Weed Control Practices

in New Zealand Pipfruit Orchards

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ABSTRACT

A survey of 77 growers, mainly in Hawkes Bay and Nelson, was undertaken during the summer of 1989/90. Personal interviews were conducted on each property. All growers were found to use herbicides for weed control, and all but one established herbicide strips with mown grass between. The major herbicide application period was spring. Three-quarters of growers relied on four herbicide formulations, amitrole, glyphosate, simazine and terbuthylazine/terbumeton. Of the residual herbicides used, 70% were triazines. Grower knowledge about herbicides was found to be lacking.

Grass species from the sub-family Paniceae were found to be the most problematic weeds, along with mallows, black nightshade, Californian thistle, tall willow herb and docks. These weeds were not adequately controlled by current weed control practices. Off-label use and herbicide damage to crop trees was noted.

Growers were found to be applying herbicides through a wide array of equipment, through fan and off-centre nozzles with one to four nozzles on each boom.

Only 37% of sprayers were calibrated at least annually. During the survey 41 sprayers were calibrated, with only 17% being correct within ± 5% of intended application rate. Of those sprayers with errors over ±5% two-thirds were underapplying at mean error of 37%, and one-third were overapplying at a mean error of 18.1%. Spray distribution patterns were found to be unacceptably uneven across the herbicide strip in most cases.

Over 40% of growers were not able to relate the actual amount of herbicide used to a target application rate per hectare.

A lack of training in both chemical use for weed control and sprayer calibration was apparent, and 80% of growers saw a need for a field manual.

ADDITIONAL KEYWORDS

New Zealand; pipfruit; weed control practices; herbicide use; sprayer calibration; accuracy of application; portable spray patternator.

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Common names for plants have been sourced from Healy, (1984).

apple	Malus domestica Borkh.
amaranthus	Amaranthus spp.
asparagus	Asparagus officinale L.
barnyard grass	Echinochloa crus-galli (L). Beauv.
black nightshade	Solanum nigrum L.
bracken fern	Pteridium esculentum (Forst.f.) Ckn.
brambles	Rubus spp.
bristle grass	Setaria spp.
broad leaved plantain	Plantago major L.
Californian thistle	Cirsium arvense (L.) Scop.
catsear	Hyphochaeris radicata L.
cocksfoot	Dactylis glomerata L.
cornbind	Polygonum convolvulus L.
couch	Agropyron repens (L.) Beauv.
creeping buttercup	Ranunclulus repens L.
creeping mallow	Modiola caroliniana (L.) G. Don.
creeping yellow cress	Rorippa sylvestris (L.) Besser.
docks	Rumex spp.
dwarf mallow	Malva neglecta Wallr.
fathen	Chenopodium album agg.
fennel	Foeniculum vulgare Mill.
field bindweed	Convolvulus arvensis L.
fleabane	Conyza spp.
French mallow	Malva nicaeensis All.
gorse	Ulex europaeus L.
greater bindweed	Calystegia silvatica (Kit.) Griseb.
groundsel	Senecio vulgaris L.
hawksbeard	Crepis capillaris (L.) Wallr.
hedge mustard	Sisymbrium officinale (L.) Scop.
Indian doab	Cynodon dactylon (L.) Pers.
Jersey cudweed	Gnaphalium luteo-album L.

large flowered mallow	Malva sylvestris L.
mercer grass	Paspalum distichum L.
narrow leaved plantain	Plantago lanceolata L.
nashi	Pryus pyrifolia (Burm.f.) Nakai var. culta (Makino) Nakai.
nectarine	Prunus persica (L.) Batsch var. nectarina (Ait) Maxim.
oxalis	Oxalis spp.
oxtongue	Picris echioides L.
paspalum	Paspalum dilatatum Poir.
penny royal	Mentha pulegium L.
phalaris	Phalaris aquatica L.
praire grass	Bromus willdenowii Kunth.
ryegrass	Lolium spp.
scrambling speedwell	Veronica persica Poir.
sheeps sorrel	Rumex acetosella L.
small flowered mallow	Malva parviflora L.
summergrass	Digitaria sanguinalis (L.) Scop.
sweet gum	Liquidamber styraciflua L.
tall willow herb	Epilobium cillatum Rat.
thorn apple	Datura stramonium L.
white clover	Trifolium repens L.
wild carrot	Daucus carota L.
wireweed	Polygonum aviculare agg.
yarrow	Achillea millefolium L.
yorkshire fog	Holcus lanatus L.

LIST OF CHEMICALS

Chemical names (IUPAC) have been sourced from Worthing and Walker (1987).

amitrole	1H-1,2,4-triazol-3ylamine
asulam	methylsulphanilylcarbamate
clopyralid	3,6-dichloropyridine-2-carboxylic acid
diazanon	0,0-diethyl 0-2-isopropyl-6-methyl pyrimidin-4-yl phosphorothioate
dicamba	3,6-dichloro-o-anisic acid
diquat	9,10-dihydro-8a, 10a-diazoniaphenanthrene
diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
fluazifop-P-butyl	(R)-2-[4-(5-trifluoromethyl-2-pyridyloxy)phenoxy] propionic acid.
glufosinate	4-[hydroxy(methyl)phosphinoyl]-DL-homoalanine
glyphosate	N-(phosphonomethyl) glycine
haloxyfop	(RS)-2-[4-(3-chloro-5-trifluoromethyl-2-pyridyloxy-phenoxyl] propionic acid
linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
methabenzthiazuron	1-benzothiazol-2-yl-1,3-dimethylurea
metolachlor	2-chloro-6′-ethyl-N-(2-methoxy-1-methyl-1-methylethyl)acet-o-toluidide
metsulfuron	2-[3-(4-methylxy-6-methyl-1,3,5-triazin-2yl)ureidosulphonyl] benzoic acid
norflurazon	4-chloro-5-methylamino-2(*α,α,α*-trifluro-m-tolyl) pyridazin-3(2H)-one
oryzalin	3,5-dinitro-N^4,N^4-dipropylsulphahilamide
oxadiazon	5-*tert*-butyl-3-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazol-2(3H)-one
oxyfluorfen	2-chloro-*α,α,α*-trifluoro-p-tolyl-3-ethoxy-4-nitrophenyl ether
paraquat	1,1-dimethyl-4,4-bipyridium
pendimethalin	N-(1-ethyl propyl)-2,6-dinitro-3,4 xylidine

picloram	4-amino-3,5,6-trichloropyridine-2-carboxylic acid
simazine	6-chloro-N^2,N^4-diethyl-1,3,5-triazine-2,4-diamine
terbacil	3-*tert*-butyl-5-chloro-6-methyluracil
terbumeton	N^2-*tert*-butyl-N^4-ethyl-6-methoxy-1,3,5 triazine-2,4-diamine
terbuthylazine	N^2-*tert*-butyl-6-chloro-N^4-ethyl-1,3,5-triazine-2,4-diamine
2,4-D	(2,4-dichlorophenoxy) acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy) acetic acid

EXECUTIVE SUMMARY

In the summer of 1989/90 77 pipfruit growers were surveyed to ascertain their weed control practices and accuracy of herbicide application.

In regions visited all 77 growers used herbicides to control weeds. All but one of these growers had established herbicide strips beneath the trees with grass growing between the rows. All growers used mowers, and some also grazed their orchards in autumn. Over 80% of the growers aimed to keep their herbicide strips free from all weeds.

The common application period for herbicides was spring, with most growers using a combination of knockdown and residual herbicides. Over 90% of orchardists used herbicides during the summer.

Glyphosate was the most popular herbicide being used on two-thirds of the orchards surveyed. Seventy-five percent of growers relied on four herbicide formulations, glyphosate, simazine, amitrole and terbuthylazine/terbumeton. Knockdown herbicides, used by all growers, ranged from one to five applications per annum, with 70% of growers applying two or three. Residual herbicides were used by 87% growers, with applications ranging from one to three per annum, one being applied by two-thirds of the growers. Herbicides from the triazine group were used by 70% of growers.

Two-thirds of the growers were unhappy with their weed control programmes, as they failed to control their problem weeds. A lack of understanding and knowledge of herbicides was found to be common. At least a quarter of growers anticipated increasing their herbicide use next season (1990/91).

Paspalum, Indian doab, couch, mallows, black nightshade, summergrass, Californian thistle, tall willow herb, docks and barnyard grass were found to be the ten most problematic weeds, although convolvulus was a particular problem in Hawkes Bay. These weeds were not adequately controlled the current herbicides utilised at the rates applied. This led growers to use non-registered herbicides on some of these species. Current and past use of herbicides used in a manner not according to label

recommendations was recorded on 45% of orchards. However most of it was during innocuous careful spot spraying, and unlikely to lead to residue problems.

Herbicide damage to crop trees past and present, was recorded on 71% of orchards in 79 cases. Two-thirds of this was caused by glyphosate and most damage was isolated to single branches or young trees. Translocation through root grafting from poisoned crop and shelter trees was recorded. Most herbicide damage occurred because growers took no action if low foliage was accidentally sprayed or drift was seen to occur. Use of unregistered herbicides was not causing problems.

