Harvest:				
No	6.9	5.7	6.4	7.2
Short	6.3	6.3	5.2	5.7
Long	4.9	5.4	2.5	4.5
LSD (*P* = 0.05)	0.7	0.7	0.6	0.4
Crown size:				
Small	5.4	5.2	3.2	5.4
Medium	6.2	5.7	3.6	5.8
Large	6.8	6.2	6.6	6.0
Variable	5.6	6.1	5.6	6.0
LSD (*P* = 0.05)	0.8	0.8	0.7	0.5
H x CS Interaction	*	N.S.	**	N.S.

3. Spear yield

Yields at the end of the short and long harvest periods in both years are presented in Tables 3 and 4 for the Waikato and Canterbury trials respectively.

In 2003, the mean yield after 3 weeks of the first harvest in the Waikato trial was about 430 kg/ha and, by this time, the plants in the small and variable crown treatments had already produced over 100 kg/ha less than those established from medium and large crowns. The mean yield after 6 weeks of harvest had approximately doubled to almost 1000 kg/ha, and the plots established from medium and large crowns had produced almost 200 kg/ha more than the others. Overall yields were substantially higher in the Canterbury trial, mainly because of higher production during the first 3 weeks of harvest, and responses to the crown size and harvest treatments were similar to those in the Waikato trial.

Table 3: Total spear yields (kg/ha) in the Waikato trial. Yields are for the initial short harvest periods (3 and 8 weeks in years 2 and 3) and for the long periods (6 and 12 weeks in years 2 and 3).

	2003		2004		Total	
Treatment	3 wks	6 wks	8 wks	12 wks	Short	Long
Harvest:						
No	0	0	1857	2348	1857	2348
Short	424	424	1962	1962	2386	2386
Long	437	993	1644	2050	2080	3043
LSD (*P* = 0.05)	68	100	171	186		
Crown size:						
Small	346	586	1716	1989	2062	2575
Medium	488	779	1765	2034	2253	2813
Large	493	825	2102	2474	2595	3300
Variable	395	644	1700	1983	2095	2627
LSD (*P* = 0.05)	97	141	148	215		
H x CS Interaction	N.S.	N.S.	*	*		

Table 4: Total spear yields (kg/ha) in the Canterbury trial. Yields are for the initial short harvest periods (3 and 8 weeks in years 2 and 3) and for the long periods (6 and 12 weeks in years 2 and 3).

	2003		2004		Total	
Treatment	3 wks	6 wks	8 wks	12 wks	Short	Long
Harvest:						
No	o	0	0	0	0	0
Short	912	912	2134	2134	3046	
Long	901	1297	1354	1796		3093
LSD (*P* = 0.05)	275	366	191	262		
Crown size:						
Small	661	864	1411	1631	2070	2494
Medium	894	1024	1761	1933	2654	2957
Large	1229	1515	2026	2313	3256	3828
Variable	842	1019	1778	1983	2620	3002
LSD (*P* = 0.05)	409	542	274	377		
H x CS Interaction	N.S.	N.S.	N.S.	N.S.		

The trends were similar in the second harvest in 2004. The mean yields in the Waikato trial after 8 and 12 weeks of harvest were 1820 and 2150 kg/ha respectively. A significant interaction occurred because the yield was much higher from the plants established from large crowns, irrespective of the length of harvest in the previous year. After 8 weeks the plots established from large crowns had produced almost 400 kg/ha more than the others. At this point, plants from small, medium and variable sized crowns that were subjected to a long harvest in the year before had yielded less than their counterparts with a short harvest in the year before. The former had a slower rate of production that was evident from the start of harvest (data not shown). Also at 8 weeks, yields differed among crown size treatments that were not harvested in the first year. Previously unharvested plants from small crowns produced more than those that had been harvested, whereas large crowns produced the same, and medium and variable sized crowns the same or less.

Yield responses in the Waikato trial in 2004 were similar to those in the Canterbury trial except that yields from plants established from large crowns in the cooler climate of Canterbury were more affected by harvesting in the first year and grew less vigorously. After the first 8 weeks of the second harvest in Canterbury, all crown sizes that were harvested for the long period in the year before, including the large ones, had yielded much less than their counterparts that had received an initial short harvest. After a further 4 weeks of harvest, the large crowns eventually produced only as much over the 12 weeks as large crowns that had short harvests in both years, unlike in Waikato.

Overall, in both trials across both years, yields were highest from the longer harvest and from plants established from larger crowns. However, in addition to causing greater plant losses, longer harvests in the first year led to a slower spear production rate throughout the second year, resulting in lower yields, especially for plants grown from small crowns.

5.2.3 Discussion

Results from the two trials show clearly that crown size at planting and harvesting strategy both strongly influence plant survival, vigour and yield in the establishment years. Planting crowns that were too small and then harvesting early caused plant losses, reduced plant vigour and lowered yields. Conversely, crops established from large crowns were more vigorous, lost fewer plants, produced higher yields and were better able to tolerate the stresses caused by harvesting in the first 2 years.