Commercially made herbicide spray equipment was used by 55% of orchardists, although most had been modified, particularly the spray booms. Growers used only fan or off-centre nozzles manufactured predominantly from brass. One to four nozzles were installed on booms with 60% using two nozzles. Nozzle assemblies and filters were rarely cleaned and less often replaced.

With regards to sprayer calibration 17% of sprayers had never been calibrated, 37% calibrated at least annually, and 46% calibrated infrequently.

Of the 41 sprayers calibrated during the survey 12% were within ±5% of the intended application rate, 17% were within ± 5 to 10%, 14% within ± 10 to 20%, and 57% were over ± 20% and therefore unacceptable. Two-thirds of sprayers with errors over ± 5% were underapplying at a mean rate of 37% and one-third were overapplying at a mean error of 18%. Spray distribution patterns as monitored using a spray patternator were unacceptable in most cases.

Over 40% of growers were not able to relate the amount of herbicide used to a target rate per hectare, and were not able to accurately document use.

Only 25% of growers had formal training in chemical weed control and sprayer calibration. Eighty percent of growers saw a need for a field manual on herbicide spraying and calibration.

Overall the survey highlighted major concerns regarding the use and application of herbicides by pipfruit orchardists.

Further work should focus on developing a boom with a nozzle arrangement that will provide an even coverage across the spray width. In addition education about herbicide application and weed control is necessary and a field manual should be produced.

CHAPTER 1: INTRODUCTION

Regulations regarding the use of fungicides, miticides and insecticides that are sprayed onto fruit crops are in place and have been observed for many years. Producer boards, whilst not insisting that fruit growers use pesticides, provide growers with the choice of adopting a spray programme which results in fruit being acceptable for markets (local and export), producing detailed guidelines on how these pesticides should be used. Wall charts and sprayguides ensure that growers are aware of the implications of usage; which pesticides can be used; pesticides not to be used at all; total applications; timing of applications; and documentation required. The use of herbicides and management of the orchard floor has been given no such attention until recently when the Kiwifruit Marketing Board insisted that growers document use of herbicides used throughout the season on their export spray diary. As pesticides in general come under more public scrutiny, the role herbicides play in orchard weed control will surely be questioned. This project will help provide a good platform of knowledge for the pipfruit and associated industries to keep them ahead of public scrutiny.

This research project evolved from an interest gained during the authors' final year (1987) of a Bachelor of Horticultural Science degree at Massey University. A minor project was undertaken entitled "Orchard sprayer calibration for an orchard weed control boom" which identified many aspects which required attention. These included developing methodology for determining and measuring conventional orchard herbicide strip sprayer settings; providing tips for growers on efficient spraying techniques: and outlining a simplified procedure for calculating the volume of water used per hectare.

A review of popular articles and pamphlets on herbicide sprayer calibration available at the time identified their practical limitations such as advising growers to simply select a forward speed, select nozzles, and then calibrate via retrospective refilling of the tank, i.e. after travelling 100m when only 5-10ℓ would have sprayed out of the tank and hence leading to poor accuracy. Several of the articles also repeated a mistake relating to the influence of changes in speed on total water used per hectare. Within the limited time available the project confirmed that a problem existed in the field and identified a need for an industry survey to ascertain exactly what methods growers were using to apply herbicides, the accuracy of their calibrations, their sprayer settings and their spraying operations.

The need to do this was endorsed by the New Zealand Apple and Pear Marketing Board and a research contract was negotiated. The Board's areas of concern were broader than the initial concept so the project was modified to obtain information on weed control practices, herbicides used and spraying practices in an attempt to identify potential ways in which herbicides may contaminate fruit, and to ascertain the herbicides commonly involved. This information was used to identify ways of alleviating this problem.

Thus the objectives of the thesis were:

1. To undertake a survey of pipfruit growers in two regions (Nelson and Hawkes Bay) in order to acertain:

   - current weed control methods, techniques and herbicides used in New Zealand pipfruit orchards;

   - the accuracy of herbicide application with regards to calibration and evenness of spray distribution.

2. To develop and test the use of a portable spray patternator for simple measurement of spray application and to identify a need for its usefulness for growers in orchard herbicide application practice.

3. To identify which areas of grower practice regarding weed control could lead to contamination of fruit with herbicides and to make recommendations to correct these problems.

CHAPTER 2: LITERATURE REVIEW

2.1 Reasons for using herbicides in orchards

Weed control in fruit crops is essential for optimum fruit production. Weed competition effects vary with weed species, fruit crop and environmental conditions (Atkinson 1985). With regard to apples, Atkinson and White (1981) reviewed literature which showed fruit yield reduction due to weed competition ranged from 17 to 66%. In addition they demonstrated effects on fruit quality and size leading to a reduction in marketable yield and financial returns that can be greater than the simple reduction in crop weight. In one of their trials with mature Cox's Orange on M.26 rootstock, competition from either grass weeds or annual weeds growing in the herbicide strip reduced crop weight by 16% and 21% and financial returns by 25% and 34% respectively. So although fruit trees normally tower over the vegetation on the orchard floor, competition still occurs.

Orchard yield is a function of many factors, in which weeds play a role. For example Wilton (1990) stated that summer weeds can harbour large populations of two spotted mite which may invade the crop towards harvest. Also the berries of black nightshade are attractive to some species of birds whose droppings can cause packhouse problems through fouling the fruit with a purplish/black staining.

Trials with nectarines, apples and nashi by Hartley (1988) showed that weeds or clover needed to be controlled from late October onwards in the first year of growth so as not to cause a significant reduction in tree size. However weed competition during October-November seriously depressed the development of a good branch structure. A strong relationship between tree growth in the first year and fruit yield in the following year, showed the value of good weed control on initial tree growth. Research has also shown that fruit trees have a good tolerance to a range of herbicides (Hartley 1987; Hartley 1988). Atkinson and Crisp (1983) showed that good weed control in both young and mature apple trees increased yield. Shribbs and Skroch (1986) showed most ground cover plants, including legumes reduced young apple tree growth. In mature apples clover has been demonstrated as being beneficial. Stephens (1982) quoted data from Stott showing that an overall clover sward under the mature apples yielded more fruit than those managed with a weed-free strip and grassed alleyways.

In the British Isles orchard soil management has undergone several major changes during this century. In the 1930's and 1940's, clean cultivation was largely replaced with closely mown grass. Subsequently as herbicides developed a compromise based on herbicide strips with grass alleys between the tree rows became popular in many areas (O'Kennedy and Robinson 1984).

Likewise, Wilton (1989) stated that all New Zealand orchards in 1949 were cultivated between the rows, but often had weeds round the butt of the tree. He further claimed that "pretty well all our orchards are grassed down with weed free herbicide strips along the tree rows". The change to "hedgerow" planting improved canopy area utilisation and made it possible to lower the level of the main fruiting zone along the row direction. Grassing down on sloped orchards reduced soil erosion and enabled the buildup and retention of a fertile top soil which under the older clean cultivation practices was lost on an almost annual basis.

Thus the traditional form of vegetation control in New Zealand orchards is to control all vegetation within tree rows using a variety of herbicides, and to reduce the competitive effects of vegetation between these rows by occasional mowing. There are a number of problems with this strategy, as outlined by Harrington (1991). The bare soil between tree rows provides excellent conditions for weed seed germination, so residual herbicides must be applied regularly. These herbicides may leach into ground-water, cause crop damage and possibly result in residues within the fruit. Continuous selection pressure on weed populations by herbicides can result in the development of herbicide resistance. The structure of bare soil can be damaged by raindrop impaction, and the vegetation between the rows competes with fruit trees, despite being mowed.

Given the ease of weed management afforded by herbicides, it is no wonder that growers readily use them, conforming to the soil management system described above. However it could be seen as another area in which primary producers are putting the consumer at risk from pesticide residues.

2.2 Pesticide Issues

The report on pesticides prepared by MacIntyre et al, (1989) swung the public gaze onto primary products and chemical inputs. This harshly criticised and fulsomely praised "Lincoln report", was a scathing review of New Zealand's pesticide use. It called for strong financial incentives for responsible pesticide use; education and training for pesticide users; and New Zealand specific Integrated Pest Management (IPM) technologies that could reduce our dependence on the less desirable pesticides. Only a discussion document it was part of a lengthy process aimed at more effective management of pesticides. It was condemned as being biased, inaccurate and lacking balance by primary industry leaders. The media was also attacked. Taylor (1989), when President of the New Zealand Fruitgrowers' Federation stated "the media played its usual role by manipulating the public emotion which surrounds this issue". Federated Farmers also critised the report. President, Brian Chamberlain, insisted that the debate on pesticide use " should be reasoned and based on sound scientific evidence - not unfounded emotions railed by scare tactics that document ulterior motives" (Anon 1989a). The report did not highlight any herbicide residue problems on fruit, but did identify some important points. It found that the "...Department of Health's calculations on human exposure to pesticides are a charade and its poorly-designed food monitoring efforts offer false assurances of consumer safety". The popular argument that our stringent *export* residue monitoring programme guarantees New Zealanders a diet of low-residue food is also shown to be flawed" (MacIntyre et al 1989).