From the first year of planting, before any harvest, low vigour was already evident in the plants established from the smaller crowns. They were less able to cope with stresses caused by competition from weeds and dry conditions during summer, and many died. Some of the crowns that survived died later when spears were harvested from them. However, most plants established from smaller crowns that were left unharvested in the first year went on to become successful, vigorous plants. In some cases, these yielded as much in one harvest in the second year as in two short harvests in years 1 and 2, but with lower risk of plant losses. On the other hand, planting larger crowns reduced the risk of plant death during establishment and led more quickly to vigorous, well established plants. Also, they were better able to withstand earlier harvesting.

Larger crowns are more vigorous because, in addition to their greater size, they have more resources in terms of buds and storage roots. This was illustrated by measurements on a sample of the JWC1 crowns used in the Canterbury trial. The results showed that the larger crowns had twice as many buds and roots as the small ones (Fig. 2).

The economic impact of losing plants from crops is immediate, and has a permanent effect on the profitability and sustainability of a crop. Yield reduction is directly proportional to the number of plants lost from the population because remaining plants cannot compensate for the loss. The scale of the impact can be assessed easily. For example, assume that a typical crop has a population of 22 000 plants/ha. Also assume that, once fully established, an average plant in the crop produces 20 spears per season and each spear has 20 g of saleable weight. Thus the average plant produces 0.4 kg of spears per season. On this basis, the potential annual yield is about 8900 kg/ha. If 10% of plants are lost from the crop (i.e. 2200 plants/ha), the annual yield reduction is 890 kg/ha.

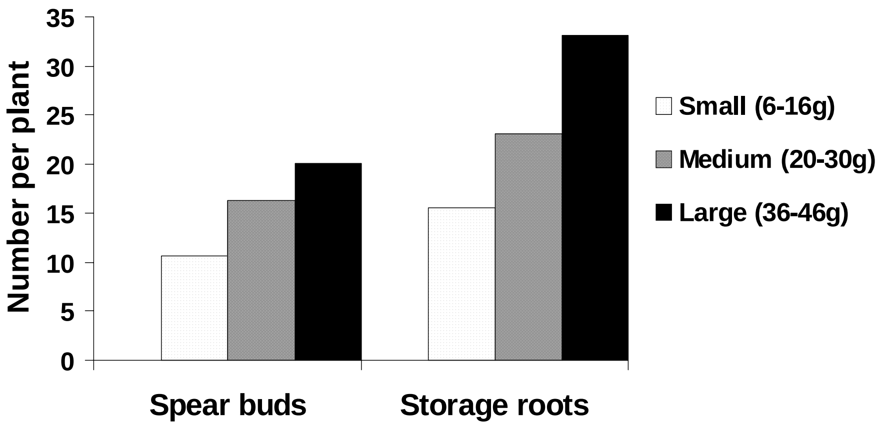

Figure 2: Numbers of buds and storage roots per crown for small, medium and large JWC1 crowns used in the Canterbury trial.

The importance of establishing crops by planting large, uniform crowns with high vigour is well recognised in European asparagus production. Considerable effort is devoted to producing high quality crowns through intensive management during nursery production, and crowns are graded to assure uniformity of size. Larger crowns attract a premium price, and smaller ones are discounted. In the Netherlands, for example, premium A-grade crowns weigh from 80 to 120 g and B-grade crowns weigh from 50 to 80 g. Crowns smaller than 50 g are rejected. The minimum acceptable crown size in France and Germany is also 50 g.

Virtually all the crowns in both the Waikato and Canterbury trials were below this minimum value. About 50% weighed 20 g or less and only about 20% were big enough for the large grade (over 36 g) (Fig. 1).

We conclude that more care is needed to produce higher quality crowns for establishing asparagus crops in New Zealand. Although it may not be economic to adopt European standard practice, we need to find ways to grow more larger crowns and to improve uniformity of crown size in nursery production systems. Growers will need to accept that the cost of plant material will be higher, and be prepared to discard small crowns. However, the benefits are clear. Therefore, we recommend (a) that crowns should be grown and graded to produce a uniform size with at least 40 g per crown minimum weight and (b) that crops should not be harvested in the first establishment year.

5.3 Population monitoring in commercial crops

In addition to the trials, growers in each region were invited to participate by monitoring plants in their own establishing crops. The aims were to quantify plant survival and loss in different situations and, also, to demonstrate monitoring techniques so that growers can observe their own crops in the future. Six 10 m lengths of row were marked out in each of 10 young crops in Waikato, Manawatu and Canterbury during the fern growth season in autumn 2003. Then every plant in each row was observed during fern growth in 2003, 2004 and 2005. Plants that had died were recorded, and each surviving plant was given a low, medium or high vigour score based on a visual assessment of its fern size and number.

The results from the first year are in Figure 3. There was a consistent pattern of size distribution across most of the crops. About 45% of the plants were of medium vigour, 25% were small, 25% were large and 5% were missing. The main exceptions occurred in three crops in Waikato. Crop W1 had an unusual distribution, with many small and large plants. Many of the small ones died in the first year because they had grown from small, reject crowns that were planted by mistake. The gaps left by these plants were replanted with new crowns in the spring of the second year. During the summer, the replacement plants were dominated by their neighbours and remained small. Crop W2 had an unusually high proportion of large plants, presumably because it was grown from large, vigorous crowns. Crop W3 suffered competition from a severe grass weed infestation and many of the plants either remained small or did not survive.