Archie (1990) in a popular article entitled "What's your poison?" discussed the potential risk of eating fruit and vegetables, due to the ad hoc way in which domestic produce is checked. The lack of world knowledge about the potential long-term effects of pesticide residues was also highlighted and is the other side of the story. Public concern about the use of pesticides has been escalating for years and the issue is no longer solely the concern of the much maligned "greenies". People are worried, consumers and producers alike, although their reasons don't always overlap (Smith 1989.)

Specifically relating to herbicides MacIntyre et al (1989), used data from the Agricultural Chemical and Animal Remedies Manufacturer's Association (AGCARM), whose 35 members supply 95% of the agricultural pesticides sold in New Zealand. Herbicides accounted for at least 60% of the sales in 1983, 1985 and 1987, and records from 1973 to 1987 indicated that this has been a trend for the past decade. Herbicides sold to the sector indentified as "trees and vines" (pipfruit, stonefruit, kiwifruit exotics and grapes) over the period 1983 to 1987 increased by 42% to 133.3 tonnes active ingredient (5.9% of total) with combined increases in herbicide sales to all horticultural sectors offsetting a 60% fall in herbicide sales due to the lower demand in pastoral agriculture.

Some of the increase of the mid 80's was due to the growth of the kiwifruit industry from 7645ha in 1981 to 18905ha in 1988. In the pipfruit industry the emergence of corporate horticulture - Grocorp, Applefields, Limnos Investments, Eastern Equities, etc, has contributed to an increase in area of pipfruit from 6676ha in 1981 to 11225ha in 1988. (Department of Statistics 1983; Department of Statistics 1990). Pipfruit plantings have continued to expand reaching 13023 ha in 1990, whilst kiwifruit plantings have fallen to 17508ha (Department of Statistics 1991). It is likely that the 133.3 tonnes of ai herbicide used has not decreased in recent years.

A Ministry for the Environment report (Vaughan 1989) on pesticides recommended the setting up of a Hazards Control Commission. One of its functions would be to maintain adequate data and provide technical advice and to do this it should:

1. carry out a national survey to identify major types of equipment and equipment performance in the application of pesticides;

2. prepare or adapt international specifications for the type, design and calibration of equipment to be used for the application of particular pesticides;

3. discuss with manufacturers and user groups the question of registration of equipment and in the event of equipment being required to be registered ensure the specifications identified in (2) above become a requirement for equipment registration with the HCC;

4. consult organisations with expertise in this area such as the Agricultural Engineering Institute about the detailed means needed to undertake (1),(2), and (3) above;

This project partly met these recommendations as they relate to weed control of pipfruit.

2.3 Accuracy of field sprayers

In 1976 the British Agricultural Development and Advisory Service, (ADAS) studied 91 crop sprayers in England and Wales (ADAS 1976). An advisor visited each farm site, performed a routine inspection of the sprayer and calibrated it. Of the sprayers checked 40% had not been previously calibrated by their owners, and for 46% of the sprayers errors of over ± 10% were recorded, with 20% of sprayers operating with errors over ± 20%. Errors were not divided into under or over application, and the spray distribution patterns were not checked.

A similar study was conducted in Nebraska in 1979 (Rider and Dickey, 1982). A total of 152 private and commercial pesticide applicators were surveyed to check both calibration and mixing accuracy. Of those applying liquid pesticides (95 cooperators), 85% had a calibration and/or mixing error in excess of 5%. This was made up of calibration errors (47.3%), mixing errors (7.1%) and both calibration and mixing errors (30.6%). Nearly as many operators were underapplying as were overapplying, with a mean underapplication rate of 25.5% and a mean overapplication rate of 29.2%.

Rider and Dickey (1982) introduced the concept of "Known Area" as used by 42.4% of spray cooperators in their survey. Operators spray over a specific area then refill their tank calculating litres per hectare from the amount of liquid sprayed over a proportion of a hectare. Less than one third of operators calibrated with the use of the operator manual recommendations. There was no statistical difference in errors between either calibration method.

Ozkan (1987) evaluated 32 crop sprayers in Iowa and Ohio. Only seven (20%) were capable of applying a tank mix within 5% of the intended application rate. Of the other 25 sprayers which were unacceptable, 44% overapplied the spray at a mean rate of 22.3% whilst 56% underapplied the spray at a mean rate of 23%. Sprayers also had their nozzle outputs across the boom checked. Two thirds of the sprayers had a coefficient of variation of less than 10% among nozzles on individual booms. He suggested that using the coefficient of variation values alone to analyze the application accuracy could be misleading as it is not a measure of distribution uniformity. The spray pattern of each sprayer was analyzed using a portable corrugated spray patternator taking 20 readings per metre. Ozkan (1987) found that the majority of sprayers calibrated produced non-uniform spray distributions in spite of having nozzles with low coefficients of variation. The most common causes of poor distribution was misaligned nozzles, nozzle tips with different spray angles, clogged nozzles, and uneven or improper boom height.

Grisso et al (1988) conducted a field survey of 140 private and commercial pesticide applicators in Nebraska. They found that over 60% of the cooperators had a calibration and/or mixing error in excess of 5%. Commercial applicators had almost

50% fewer errors than private applicators. Expanding the tolerance limits to 10% of intended application rate, brought 75% of the commercial and 60% of the private applicators into a "satisfactory" category. By comparing the results from an earlier survey (Rider and Dickey 1982) in the same area, many of the extreme application errors (>25%) had been reduced, and the coefficient of variation from nozzles had improved four fold to below 5%, although the spray distribution patterns were not checked.

Grisso et al (1989), surveyed 103 private herbicide applicators. The results showed that only 30% of the cooperators were applying herbicides within 5% of their intended application rate. Overapplication of herbicides by more than 5% was reported for 26% of operators, at an average overcharge cost of $3.11/ha, or $573.00 over the average area treated. Underapplication by more than 5% was reported for 44% of growers, these operators spending $3.06/ha less on chemicals than anticipated, or saving $1053 over the average area treated. Values did not reflect the potential yield reduction and poor crop quality due to reduced weed control and increased weed pressure.

Varner et al (1990) surveyed 53 private and municipal golf course pesticide applicators, finding that only one in six applicators applied pesticide carrier volumes within 5% of their intended volume. Application accuracy was strongly associated with calibration frequency, with only 5% of applicators who calibrated less than once a year being within 5% of their intended rate. This study gave the largest reported errors found in the literature ranging from 83% underapplication to 177% overapplication; with 36% of applicators overapplying at a mean error of 19%, and 47% of applicators underapplying at a mean error of 34%.

The literature search did not reveal any similar sprayer surveys of the above nature in New Zealand, or on orchard herbicide booms anywhere in the world.

Couch (1988) estimated that the extent of individual pesticide errors averaged 25 to 35% in the United States. This was supported by Rider and Dickey (1982), Ozkan (1987), Grisso et al (1988), Grisso et al (1989) and Varner et al (1990). Comparatively, applicators underapplied pesticide carrier volumes at higher error rates than those that overapplied, expect Rider and Dickey (1982) where the results were similar for both.

Grisso et al (1989) stated that in many cases the time spent calibrating, or the cost of refitting an existing sprayer could be rapidly recovered by the improved accuracy of application.

In the reported surveys only Ozkan (1987) measured spray distribution across the boom. Varner et al (1990) averaged nozzle output across the boom, and did not state if any nozzles were replaced, although 74% of the sprayers had a coefficient of variation among nozzles of less than 10%. Couch (1988) stated that the boom's nozzle configuration should provide a uniform distribution of spray material across the entire width of the boom. He agreed with Ozkan (1987) in stating that the degree of uniformity of spray output within the boom's area of coverage can not be determined by flow rate procedures alone. He described a "special spray pattern analyzing pan" manufactured in Montana. The pan used floats catching in the tubes and measured the spray at 50mm increments. Slocombe et al (1990) reported the design of 10 laboratory-scale spray tables for use in teaching pesticide application technology at Kansas State University, Manhattan, to improve participation demonstrations in statewide pesticide application educational programmes.

A single nozzle was mounted on an adjustable boom at the centre of each table. The spray impact surface was corrugated fibreglass with 32mm corrugations positioned on a 5% slope. A 19mm ouside diameter collection tube was aligned with each valley of the corrugated surface, collecting the spray distribution pattern across the width.

2.4 Concluding statement

The need for more careful and precise application of pesticides has received considerable attention by the agrichemical industry, producers, scientists, extension educators, and the general public (Slocombe et al 1990). Thousands of litres of pesticides and billions of dollars are wasted annually because improperly calibrated equipment is used to apply chemicals (Ozkan 1987). Obtaining the correct application rate requires accurately calibrated equipment and an operator who is knowledgeable about pesticide application technology (Rider and Dickey 1982). Proper and efficient utilization of pesticides has both economic and environmental importance (Slocombe et al 1990).

John Maber, a consultant employed by a primary industry group stated that overseas markets are going to demand, more and more, evidence that New Zealand growers are conforming to an agrichemical code of practice (Anon 1990).

Apples, European and Asian pears exported from New Zealand are closely monitored for insecticide and fungicide residues by agencies such as the United States Department of Agriculture. Herbicides are also coming under scrutiny and it is important to have information on how herbicide residue problems may occur and to be able to overcome such problems quickly, advising growers and their staff from an informative base. Thus the present survey on weed control practices in orchards is an appropriate step towards providing this type of information.

CHAPTER 3 : METHODOLOGY

An interview survey of 77 pipfruit growers was undertaken. Details of the survey format and the method of selection of growers are given below along with details of a patternator developed to evaluate the distribution of spray across the spray swath.

3.1 Survey Format

The survey was divided into 11 sections. A copy of the questionnaire is given in Appendix 1.

Section 1 sought details of the grower, including orchard locality, crops grown and area planted.

Section 2 covered the growers' objectives regarding weed control, including its priority in orchard management operations and how it fitted in with other activities.

Section 3 attempted to ascertain the methods used to achieve weed control, the herbicide programme employed for the current season, and any changes anticipated in herbicide selection for the next season.

Section 4 focused on growers' impressions of the effectiveness of specific herbicides they had used. Utilisation of herbicides lacking label claims and observed herbicide damage to crops were also covered. Problem weeds were identified and attempts to control them were evaluated.

Section 5 identified how much growers knew about their sprayer settings (e.g. sprayer output, forward speed, pressure) and other aspects of the spraying operation such as boom stability, drift, and other alternative application rates used. Combined with questions on chemical practices, the information was used to discuss ways in which herbicide applications might contaminate fruit.

Section 6 covered the use of the herbicide sprayer and its calibration; whom growers take advice from; what was done as a result; and basic maintenance practice undertaken.

Section 7 identified the equipment used, including details on the boom design, and how it was controlled in order to highlight design faults and improvement made by growers.

Section 8 recorded the results from the sprayer calibration carried out for the grower as part of the interview. A calibration section was included to obtain an industry standard on the accuracy of desired application rates, by comparing intended rates to those measured.

Section 9 covered the orchard operation as observed during the calibration process in section 8.

Section 10 covered background training and potential needs of growers, including the need for a field manual for sprayer calibration and boom design.

Section 11 evaluated the success of the various weed control programmes, and provided an opportunity to measure the spray strip width and lowest tier height in the orchard. This was done informally and the impressions were recorded.

A test of the questionnaire logic was undertaken by means of a pilot survey of three growers and minor modifications made to the wording and organisation of the questions.

3.2 Selection of Orchardists

At the request of the New Zealand Apple and Pear Marketing Board the survey was mainly limited to the two main pipfruit growing regions, Nelson and Hawkes' Bay.

Mr David Binns, Senior Field Officer for the New Zealand Apple and Pear Board, Nelson, supplied a list of growers in the Nelson area. A sample of growers was selected as follows. The MAF scheme of registration started in 1975 for "every commercial orchardist of not less than 4000 metres square, for the purpose of growing any of the following fruit for sale". (A full list of fruiting types was quoted.) The first letter of the mark denotes the MAF region (Nelson is "H"), with all numbers being under 1000. New orchardists were allocated a number which has never been previously used or has been cancelled for two or more years (Reeve 1991). Some requests for specific numbers are accommodated. For the purpose of this project the selection process can be considered random.

From growers with a "3" in their registered MAF number, fifty were randomly selected and sent a letter to introduce the survey and outline the objectives. They were then contacted by phone and appointments for an interview made. Each was asked whether it would be possible for his herbicide sprayer to be available for calibration during the visit.

In Hawkes Bay the names of 60 growers were supplied by a Hastings New Zealand Apple and Pear Board Field Officer following a request for a list of growers' with a wide range of abilities both good and bad. These were contacted in the same way as the Nelson orchardists.

A list of the growers visited is appended. Those whose sprayers were calibrated are identified and properties where the portable patternator was used are also noted. (Appendix 2.)

3.3 Interview technique

All growers were interviewed personally by the author. The survey took over an hour to fill out in most cases and was usually carried out in the grower's home, packhouse or in the orchard. The formal questions were asked first, followed by calibration of the sprayer in the field. Rain interrupted only one day over the two survey periods.

3.4 Equipment Used for Calibration

All sprayers were calibrated in the orchard. Spray pattern width was measured with a tape measure also used for measuring distances on the boom and nozzle arrangements. Timekeeping was achieved using a Remy 12*12 Sports stopwatch, which read to 1/100ths of a second.

Forward speed measurement was carried out by timing the growers over a known distance. This was usually more than 50m, and done more than once as a check. All forward speeds were measured with the herbicide sprayer attached and the pump running whilst travelling along the orchard rows. Fruit trees were usually used as markers to facilitate the calibration demonstration using graphs developed by Berry (1987) shown in Appendix 1, Charts A1.1 and A1.2.

Speed was then calculated using the formula

$$\text{km/h} = \frac{\text{metres travelled}}{\text{time (seconds)}} \times 3.6$$

Nozzle output was measured by one of two methods. A 5*l* jug with 0.1*l* (100m*l*) graduations was used in conjunction with a stop watch, and a McKenzie calibrator was also used, which read up to 3.2*l*/min in 0.05*l* (50m*l*) graduations. After several calibrations using both methods with excellent agreement, the McKenzie calibrator was used, except when nozzle flow exceeded 3.2*l*/min or access to the nozzles was difficult. The McKenzie calibrator also showed variations in spray flow and or pressure, expressed by the flucuations in the beads' position as nozzle discharge flowed through it.

Forward speed, nozzle output and spray width were used to calculate litres of water applied per hectare. Some growers were taken through the calculation: all were then shown a graphical method of calibrating herbicide sprayers (Berry 1987) (Charts A1.1 and A1.2, Appendix 1).

The graphs utilised three simple measurements; forward speed, spray width, and nozzle output, and one calculation, forward speed x spray width. Speed could be derived graphically, and this information transferred to the final calibration graph. It was hoped that this survey could help derive more accurate graphs as the practical upper and lower limits will be better understood. Growers impressions of each process were gauged in Section 10 of the survey. (Appendix 1).

3.4.1 Portable Spray Patternator

Once conventional calibration was complete, and the forward speed was known the distribution across the spray width was measured using a portable spray patternattor.

The prototype patternator consisted of a series of plastic Exalon tubes attached to a flat wooden backing, hinged in the middle (Plate 1). It was ruggedly constructed to ensure it survived the travelling required to visit 80 orchards over both islands. The tubes of 33mm external diameter gave just over 30 readings per metre. They were cut open for 185mm from the top to allow entry of the spray when laid in a horizontal position.

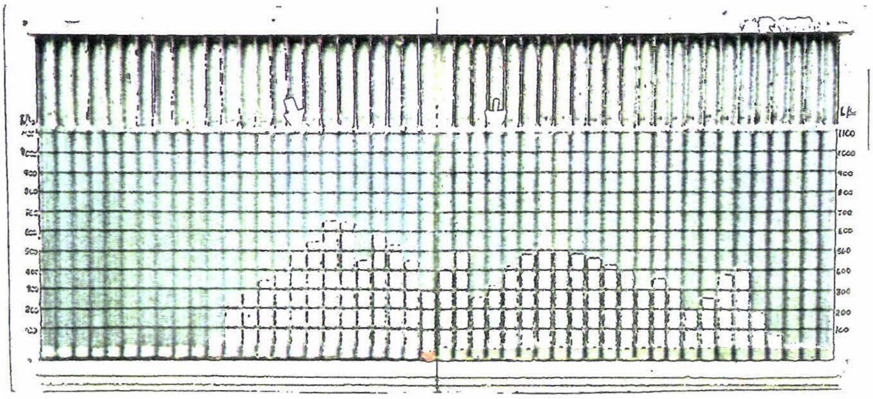

Plate 1: **Prototype spray patternator after has been used to collect spray.**

The internal diameter of the pipes was 26.6mm, and thus the internal area was 556mm². The fact that the catchment width of each tube was 33mm across but the "collection area" was 26.6mm was taken into account when calibrating the patternator. (Figure 1.)