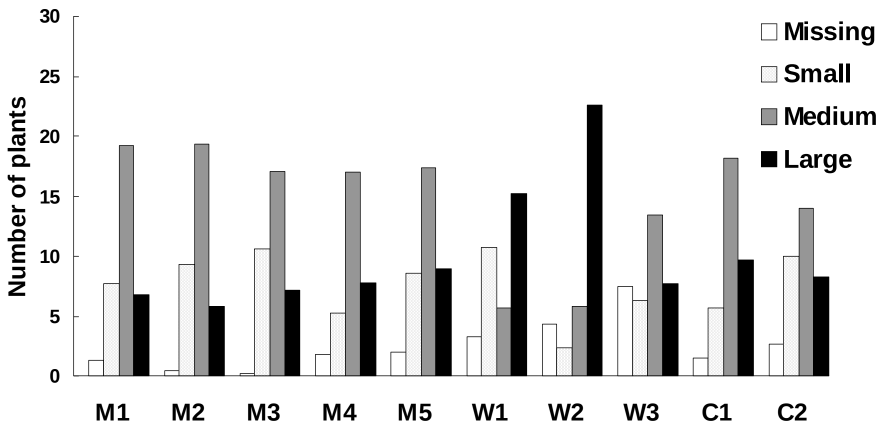

Figure 3: Numbers of missing, small, medium and large plants in 10 establishing commercial crops in Manawatu (M), Waikato (W) and Canterbury (C) in autumn 2003.

Plant losses in the second and third years differed among the crops. In some cases (M4, M5, W3, C1 and C2) few further plants died after the losses in the first year while in others (M1, M2, M3, W1 and W2) losses continued in the second and third years. Over 20% of the plants were missing from half of the crops by the end of the third year.

In general, vigour of the surviving plants continued to increase so that most were rated as medium or large by the third year in six of the ten crops. On the other hand, after accounting for lost and small plants, less than 60% of plants were medium or large in the other four crops.

These results from 10 commercial crops indicate that there is considerable scope to improve the establishment of asparagus crops in New Zealand. Information from the trials in this project showed how this can be achieved.

6 *Length of harvest*

Most asparagus growers in New Zealand stop harvesting and close-up their crops in December. However, there is often a good opportunity to achieve higher yields by extending the harvest period in established crops without adversely affecting their long-term viability. Furthermore, the additional production could be obtained in late December and early January when asparagus prices are usually highest.

The objectives of this part of the project were: (a) to determine when harvests can be extended without too much risk of causing yield reductions in following years, and (b) to develop guidelines for deciding when to stop harvesting, taking account of the status of resources in the root system (particularly soluble carbohydrate (CHO) content) which are depleted during harvest. Deciding when harvest can be extended safely depends on: the level of root resources at which it is advisable to stop harvesting; the latest close-up that will allow enough time for fern growth and recharge of root resources in autumn; and the balance between benefits (extra yield) and disadvantages (risk of running crops down, missed yield opportunities) of extra harvesting.

Three trials were set up in Waikato, Hawke's Bay and the central North Island to examine the effects of harvest duration treatments on established crops.

6.1 Waikato trial

6.1.1 Methods

The trial was set up in spring 2002 in an established high-yielding Jersey Giant Syn 4 crop with a large storage root system. Three harvest treatments were applied: usual grower practice, with close-up in late December; extended harvest with close-up a week later than the first treatment; and close-up when root CHO content dropped to about 300 mg/g, but no later than 12 January. There were three replicates of each treatment. Plots were 12 m long x 5 rows (7.5 m) wide. The two outside rows were buffers, two were used for spear yield measurements, and one was used for root and fern sampling.

The CHO content of root samples was determined several times during 2002 and 2003 using standard measurement procedures. Spear yield was measured during the 2002 harvest season. It was estimated by counting the number of spears every day. Mean spear weight, which changes slowly with time, was determined every 7 to 10 days by measuring and weighing a sample of spears from each plot. The longer term impact of the treatments was assessed by measuring spear yields again in the following spring. All treatments were harvested for the same duration, with close-up on 30 December 2003.

6.1.2 Results

Root samples taken in early spring 2002, at the start of the harvest period, had an average CHO content of 415 mg/g. Since the crop had a large root system, this indicated a good level of root CHO recharge during the previous season, and good potential for a high spear yield.

The high CHO content led to high yields in all treatments, with an average saleable yield of 6740 kg/ha. The yield increased as the harvest duration increased (Table 5). The yield from the treatment based on root CHO content was lowest (6290 kg/ha) because it was closed up first, on 29 December following a root CHO content reading of 318 mg/g on 19 December. The early summer period was cool and spear production was slow. For this reason the grower stopped harvesting about a week later than usual, on 5 January 2003. By that time the root CHO content was 302 mg/g and the yield was 550 kg/ha higher than from the 29 December close-up. The root CHO content was only slightly lower (300 mg/g) when the extended harvest treatment was closed up a week later, on 12 January 2003. By that time a further 240 kg/ha had been harvested.

Table 5: Saleable spear yields (kg/ha) in the three harvest treatments in the Waikato trial in 2002 and 2003.

Treatment	Close-up date	2002	2003	Total
Root CHO content close-up	29 Dec 2002	6290	6780	13070
Grower close-up	5 Jan 2002	6840	6990	13830
Extended close-up	12 Jan 2002	7080	5880	12960

Root CHO replenishment in autumn was disrupted in February by an outbreak of *Stemphylium,* which was earlier and more severe than usual. This was followed by a flush of new fern growth. By 9 April 2003, root CHO content had recovered to 352, 367 and 342 mg/g in the CHO content, grower practice and extended harvest treatments respectively.

The treatments had different carry-over effects on the saleable yields in the second harvest, which ended on 30 December 2003. At that time, root CHO content had dropped to 268, 293 and 271 mg/g in the CHO content, grower practice and extended harvest treatments respectively. The yield was similar in the two treatments which had the shorter harvests in 2002, but it was reduced by about 1000 kg/ha following the longest harvest in the previous season. The combined result was that the total yield over the two seasons was highest from the treatment with intermediate harvest length.

6.2 Hawke's Bay trial

6.2.1 Methods

This trial was similar to the one in Waikato except that harvests were done over three seasons, and there were only two treatments which were applied in the first and third seasons.

The trial was set up in an established, high-yielding Jersey Giant Syn 4 crop with a large storage root system on 29 December 2000. In one treatment the plots were closed up on that day, which was the same as usual grower practice. In the other treatment, an extended harvest was continued for another 17 days, until 15 January 2001. In the second season (spring 2001) the longer term impact of the treatments was assessed by harvesting both treatments for the same duration, with close-up on 29 December 2001. In the third season, harvest in the usual grower treatment ended on 20 December 2002 whereas it continued for another month, until 19 January 2003, in the extended harvest treatment. There were three replicates of each treatment. Plots were 10 m long x 5 rows (7.5 m) wide. The two outside rows were buffers, two were used for spear yield measurements, and one was used for root and fern sampling.

6.2.2 Results

In the first season (2001), the 17-day extension of harvest produced an extra yield (saleable for canning) of 1220 kg/ha (Table 6). After the harvest, the new fern growth was infected by a severe outbreak of *Stemphylium* in February. The disease was controlled partially by two fungicide applications, but then another flush of new fern growth occurred. This was probably triggered by a combination of the *Stemphylium* infection and rain that occurred at the same time. Then another *Stemphylium* infection occurred in March. The result of these events was that root CHO accumulation was disrupted, and the root CHO contents at the end of the season were lower than desirable. Values were 422 and 361 mg/g in the usual close-up and extended harvest treatments respectively, so the adverse effect was greater in the extended harvest treatment.

Table 6: Saleable spear yields (kg/ha) in the two harvest treatments in the Hawke's Bay trial in 2000, 2001 and 2002.

Treatment	2000	2001	2002	Total
Grower close-up	--	9550	7610	17160
Extended close-up	1220	7520	11970	20710

Despite the relatively low root CHO content values, spear yields were high in the following season (Table 6), probably because the crop was well established with a large root system. However, the different root CHO contents resulted in a substantial yield difference between the treatments (2030 kg/ha), which more than cancelled out the advantage of the extra yield in the previous extended harvest. Root CHO contents at the end of harvest were 335 and 287 mg/g in the usual close-up and extended harvest treatments respectively. Conditions for fern growth after close-up were much better than in the previous year, and fern growth was good. However, there was a clear difference between the treatments. On 27 February 2002, fern biomass was 7800 and 4700 kg/ha in the usual close-up and extended harvest treatments respectively. These treatments had similar numbers of ferns, but ferns were smaller in the extended harvest treatment. In both cases there was little disruption to fern growth, and root CHO contents at the end of autumn were 494 and 467 mg/g in the two treatments. These values were much higher than in the previous season, and indicated that the crop was well placed to support an extended spear harvest in the 2002-03 season.

This indication proved to be correct. Yields in 2002 were also high, and the extra month in the extended harvest treatment produced additional yield of 4360 kg/ha (Table 6). Thus, despite the penalty in the second year, the strategy of alternate extended and normal harvest durations produced an overall yield advantage of 3030 kg/ha over the three years.

6.3 Central North Island trial

6.3.1 Methods

This trial was set up on 16 December 2003 in an established high-yielding JWC1 crop with a moderately sized storage root system. Three harvest treatments were applied for the rest of that season and in the following two years: usual grower practice, with close-up in early January; harvest extended by seven days; and harvest extended by 14 days. There were three replicates of each treatment. Plots were 10 m long x 5 rows (7.5 m) wide. The two outside rows were buffers, two were used for spear yield measurements, and one was used for root and fern sampling.

The CHO content of root samples was determined several times during 2004 and 2005 using standard measurement procedures. In the first year, spear yield was measured in the extended harvest treatments from the time of grower close-up on 6 January 2004 until 13 and 20 January respectively. In the second year, yield was measured during the season until the three close-up dates – 18 and 26 January and 3 February 2005.