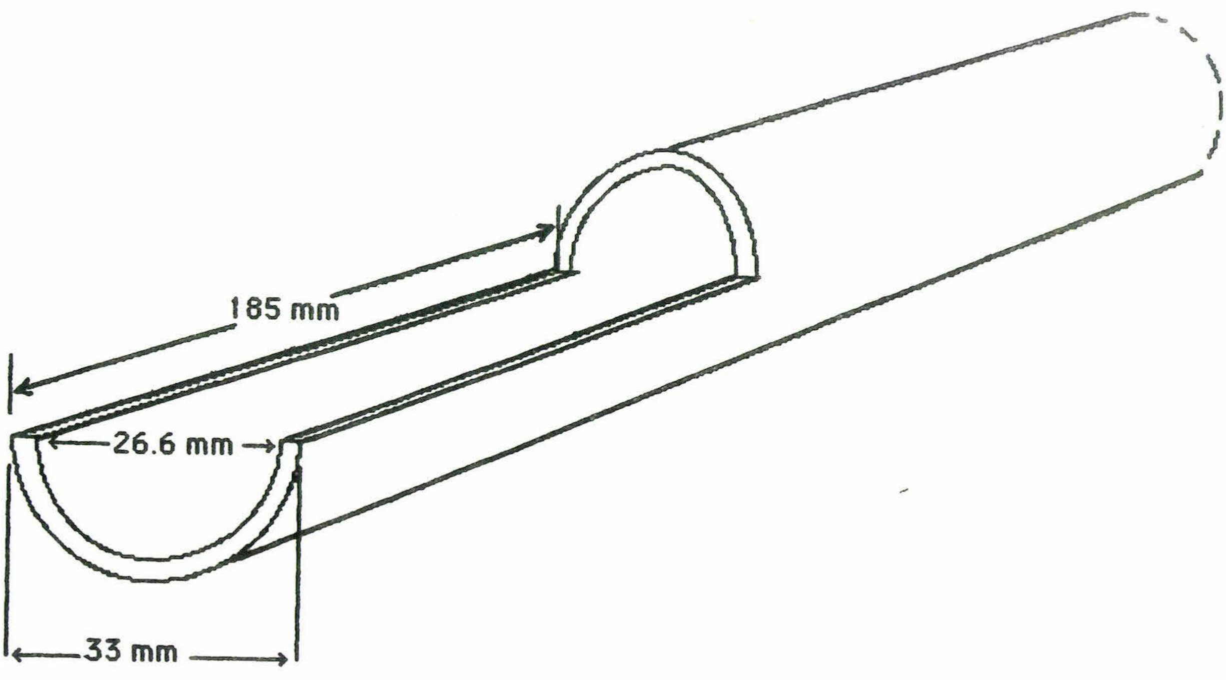

Figure 1: **External and internal diameter of the pipe (not to scale).**

It was not expected to calibrate any herbicide sprayers applying more than 800ℓ/ha. Allowing for 30% overapplication or errors in spray distribution the length of each tube was set at 450mm, to carry the equivalent of 1040ℓ/ha. Thus each 10mm column of the tube would have to carry the equivalent of 1040/450 = 23.1ℓ/ha. To simplify this, calibration of the tubes was undertaken to give 25ℓ/ha/10mm of tube. Given that the cross-sectional area was 556mm², 10mm of tube length had a volume of 5.56ml.

For 5.56ml to be equivalent to 25ℓ/ha an area of 2.22m² of land would need to be sprayed. To get an area of 2.22m² at 33mm catchment width required a distance travelled of 67.27m, ie 2.22m² = 67.27m x 33mm. Thus each 10mm tube length when filled was equivalent to 25ℓ/ha or 40mm equivalent to 100ℓ/ha.

A spreadsheet was created to calculate the time taken to travel 67.27m, for the range of speeds at which growers were expected to be travelling (Appendix 1, Chart A.3)

Lines were drawn across the patternator tubes at 40mm intervals to represent the equivalent application rate of 100ℓ/ha.

The patternator was laid flat and the nozzles positioned above the open ends of the tubes (Plate 2). The sprayer was operated whilst stationary, at the usual height and pressure and the spray collected for a time dependent on the usual measured forward speed (Appendix 1, Chart A.3). The patternator was then stood upright, displaying the levels of liquid in each tube in the form of a histogram to represent the spray distribution pattern (Plate 1).

Conventional methods of calibration require a calculation which gives average ℓ/ha over the full spray width regardless of the evenness of spray distribution. Using the patternator one can easily determine an approximate average application rate but also determine the fluctuation around this mean. This is easier to do for more even spray patterns and level with a greater degree of accuracy.

The patternator can also be used to visually present to growers and users the effects of nozzle wear, nozzle drip, nozzle spacing and poor nozzle combinations.

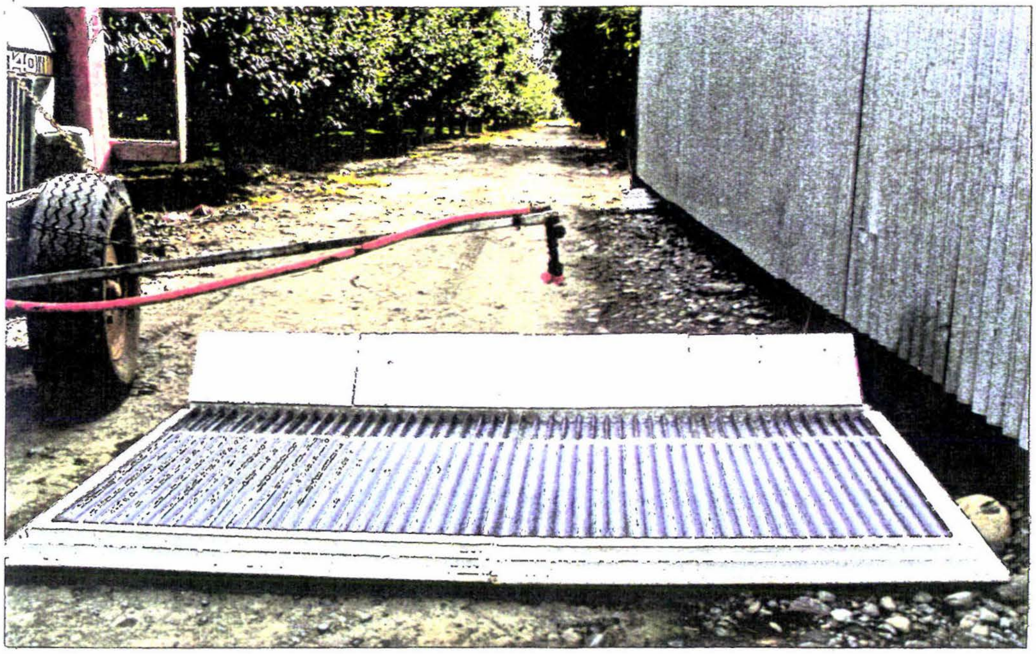

Plate 2: Portable spray patternator in position for collection of spray distribution.

The spray patternator won a prestigious prototype award at the 1990 World Agricultural Expo, Hamilton,New Zealand (Plate 3).

Plate 3: Display of patternator use and results at World Agricultural Expo.

A copy of the prototype award certificate is displayed on the following page.

A grower needs to evenly apply both knockdown and residual chemicals but has no practical method available to aid the setting up of the boom to acheive this. Nozzle wear further exaggerates this problem.

3.5 Statistical analysis

A statistician consultant (Brook 1991) stated "the nature of the thesis and the way the data has been collected, I believe the descriptive method used seems entirely appropriate and satisfactory. It was not appropriate to carry out inferential statistics other than those presented on the results."

In reporting the thesis results statistics have been used to analyse differences between Hawkes Bay and Nelson growers and for the calibration section. Statistics were limited by the relatively small samples.

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N.Z. National Fieldays Society Inc.
Private Bag, Hamilton
New Zealand

CHAPTER 4: Results and Discussion

4.1 Description of Crops Grown

An analysis of the land area of orchards visited during the survey and the type of pipfruit grown is given in Table 1. Only 28 orchards were greater than 15 hectares but these accounted for about half of the total land area surveyed.

TABLE 1: Size of orchards visited and crops grown.

Orchard Size (hectares)	Crops Grown					TOTAL
	A	AP	AN	APN	N	
0 - 5	11	10	1		2	24
5.1 - 10	8	5		1		14
10.1 - 15	8	2	1			11
15.1 - 20	4	8				12
20.1 - 25	1	3				4
25 plus	6	5	1			12
TOTAL	38	33	3	1	2	77

KEY: A = Apples
P = European Pears
N = Asian Pear (Nashi)

All but one of the orchards were bearing. An attempt was made to gauge the age of the trees in the orchard. Some growers provided an estimated average of ages, some answered "mixed" or "mature", and others gave ranges "1 - 100 years". This data was unable to be analysed.

4.2 Weed Control Objectives

A summary of the weed control objectives of pipfruit growers is given in Table 2. Approximately 83% aimed for bare soil or few weeds. However, growers tolerating some hard to control weeds like paspalum often wound up with strips in which weed control could only be considered poor. (Plate 4).

TABLE 2: Overall objectives for weed control.

Weed Control Objective	No. of growers claiming this objective	Proportion of growers %	Proportion of growers meeting their objective or better %
Total vegetation control, i.e. bare soil	27	35.1	78
Try to achieve bare soil but tolerate some weeds if hard to control	37	48.0	78
Don't mind occasional small weeds	7	9.1	86
Not too worried about weed patches	2	2.6	100
Weeds are acceptable	0	0	-
Other			
Sprays around base of trunks only	1	1.3	100
Bare only over season, spring to harvest	3	3.9	-
TOTAL	77	100	

Nine growers, after their first response, added further comments. Five liked to see weeds regrow in late autumn and winter as an assurance that they had not "poisoned the soil" with residual herbicides. One of the 9 growers who did not mind some weeds, would not tolerate paspalum. One grower aimed to have the herbicide strips clear of weeds for the harvest period. Another grower liked to have no weeds over winter to assist with frost protection.

Plate 4: Stand of paspalum down an apple row in Nelson.

When each orchard was visited the extent to which weeds had been controlled was recorded, under four rankings that equated to their objectives.

Of the 64 growers with the first two objectives in Table 2, 48 (or 75%) met this criteria. The 16 growers who did not, meet their objective had their orchard ranked as patchy or full vegetation. Of the growers not meeting their particular weed control objective, the predominant troublesome weeds were grasses from the sub-family Paniceae such as paspalum, (Plate 4) summer grass, Indian doab, couch and barnyard grass. These species are not controlled by triazine herbicies, and low rates of commonly used knockdown herbicides. Two growers reached a higher level of weed control than their objective, so that 65% of orchards were scored as clean (Plate 5) or having large bare areas with few weeds.