6.3.2 *Results*

In the first season, root CHO content was 338 mg/g at the usual close-up time on 6 January 2004, and the 7 and 14-day harvest extensions went on to produce extra yields of 580 and 1380 kg/ha (Table 7). Root CHO content at the end of the 14-day extension was 316 mg/g.

Table 7: Saleable spear yields (kg/ha) in the three harvest treatments in the Central North Island trial in 2004 and 2005.

Treatment	Summer 2004	2005	Total
Grower close-up	--	5590	5590
Harvest extended 7 days	580	6400	6980
Harvest extended 14 days	1380	7060	8440

The fern generally grew well over the summer and early autumn period, but it was partly defoliated by a *Stemphylium* infection in early April. Fungicide was applied but, because of a delay caused by unsuitable weather conditions, it was too late to prevent defoliation. On 20 April 2005, fern biomass following the normal harvest treatment was 2160 kg/ha, and it was 1470 and 1340 kg/ha following the 7 and 14-day extended harvests respectively. These values would have been higher if measured a few weeks earlier, before defoliation. Ideally, crops with moderately sized root systems should reach 450 mg/g by the end of fern growth in order to expect a normal spear harvest the next season. Although the fern biomasses were relatively low, they were enough to fully replenish the root system. Root CHO contents were 499, 454 and 451 mg/g in the three treatments on 20 April 2004.

Yields in 2005 were also high, and the extra 7 and 14 days in the extended harvest treatments produced additional yields of 810 and 1470 kg/ha respectively (Table 7). Thus, the extended harvest durations produced overall yield advantages of 1390 and 2850 kg/ha respectively over the 2 years. Furthermore, these gains were achieved without any apparent adverse effects. Root CHO contents were 507, 467 and 464 mg/g in the three treatments on 23 May 2005, indicating that the crops were well placed to produce high yields in spring 2005.

6.4 Discussion

Results from all these trials showed that there was a yield advantage from longer harvests in established crops. Furthermore, the additional yields were obtained at the time of year when asparagus prices are usually highest. However, the results from Waikato showed that there can be an adverse carry-over effect if the harvest is extended too much. The option of using alternate extended and normal, or perhaps shorter, harvest durations could be a good strategy for obtaining higher yields without too much risk. Whatever the strategy, root CHO contents should be monitored to ensure that the status of resources in the root system is not allowed to go too far below recommended guidelines.

The long-term effect of extended harvests on crop viability remains uncertain. Ideally, studies such as these need to be extended over more seasons to define better how far crops can be extended without too much risk of causing long-term harm.

7 Management of fern growth

Management during the fern growth phase in summer and autumn is important because the root system resources for spear production in the following season (i.e. new buds and CHO) are generated during this period. Therefore, higher yields and/or reduced costs could result from better management during fern growth. In general, the aim is to encourage and maintain production of healthy fern in order to maximise accumulation of reserves in the roots for driving spear production the following season, but to avoid unnecessary excessive growth.

Growers can influence fern growth mainly by managing nutrient and water availability and control of foliar diseases such as *Stemphylium*. In this project it was decided to focus on availability of nutrients, particularly nitrogen (N) and boron (B). N fertiliser is often applied because it is thought to be necessary to boost fern growth. B is also commonly applied because asparagus is thought to be sensitive to B deficiency. However, in both cases, there is uncertainty about whether they produce any benefit in terms of their effects on fern growth, CHO accumulation in the root system and, ultimately, spear yield.

Three field trials were established in growers' crops, two in Waikato and one in the south-west North Island, to determine the effects of N fertiliser application on fern growth, root CHO content and yield. Responses to B application were investigated in a fourth trial in Waikato.

7.1 Waikato N trial #1

7.1.1 Methods

The first N fertiliser trial in Waikato was set up in spring 2002 in an established high-yielding Jersey Giant Syn 4 crop. Four N fertiliser treatments were applied in 2002 and 2003: no fertiliser; 100 kg N/ha applied as urea (N

= 46%) in spring, at the start of the harvest season; 100 kg N/ha applied as urea at close-up, on 5 January and 30 December 2003; and 200 kg N/ha applied at close-up. There were four replicates of each treatment. Plots were 12 m long x 5 rows (7.5 m) wide. The two outside rows were buffers, two were used for spear yield measurements, and one was used for root and fern sampling.

Soil N status and root CHO content were measured at the start, on 19 September 2002. Then spear yields were measured in the first two treatments in spring 2002 to determine whether there was any effect of the N application at the start of harvest. Spear yield was measured again in all treatments in spring 2003 and 2004. Fern N content and root CHO content were determined at the end of the season, in April 2003, and fern biomass and N content were measured at the end of the second season, in March 2004.

7.1.2 Results

A readily available soil N value of 43 kg N/ha on 19 September 2002 showed that N fertility at the site was low. For most crops this would indicate a strong likelihood of a yield response to N fertiliser application. However, subsequent results showed that N application had little effect on the asparagus crop.