Plate 5: Established herbicide strips showing no weeds down the row and closely mown grass.

The growth of oxalis prevented one grower from reaching his objective (Plate 6).

Plate 6: Sward of oxalis in a Nelson orchard. Good control of other species.

The distribution of these weeds within the herbicide strip was recorded to identify areas of reinfestation or weed patterns due to poor spray distribution. Some weeds are able to grow in the grass alleyway and spread vegetatively from here (e.g. yarrow, white clover, paspalum, creeping yellow cress, creeping buttercup and creeping mallow) and this was noted in four orchards. Weeds were noticed to cluster around irrigation emitters in four orchards, with Californian thistle seen growing predominantly up the middle of herbicide strips in one Hawkes Bay orchard.

With regard to the priority of weed control amongst the other orchard management operations, weed control was rated a high priority over the period bud-burst to fruit-set and/or over summer by 70% of growers. Two growers stated weed control was a high priority in autumn. Five growers ranked weed control equal to pest and disease spraying, with four ranking it second in importance.

Two growers indicated that they liked to "keep on top of" weed control, and that prevention was the best cure. Another two growers only sprayed when they thought it was required, judged by themselves. Four growers did not rate weed control as a high priority, and another four felt it was a nuisance.

When asked about possible job conflicts over 50% of growers said they always managed to fit weed control in amongst other operations, whilst another 12% usually managed this.

Over half (39) of the growers indicated that weed control conflicted with labour demand for other jobs such as gate sales, fertiliser application, first cover sprays, and pruning. Another 15 growers found that the weather was the major conflict.

4.3 Weed control methods

An analysis of the methods of weed control used by the 77 pipfruit orchards surveyed is given in Table 3. All growers used herbicides and all growers used more than one method of weed control.

TABLE 3: Methods of weed control including herbicide application as used by growers surveyed.

Weed Control Method	Number of growers
Herbicides applied by:	77
- Conventional hydraulic spray nozzles and boom	76
- Knapsack sprayers (manual)	23
- Wick Booms	3
- Controlled Droplet application (CDA) equipment	4
- Handguns	
(a) trailed (+ individuals with 1-2 hoses)	32
(b) tractor mounted, driver spraying with gun	17
- Mulches	
(a) organic, i.e. bark, hay	2
(b) inorganic, i.e. plastic, matting	0
- Mowing	
(a) down alleyways between trees	76
(b) cross mowing between trees where no herbicide strips are established	1
(c) ocassional mowing of weeds growing in herbicide strip	5
- Heat	
(a) - LPG rollers	0
(b) - steam	0
(c) - flame	0
- Animals grazing (sheep in autumn/winter)	36
- Cultivation	0

Only one grower did not have established herbicide strips, spraying around the base of trees with a handgun and then cross mowing. Although herbicides were used by all growers surveyed, the non-chemical weed control strategy of mowing was also used by all growers, with this often being the only form of weed control used between the rows. Table 3 shows only five growers used a mower to control weeds between trees as well as between the rows.

Knapsack sprayers were mainly used in summer to control weeds missed by the main spraying operation, or to apply specialised herbicides such as asulam for docks, or 2,4-D/dicamba for control of greater bindweed.

4.3.1 Herbicide programmes

Growers were asked to describe the seasonal herbicide programme they used beginning in Autumn 1989. The season was divided into four periods.

1. Leaf fall/autumn (mid-April to mid-June);
2. Dormancy to bud movement, i.e early spring (August and September);
3. Spring (flowering - fruitset) (October and November);
4. Summer (December to March).

Dividing the time intervals into two over the period bud-movement to fruitset was intentional to help identify any potential problems from "late" applications of both residual herbicides and amitrole.

Growers were asked to list the specific herbicides used with application rates. Nearly all growers related their programme from memory with very few keeping records. Although most quoted herbicide timing and rate without looking up any records, this was deemed to be sufficiently accurate for this project.

From these responses herbicide selection was linked with weed problems; use of non-registered herbicides was linked to damage of trees, and the potential for fruit to absorb herbicides was assessed.

One grower who only sprayed around the base of trees as required with materials most appropriate for the weeds present was excluded from this part of the analysis.

Herbicides are identified by their active ingredient, not trade name. A glossary of herbicides is given in Appendix 3. Where a herbicide is sold with two active ingredients this is indicated by a slash (/), i.e. linuron/diuron (trade name: Cohort). The word "plus" indicates that the grower has mixed two herbicides i.e. amitrole plus simazine. The word "or" is used to indicate where two different herbicides were used. For example "glyphosate plus simazine or terbacil" depicts that the grower used glyphosate plus simazine on some orchard areas and glyphosate plus terbacil on the rest. The word "then" indicates two separate applications. For example "glyphosate then simazine," the latter being the last applied. The word "maybe" indicates a possible future intention.

Wick booms in the form of "hockey sticks" (hand held weed wipers), were used to apply broad spectrum herbicides such as glyphosate, to paspalum and bristle grass, but would work over most weed species.

4.3.1.1 Autumn Application Period

Autumn applications of herbicides were applied on 35 of the 76, just under half of the orchards (Table 4). However weed control was not limited to herbicides, with 36 growers using sheep to graze out the orchard in the autumn/winter period. Cross mowing between trees was carried out on 5 orchards over the season as well. Disadvantages of these alternatives are that weeds are not killed but merely suppressed by mowing and grazing, and that new weed species can be introduced by livestock, in faeces, and in the case of sheep, in the wool.

TABLE 4: **Herbicides used during autumn in the 76 orchards surveyed.**

Herbicides	Number of orchards	Proportion of use %
No herbicides used	41	54.0
Glyphosate only	22	29.0
Amitrole only	7	9.2
Paraquat/diquat	2	2.6
Glyphosate **or** amitrole	2	2.6
Amitrole **plus** simazine	1	1.3
Glyphosate **or** glufosinate	1	1.3
TOTAL	76	100.0

For those orchards using herbicides in this period glyphosate was used by over 70% of them. Using the residual herbicide simazine is not necessary or very practical in this period. A high level of weed control is not required over winter as there is no competition with trees which are dormant. In all probability the soil in the herbicide strip will not be bare but weedy, reducing the effectiveness of simazine which, according to label recommendations, should go onto bare soil (O'Connor 1989). The life of simazine at orchard rates is 3-4 months and this application will not be controlling weeds germinating as the soil warms up in spring.

4.3.1.2 Dormancy to bud movement application period (early spring)

The herbicide combinations used in early spring (dormancy to bud movement) are shown in Table 5. Individual herbicide formulations used in this period are summarised in Table 6.

Of the 41 growers who did not use any herbicides in autumn this is the first application since summer, except for four growers who apply neither summer nor autumn herbicides.

This period is the traditional time for growers to begin their weed control programmes for the growing season.

TABLE 5: **Herbicide combinations used in period of dormancy to bud-movement (August and September) (early spring).**

Herbicide(s)	Number of Orchards	Proportion of use %
No herbicides used	16	21.0
amitrole plus simazine	13	17.2
amitrole plus terbuthylazine/terbumeton	4	5.3
glyphosate only	4	5.3
glyphosate plus simazine	4	5.3
glyphosate plus terbuthylazine/terbumeton	3	3.9
terbuthylazine/terbumeton	3	3.9
amitrole only	2	2.7
paraquat/diquat plus terbuthylazine/terbumeton	2	2.7
amitrole plus terbacil plus simazine	2	2.7
simazine plus terbacil	2	2.7
simazine only	1	1.3
glyphosate or amitrole plus terbuthylazine/terbumeton	1	1.3
glyphosate then glyphosate plus terbuthylazine/terbumeton	1	1.3
amitrole plus terbacil	1	1.3
glyphosate plus terbuthylazine/terbumeton (young trees) amitrole plus linuron/diuron (old trees)	1	1.3
glufosinate plus oxadiazon	1	1.3
glyphosate plus linuron/diuron or simazine	1	1.3
paraquat/diquat plus simazine or linuron/diuron	1	1.3
linuron/diuron	1	1.3
glyphosate or paraquat/diquat	1	1.3

amitrole **then** simazine **or** terbacil	1	1.3
amitrole **or** paraquat/diquat	1	1.3
glyphosate **plus** clopyralid	1	1.3
paraquat/diquat **plus** terbuthylazine	1	1.3
glyphosate **plus** dicamba **or** amitrole **plus** dicamba	1	1.3
glyphosate **plus** terbuthylazine	1	1.3
pendimethalin **or** terbuthylazine/terbumeton **or** simazine **or** norflurazon	1	1.3
glufosinate **or** glyphosate	1	1.3
oryzalin **plus** linuron/diuron **or** diuron/methabenthiazuron	1	1.3
glyphosate **or** paraquat/diquat **plus** simazine **plus** oryazlin	1	1.3
paraquat/diquat **plus** terbuthylazine/terbumeton	1	1.3
TOTAL	76	100.0%

In this period from dormancy to bud movement the majority of growers apply both knockdown and residual herbicides. Knockdown herbicides (amitrole, glyphosate, paraquat/diquat, dicamba, clopyralid and glufosinate) were applied without residual herbicides on 11 out of 60 orchards. Likewise residual herbicides were applied without knockdown herbicides on nine out of 60 orchards, though linuron/diuron and terbuthylazine/terbumeton both have some knockdown activity.