Root CHO content on 19 September 2002 was 428 mg/g. Since the crop had a large root system, this indicated a good level of root CHO recharge during the previous season, and good potential for a high spear yield. Saleable yields were high, with 7580 and 7040 kg/ha in the 0 and 100 kg N/ha treatments respectively. Therefore, if anything, there was a suggestion of a yield reduction with the N application at the start of harvest. However, the difference was not significant.

Fern growth on 9 April 2003 appeared to be greater in all three treatments with N applied than in the one with no N applied. However, the crop was badly affected by Stemp*hylium* and this made it impossible to measure fern biomass. Mean foliar N content was 2.9%, which was within the normal range of 2.5-4.0%, and there was no significant difference among the treatments. The root CHO content in the treatment with no N applied was lower (343 mg/g) than in the other three treatments (Mean = 368 mg/g, LSD = 28 mg/g).

Root CHO content on 10 September 2003 averaged 426 mg/g. Subsequent yields differed as a result of the N applications in the previous year. At 5880 kg/ha, the yield following the highest N fertiliser application (200 kg N/ha) was significantly lower (P = 0.05) than following the other three treatments. The latter were similar with a mean yield of 7160 kg/ha.

Fern biomass and N content on 4 March 2004 averaged 3490 kg/ha and 3.6% respectively, with no difference among the treatments. Root CHO content on 16 September 2004 averaged 380 mg/g, and ensuing spear yields averaged 6890 kg/ha. There were no significant differences, but once again there was a tendency for a lower yield with the 200 kg N/ha fertiliser application.

7.2 Waikato N trial #2

7.2.1 Methods

The second N fertiliser trial in Waikato was set up with three unreplicated demonstration plots in a grower's established crop. Readily available soil N was measured at the end of harvest on 8 January 2003, and then three N fertiliser treatments were applied: no fertiliser; 100 and 200 kg N/ha as urea (N = 46%). The same treatments were applied again after the following harvest, on 18 December 2003. Plots were 20 m long x 5 rows (7.5 m) wide.

Fern numbers and N content were measured on 10 April 2003, and fern biomass was measured again on 5 March 2004.

7.2.2 Results

A readily available soil N value of 52 kg N/ha on 8 January 2003 showed that N fertility at this site was also low. However, once again, the N applications had little effect.

Fern number and N content on 5 March 2004 were 13/m of row and 3.5% respectively, and appeared very similar in all the treatments. Fern biomass on 5 March 2004 averaged 4580 kg/ha, and was similar for all the treatments. After discussions with the host grower, plans to measure spear yields were abandoned after the N treatments had no effect on fern growth.

7.3 South-west North Island N trial

7.3.1 Methods

This trial was set up in a lower yielding crop on 15 December 2003, at the end of harvest. Three N fertiliser treatments were applied: no fertiliser; 100 and 200 kg N/ha as urea (N = 46%). There were three replicates of each treatment. Plots were 10 m long x 5 rows (7.5 m) wide. The two outside rows were buffers, two rows were used for spear yield measurements, and one row was used for root and fern sampling.

Fern biomass was measured on 2 March 2004, root CHO content was measured at the start of harvest on 16 September 2004, and spear yields were measured in spring 2004.

7.3.2 Results

A readily available soil N value of 37 kg N/ha showed that N fertility was low. Fern growth was good in autumn 2004, with an average biomass of 4460 kg/ha on 2 March. Biomass was lowest (4000 kg/ha) in the 0 kg N/ha treatment, but it was not significantly lower than in the treatments with N application. Root CHO content at the start of harvest averaged 502 mg/g, and was similar for all treatments. Subsequent spear yields were also similar for all treatments, with an average of 3810 kg/ha.

7.4 Waikato B trial

7.4.1 Methods

The B response trial in Waikato was set up in an established high-yielding Jersey Giant Syn 4 crop. Three B fertiliser treatments were applied at close-up on 5 January 2003 and again on 30 December 2003: no fertiliser, and 1.5 kg and 3.0 kg B/ha applied as Boronat (B = 10%). There were three replicates of each treatment. Plots were 10 m long x 5 rows (7.5 m) wide.

Soil B status was measured at the start of the trial, on 19 September 2002. Fern B content was measured on 5 May 2003 and 4 March 2004, and spear yield was measured during spring 2003 and 2004.

7.4.2 Results

The soil test showed that the soil B level was relatively low (hot water soluble B was 1.5 mg/kg). Fern growth on 9 April 2003 appeared to be similar in all of the B treatments. The crop was badly affected by *Stemphylium* and this made it impossible to measure fern biomass. There was no significant difference in foliar B content. Values were 38, 41 and 31 mg/kg for the 0, 1.5 and 3.0 kg B/ha treatments respectively. These were all at the lower end of the normal range for asparagus fern (30-150 mg/kg). Despite this, there was no significant spear yield response to B application in either season.

7.5 Discussion

Application of N and B fertilisers to asparagus crops is common practice. However, there was no evidence from these trials of any benefit from applying N or B. In both cases this result occurred even though soil N and B fertility levels were relatively low.

The usual rationale for applying fertiliser is that it is thought to be needed for encouraging and maintaining the production of healthy fern. However, stimulating unnecessary excessive growth can be counterproductive in asparagus because the diversion of resources to fern may reduce accumulation of reserves in the roots for driving spear production in the following season.

Large nutrient inputs should not be needed for asparagus because removal in the harvested spears is very small. For example, in the case of N, a relatively high 7 t/ha spear yield removes only 21 kg N/ha, assuming it has typical dry matter and N contents of 10 and 3% respectively. A substantial amount of N is required for fern growth. For example, 6 t/ha of fern biomass requires about 180 kg N/ha. However, this N is not removed. Most of it is returned to the soil and recycled for growth in the following season.

There was consistently no response to fertiliser applications in these trials. If this result has wider applicability it might be possible for growers to increase profitability by reducing fertiliser applications without any reduction in crop productivity. Fertiliser application is probably worthwhile in some circumstances because there is evidence that asparagus does respond to the availability of nutrients. For example, recent work at Massey University has shown that N availability may have a role in stimulating bud initiation and development during spear growth. However, it remains to be shown that this can be connected to positive effects on yield. The challenge is to define when it is necessary, or not necessary, to apply fertilisers, and how much it is economic to apply.

8 Outcomes

From an early stage the project had a strong profile among asparagus growers, and this led to early impacts on management decisions that influence production and sustainability of crops. In particular, important practical messages about the establishment and management of young crops have emerged. The project achieved the following outcomes:

- ***Growers are very aware of the benefits of using high quality crowns to establish crops.*** Initial results from the population trials showed a clear benefit of establishing crops by planting uniform large crowns, and growers started to stipulate that they would only accept large crowns from nurseries. This was a significant change in their decision making because, previously, they had accepted inferior crowns that resulted in poor crop establishment.
- ***Growers know that they should avoid harvesting crops in the first establishment year.*** Despite economic pressure to start harvesting early, growers now understand the need not to harvest crops during the first year because of the high risk of causing early plant losses and, therefore, compromising long-term sustainability.
- ***Growers have options for more flexible end-of-harvest management practices.*** Additional production is possible at the time of year when asparagus prices are usually highest by extending the usual harvest period. The project demonstrated that this is feasible provided the extension is managed to minimise the risk of adversely affecting the long-term viability of crops. The project has challenged growers to get away from the traditional calendar-based close-up time, and to base the decision about when to stop harvesting on several factors. These include the condition of the crop, market opportunities at the time and the need to ensure the long-term sustainability of crops.
- ***Growers can increase profitability by reducing fertiliser inputs during fern growth.*** The project reduced uncertainty about the need for N and B fertiliser applications by showing that they produced no yield benefits in several trials.
- ***Growers have a package of guidelines to help achieve increased production.*** The project provided an excellent forum for a sustained period of technology transfer activities focused on improving asparagus productivity (see Section 9). In addition to its immediate objectives, it was the culmination of a 12-year programme of research on the yield physiology and agronomy of asparagus which was funded by the Foundation for Research, Science and Technology, Technology New Zealand, the NZAC and the SFF. The key practical messages from this

research were summarised in a poster presentation at the NZAC Research Seminar in June 2005. The text from that presentation is in Appendix II.

9 Technology transfer

In keeping with the intent of SFF projects, there was a strong emphasis on technology transfer to encourage grower involvement and maximise the project's impact. The following activities ensured that the project had a high profile in the industry during its three years.

9.1 Field days

Presentations were made at four field days during the project: south-west North Island growers' field days in March 2003 and 2004, and South Island growers' field days in March 2004 and 2005. Handouts with information about the project were distributed each time.

9.2 Seminars

Presentations about the project were made at NZAC Research Seminars in June 2003 and 2005. Two poster displays were also presented at the 2005 seminar. Also, a presentation was made at the South Island Asparagus Growers' Association annual meeting in August 2003. Handouts were distributed to participants at each event.

9.3 *Items in* Spearhead

Articles about the project were published regularly in the industry newsletter (*Spearhead*) which is distributed to all asparagus growers in New Zealand. Items were included in the following editions: winter and spring 2002, autumn 2003, autumn 2004 (3) and autumn 2005. The full mid-project report was distributed to all growers in a research supplement with the winter 2004 edition of *Spearhead*. Key findings from the final report will be published in another research supplement with the spring 2005 edition.

9.4 Conference paper

A paper on the plant population aspect of the project (Minimising plant losses in establishing asparagus crops, by Sarah Sinton and Derek Wilson) was presented at the 11th International Asparagus Symposium in The Netherlands in June 2005. The paper will be published in *Acta Horticulturae* and includes acknowledgements to the SFF and NZAC.

9.5 Technical reports

In addition to this final report, a substantial mid-project progress report was completed in February 2004 and distributed to growers at seminars and field days. Three articles with main points from the report were published in the autumn 2004 edition of *Spearhead* and the report was included in a research supplement with the winter 2004 edition of *Spearhead*.

9.6 Further plans

The NZAC has indicated informally that it may support follow-up technology transfer activities, such as more presentations at seminars and field days, to ensure that the practical messages are reinforced to growers after the project has ended.