TABLE 6: Frequency of herbicide use whether applied individually or in a mix in the period of dormancy to bud movement on 60 of the pipfruit orchards surveyed.

Herbicides	Frequency	Proportion of use %
amitrole	26	21.60
simazine	26	21.60
glyphosate	21	17.50
terbuthylazine/terbumeton	18	15.00
paraquat/diquat	8	6.60
linuron/diuron	5	4.10
terbacil	5	4.10
glufosinate	2	1.66
oryzalin	2	1.66
clopyralid	1	0.87
terbuthylazine	1	0.87
pendimethalin	1	0.87
norflurazon	1	0.87
diuron/methabenzthiazuron	1	0.87
dicamba	1	0.87
oxadiazon	1	0.87
TOTAL 16 HERBICIDE FORMULATIONS	120	100.00

Although 16 different herbicide formulations have been recorded just under half of them (seven) were used by more than two growers. Four of the 16 herbicide formulations namely amitrole, simazine, glyphosate and terbuthylazine/terbumeton, made up over three-quarters of the herbicides used.

Applications of knockdown herbicides (59) were matched by applications of residual herbicides (61). Two growers used a combination of residual herbicides to extend the range of weeds controlled. Oryzalin was added to urea herbicides to extend control to grasses which ureas do not readily control (O'Connor 1989; Matthews 1975). Terbacil was applied with simazine by two growers to give the same effect, although terbacil itself controls a wide range of weed species. Simazine controls a wide range of annual and perennial grass and broadleaf weeds at germination (O'Connor 1989). This herbicide belongs to the triazine group of chemicals which has experienced problems recently with the development of resistant biotypes of weeds. Herbicide resistance is not really a problem in New Zealand orchards at present. It is the inability of triazines to control species such as C_4 grasses, nightshade etc, which is the problem. These weeds have always been resistant or tolerant of triazines. Herbicide resistance was first documented in the triazine family of herbicides (Anon 1989) and is documented in a total of 54 weed species (not all to traizines), up from just 12 in 1980. Rotating herbicides or using them in combinations reduces the buildup of resistance. Jones (1980) indicated that the need for mixtures with simazine is well recognised because its spectrum of activity is not sufficently wide. Gilchrist (1988) showed that oryzalin controls germinating weeds, particularly grasses that are not controlled by simazine, was the best companion herbicide to go with simazine, and this has also been the advice of FruitFed Supplies Ltd. Too few growers appear to be doing this which is further discussed in 4.4.1.

Separate applications for apples or pears were not recorded in this period, and it was noted that one grower applied terbacil to apples as well as pears, despite label recommendations that terbacil not be used on pears. (Also against label recommendations amitrole was used around trees less than 3 years old, with one grower reducing the rate used from 10ℓ/ha to 4ℓ/ha.) Only one grower applied separate programmes for young and old trees, but the residual herbicide terbuthylazine/terbumeton used does not have label claims for trees established for less than 3 years. Difficulties arose where replants in established rows gave a range of ages within the row, and many cases of amitrole damage in young trees treated with older trees were noted (Plates 7 and 8).

Plate 7: Amitrole damage observed in young trees interplanted amongst older trees.

Plate 8: Dead tree possibly resulting from ponding of simazine around its base following replanting in a row of older trees.

4.3.1.3 Greentip to fruitset application period (late spring)

In this period, residual and knockdown herbicides were both applied, but with a lesser frequency than during the last period (Tables 7 and 8).

TABLE 7: Herbicides used in the period of green tip to fruitset.

Herbicide(s)	Number of orchards	Proportion of use %
No herbicides used	39	51.3
glyphosate only	8	10.6
terbacil **plus** simazine	3	4.0
glyphosate **plus** simazine	2	2.6
glyphosate **plus** clopyralid	2	2.6
amitrole **plus** terbuthylazine/terbumeton	2	2.6
linuron/diuron only	2	2.6
amitrole **plus** simazine	2	2.6
paraquat/diquat	2	2.6
dicamba **plus** glyphosate	1	1.3
paraquat/diquat **plus** terbuthylazine/terbumeton	1	1.3
amitrole **plus** simazine **or** terbuthylazine/terbumeton	1	1.3
glyphosate **plus** picloram/2,4-D (**plus** diesel)	1	1.3
terbuthylazine/terbumeton only	1	1.3
metolachlor/terbuthylazine	1	1.3
amitrole only	1	1.3
amitrole **plus** terbuthylazine/terbumeton (apples), glyphosate **plus** simazine (pears)	1	1.3
glyphosate **plus** terbuthylazine/terbumeton	1	1.3

glyphosate **plus** terbacil **plus** diuron	1	1.3
terbuthylazine only	1	1.3
paraquat/diquat **plus** simazine	1	1.3
glyphosate **plus** simazine **or** terbuthylazine/terbumeton	1	1.3
glyphosate **plus** 2,4-D/dicamba	1	1.3
TOTAL	76	100.0

Knockdown herbicides were applied singly on 16 orchards during this late spring period and residual herbicides were applied singly on 8 orchards. Separate herbicide programmes for apples and pears were undertaken by only one grower.

Only three out of 11 growers applying simazine added a complementary residual herbicide, and that was terbacil in all cases.

Herbicides not registered for use in pipfruit which were used in this period included dicamba, clopyralid, 2,4-D/dicamba and picloram/2,4-D on five orchards. Applications of amitrole over the late flowering period is also not recommended (O'Connor 1989). Dicamba was added to glyphosate to control white clover on one Manawatu orchard. A mixture of glyphosate, picloram/2,4-D and diesel was used on one Nelson property as the only herbicide application for the season, and the grower stated he would use it again next season. Clopyralid was added to glyphosate on two Hawkes Bay orchards to control Californian thistles and white clover. A mix of glyphosate and 2,4-D/dicamba was used to control creeping mallow. These applications are discussed further in sections 4.3.1.5 and 4.4.

TABLE 8: Frequency of herbicide use whether applied individually or in a mix in the period of greentip to fruitset.

Herbicides	Frequency	Proportion of use %
glyphosate	19	30.1
simazine	11	17.5
terbuthylazine/terbumeton	8	12.7
amitrole	7	11.1
paraquat/diquat	4	6.3
terbacil	4	6.3
linuron/diuron	2	3.2
clopyralid	2	3.2
dicamba	1	1.6
picloram/2,4-D	1	1.6
metolachlor/terbuthylazine	1	1.6
diuron	1	1.6
terbuthylazine	1	1.6
2,4-D/dicamba	1	1.6
TOTAL 14 herbicide formulations	63	100.0

In this period just under half of the growers were applying herbicides, as many had already applied them. All but two of the 16 growers who did not apply herbicides in early spring applied herbicides in this period, with 23 of the growers applying herbicides in both periods. The pattern that these 23 growers followed was not similiar. Expecting to record most growers preceding a residual herbicide with a knockdown herbicide (the residual now going onto bare soil) instead the following was observed:

- 8 growers followed a knockdown herbicide with a residual herbicide;
- 7 growers followed a residual herbicide with a knockdown herbicide;
- 5 growers followed residual herbicides with a second residual herbicide;
- 2 growers used knockdown herbicides in each period.

The seven growers following a residual herbicide with a knockdown herbicide may have acheived poor control with the first application, or weeds resistant to that residual application have started to germinate, requiring control. Those applying two residuals may also come into this category. Again simazine, glyphosate, terbumeton/terbuthylazine and amitrole made up nearly 75% of all applications.

4.3.1.4 Summer application period

Over summer growers were aiming to control weeds that had survived the applications of residual herbicides. Some weed species will germinate as the effect of the residual is weakened over time allowing establishment. The nine growers not using any residual herbicides, control weeds that have either survived previous applications of knockdown herbicides or have emerged and established since the last application. Residual herbicides that last 3-4 months when used at correct rates (simazine, terbuthylazine/terbumeton, linuron/diuron etc) which were applied in August/September will not be effective much beyond late December of that same year. Herbicides used in summer to control these weeds are given in Tables 9 and 10.

TABLE 9: Herbicides applied during the summer period (December to March), not including special purpose applications.

Herbicide(s)	Number of orchards	Proportion of use %
glyphosate only	36	47.4
No herbicides used	8	10.5
paraquat/diquat only	6	7.0
glyphosate (twice)	5	6.6
glyphosate **plus** simazine	3	4.0
paraquat/diquat (twice)	3	4.0
glyphosate (mature trees) **or** paraquat/diquat (young trees)	3	4.0
glyphosate **plus** terbuthylazine/terbumeton	2	2.6
glyphosate **plus** linuron/diuron	2	2.6
glyphosate **and maybe** linuron/ diuron	1	1.3
glyphosate **plus** simazine **plus** norflurazon	1	1.3
glyphosate **plus** clopyralid	1	1.3
glyphosate (mature trees) **or** glufosinate (4 times-young trees)	1	1.3
paraquat/diquat **plus** simazine	1	1.3
glyphosate **then** glyphosate **plus** linuron/diuron	1	1.3
glyphosate **or** glufosinate	1	1.3
paraquat/diquat **then** glyphosate **plus** linuron/ diuron	1	1.3
TOTAL	76	100.0

The use of residual herbicides was recorded on 12 out of the 68 orchards practising summer herbicide applications, with one of these growers using a mix of two. One grower used norflurazon specifically to control summer grass but this herbicide is not available commercially, being trialed on behalf of a pesticide company. It has not been released to date although it was available in the early 1980s.