10 Acknowledgements

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Appendices

Appendix I Financial details

Progressive Asparagus Growers
Final Report: Income & Expenditure

Short Title: Improved Profitability and Sustainability in Asparagus Production
Grant Number: 02/108

All figures include GST

	Year 1 2002-03	Year 2 2003-04	Year 3 2004-05	Total
Income				
SFF Grant	$ 44,948.00	$ 44,948.00	$ 44,948.00	**$ 134,844.00**
Other - NZ Asparagus Council	$ 16,875.00	$ 16,875.00	$ 16,875.00	**$ 50,625.00**
Total income	$ 61,823.00	$ 61,823.00	$ 61,823.00	**$ 185,469.00**
Expenditure				
Cash	$ 61,823.00	$ 61,823.00	$ 61,823.00	**$ 185,469.00**
In-Kind	$ 55,900.00	$ 55,900.00	$ 67,900.00	**$ 179,700.00**
Cash Surplus (Deficit)	**$ -**	**$ -**	**$ -**	**$ -**

Appendix II Guidelines for higher asparagus yields. Text of a poster presented at the NZAC Research Seminar, June 2005

Background

New Zealand Asparagus Council Goal: *Double the national average yield by 2010*

The Goal Is Achievable:

- Currently the average yield is only about 3 t/ha.
- Many crops are performing well below potential so there scope for improvement.
- There are some very high yielding crops in New Zealand to take a lead from.
- Research has shown how to achieve high yields.

Objectives

1. What are the key features of high yielding crops?
2. What is required to achieve high crop performance?

Features of High Performance Crops

1. **Plant population at least 15,000 per ha and a low proportion of gaps in rows.**
    - Most crops start with about 20,000 plants per ha, and sometimes more.
    - Many crops lose plants, with some losing as many as 50%.
    - Most losses occur during the establishment years.
    - Missing plants leave gaps which neighbours cannot fill.
    - Yield reduction is related to the amount of gaps, because gaps don't produce yield.
2. **Root biomass greater than 10 t/ha.**
    - Large root systems can store more carbohydrate (CHO).
    - Root biomass varies from about 2 to 20 t/ha.
    - Biomass depends on plant population and size per plant.
    - Plant size can vary ten-fold, from about 0.12 to 1.2 kg.
    - 10 t/ha requires 15,000 plants/ha with an average size of about 0.7 kg/plant.

3. **Root CHO greater than 4 t/ha at the start of harvest.**
    - CHO is the 'fuel' that drives spear and fern growth.
    - Spear yield is related to the amount of available CHO.
    - CHO weight depends on root CHO content and root biomass.
    - Root CHO content at the start of harvest can vary from about 30% to 60%.
    - For a 10 t/ha root system this translates to a range of 3 to 6 t /ha of CHO.
4. **Saleable yield over 70% of total yield.**
    - Yield only has value if it is harvested and sold.
    - Up to 50% of total yield is not recovered in some crops.
5. **The best crops have all these features.**

How to Achieve High Performance

1. **Grow asparagus in deep, free-draining, unimpeded sandy-silt soils.**
    - Deep cultivate before planting if necessary to remove impediments to root growth.
    - Plant establishment is better.
    - Plants are vigorous and develop large root systems.
    - Plant survival is better.
    - There is less risk of soil-borne disease such as *Phytophthora*.
    - Crops planted in heavy soils with pans or other physical impediments to root growth are penalised from the start.
2. **Plant large, uniform crowns.**
    - Only use the best quality plant material.
    - Insist on graded crowns of uniform size.
    - Ideally, crowns should be no smaller than 50 g.
    - Plant establishment is better.
    - Plants are vigorous and develop large root systems.
    - Crops are better able to tolerate small harvests in the establishment years.
    - Plant survival is better.
    - The extra cost is a worthwhile investment.

3. **Don't harvest in the establishment year.**
   - Plant establishment is better.
   - Plants are vigorous and develop large root systems.
   - Plant survival is better.
   - Long-term crop performance is better.
4. **Optimise harvest management and opportunity.**
   - Monitor root CHO using the ***AspireNZ*** system.
   - Anticipate an early end to harvest if root CHO content is low at the start of spring.
   - Stop harvesting when root CHO content reaches 300 mg/g.
   - Don't over-harvest; stop early if necessary, especially in young, establishing crops.
   - Continue harvesting later than usual to maximise yield when safe to do so.
   - Leave enough time in summer-autumn for fern growth to recharge root CHO.
5. **Optimise management during fern growth.**
   - Monitor root CHO using the ***AspireNZ*** system.
   - Aim for a root CHO content above 500 mg/g by the end of autumn.
   - Manage inputs to maximise root growth and CHO accumulation:
     - encourage good initial fern growth.
     - avoid unnecessary excessive fern growth, especially later flushes, which can be stimulated by factors such as excessive irrigation or fertiliser.
     - avoid premature loss of fern caused by factors such as *Stemphylium*, and water or nutrient stress.
     - maintain healthy fern until the target CHO content is reached.
   - Anticipate a shorter, smaller harvest next spring if root CHO content is low at the end of autumn.
6. **Use best management practices for asparagus.**
   - Follow advice in the New Zealand Asparagus Manual concerning plant establishment, water and nutrient management, and weed, pest and disease control.
7. **Manage crops to maintain the established plant population.**
   - Follow rules 1 to 6.