Over the summer period growers mainly used knockdown herbicides which accounted for 87% of the applications. The seven applications of residuals were all applied with a knockdown, even though 7 had knockdown capacity.

Twelve orchardists applied knockdown herbicides twice over summer, two adding linuron/diuron in the second application. Growers on four orchards conducted separate herbicide applications for young or mature trees, using only non-translocated herbicides (e.g. paraquat/diquat or glufosinate) around young trees.

TABLE 10: Frequency of herbicide use over summer whether applied in a mix or individually, not including special purpose applications.

Herbicide	Frequency	Proportion of use %
glyphosate	62	65.3
paraquat/diquat	15	15.7
glufosinate	5	5.0
linuron/diuron	5	5.0
simazine	5	5.0
terbuthylazine/terbumeton	2	2.0
clopyralid	1	1.0
norflurazon	1	1.0
TOTAL 8 HERBICIDES	96	100.0

Glyphosate is a good choice of herbicide in this period because of its broad spectrum of control. At sufficient rates it will control most grasses and broad-leaved weeds (O'Connor 1989). Growers having problems with tall willow herb were adding linuron/diuron as this weed appears to tolerate glyphosate.

4.3.1.5 Special purpose applications

Over the growing season some weed species will not be controlled by the programme used. These species may be widespread or isolated in the orchards, and require or prompt special attention to control them, usually via the selection of a herbicide, outside the current programme. Some herbicides are applied to a single weed species i.e yarrow or to a narrow range (i.e. C_4 grasses), such as paspalum, couch, Indian doab.

These herbicides are not usually applied in broad-acre fashion but directed on to the target weed(s) only where present. Thus all these herbicides are knockdown herbicides, applied via knapsacks, handguns or by turning the side boom on and off. An analysis of usage is given in Table 11.

TABLE 11: Use of special purpose herbicides in 76 pipfruit orchards surveyed.

Herbicide	Target weed	Number of orchards
No herbicides used		55
asulam	docks	8
2,4-D/dicamba	convolvulus	4
clopyralid	yarrow and Californian thistle	3
fluazifop-P-butyl	couch, paspalum, Indian doab, etc	2
asulam **only or** 2,4-D **plus** glyphosate	docks	1
amitrole	white clover	1
glyphosate **plus** amitrole **plus** asulam	docks	1
clopyralid (twice)	Californian thistle	1
haloxyfop	couch, paspulum, Indian doab, etc	1

One grower used dicamba/2,4-D for convolvulus and clopyralid for Californian thistles. Thus 21 out of 76 orchards used special purpose herbicides. Growers indicating that they had convolvulus were probably referring to greater bindweed (Harrington pers. comm.). Often this and two other species, field bindweed and cornbind are generally called "convolvulus". In the time available it was not possible to identify individual species, though any of these three species may have been present.

In this period of active growing only the use of asulam, fluazifop-P-butyl and haloxyfop from Table 11 can be identified as being essentially safe. They have registration for use in orchards (O'Connor 1989) and if they do come in contact with the crop, they may translocate but will not cause herbicide damage. Crisp and Atkinson (1984) applied fluazifop-P-butyl to apples and plums causing no obvious leaf damage or reduced growth.

The grower who only sprayed around tree trunks as necessary used glyphosate, glufosinate, paraquat/diquat or fluazifop-P-butyl as required. The first three can be considered as broad spectrum, and the last as specific for grasses. No residual herbicides were used.

The two growers who mixed other herbicides with asulam were not following the label recommendations stating that asulum should not be mixed with these herbicides. (O'Connor 1989), and are unlikely to improve control of docks.

The weed species in Table 11 are perennial weeds that have survived the basic weed control programme and now require further attention as they are resistant for a number of reasons. Couch, paspalum, Indian doab, greater bindweed and yarrow have rhizomes; white clover is stoloniferous; Californian thistle has a creeping root system; and docks have a large tap-root. Once established these species are all poorly controlled by the normal application rates of most herbicides used in orchards (O'Connor 1989).

4.3.1.6 Further aspects of the seasons herbicide applications

As each application period has been treated in isolation this section brings them all together and provides an overview on the use of herbicides for the whole season of Autumn 1989 to Summer 1990.

To obtain a seasonal overview of timings of applications for the annual herbicide programmes, growers' programmes are summarised in Tables A4.2 and A4.3 (Appendix 4). To identify any regional differences in use, Nelson and Hawkes Bay applications were separated. Analysis of these herbicide applications over time showed that for the 77 orchards surveyed there was no typical programme as they virtually all differ.

The results for autumn are well represented in 4.3.1.1. However, in the biological period of dormancy to fruit set, two sets of results were given. Table 12 collates the results from Tables 6 and 8 to give one overview of this broad spring period.

TABLE 12: Frequency of herbicide use whether applied individually or in a mix in the period of dormancy to fruitset.

Herbicide	Frequency	Proportion of use %
glyphosate	40	21.9
simazine	37	20.2
amitrole	33	18.1
terbuthylazine/terbumeton	26	14.2
paraquat/diquat	12	6.6
terbacil	9	5.0
linuron/diuron	7	3.9
clopyralid	3	1.7
dicamba	2	1.1
glufosinate	2	1.1
oryzalin	2	1.1
terbuthylazine	2	1.1
diuron	1	0.5
diuron/methabenzathiazuron	1	0.5
metoalchlor/terbuthylazine	1	0.5
norflurazon	1	0.5
oxadiazon	1	0.5
pendimethalin	1	0.5
picloram/2,4-D	1	0.5
2,4-D/dicamba	1	0.5
TOTAL 20 formulations	183	100.0

In this period one grower did not apply any herbicides. He did not use residual herbicides at all, using only one knockdown in autumn and another in summer.

Table 12 shows 9 formulations of knockdown herbicides and 11 formulations of residual herbicides. Of these 20 formulations 8 were used by only one grower, with nearly 75% of the growers depending on four herbicides.

Table 13 shows the use of knockdown herbicides in the season of autumn 1989 to summer 1990. All growers used knockdown herbicides. The grower who had no set pattern of application (applying herbicides with a handgun only as required is excluded). Table 13 also exludes special purpose herbicides, focussing on those used through the boom over the whole herbicide strip.

TABLE 13: Number of knockdown herbicides used in the period autumn 1989 to summer 1990 by 76 pipfruit growers.

Number of applications	Number of growers	Proportion of use %
1	5	6.6
2	31	30.8
3	30	39.5
4	9	11.8
5	1	1.3
TOTAL	76	100.0

The way in which knockdown herbicdes have been used over the season is given in Table 14. Use of special purpose knockdowns was excluded as their use is analysed in Table 11, leaving amitrole, glyphosate, glufosinate and paraquat/diquat. However, seven growers applied either terbuthylazine/terbumeton or linuron/diuron individually, and although these are residual herbicides they have some knockdown activity. All other residuals were applied with a knockdown, except the metolachor/terbuthylazine which was applied singly over a sweetcorn crop grown between young apples, where the soil was cultivated.

TABLE 14: Application patterns of knockdown herbicides for 76 pipfruit growers over the season.

Knockdown herbicide(s)	No. growers	Proportion of use %
amitrole and glyphosate	31	40.8
glyphosate only	22	29.0
glyphosate and paraquat/diquat	13	17.1
amitrole, glyphosate and paraquat/diquat	4	5.3
paraquat/diquat only	2	2.6
amitrole only	1	1.3
amitrole and paraquat/diquat	1	1.3
glufosinate only	1	1.3
glufosinate and glyphosate	1	1.3
TOTAL	76	100.0

Only five out of 76 growers did not use glyphosate, and 96% of growers used amitrole and/or glyphosate, with or without other herbicides. Rotation of knockdown herbicides was practised by two thirds of growers, and the bulk of those who applied only one type of knockdown herbicide used glyphosate.

Growers use of residual herbicides is given in Table 15. Most of these herbicides were used in spring, although one was applied in autumn. Over summer nine growers used residual herbicides, eight using only one, and one grower applied two at the same time.

TABLE 15: Number of residual herbicides used in the period autumn 1989 to summer 1990 by 76 pipfruit growers.

Number of residuals	Number of growers	Proportion of use %
0	10	13.0
1	43	55.9
2	23	29.8
3	1	1.3
TOTAL	77	100.0

These residual herbicides come from several chemical groups. Usage of herbicides from each chemical group is analysed in Table 16. Growers whose herbicide usuage varies for separate parts of the orchard have had each different pattern scored. The order given in Table 16 is not necessarily the order of application, and some were applied together as previously seen. Where more than one application is made the chemical groups are separated by a comma. Further information on these herbicides can be sourced from Appendix 3, Table 3A.2.

TABLE 16: Pattern of use of residual herbicides analysed by chemical group used by 67 pipfruit growers.

Chemical group	Frequency	Proportion of use %
triazine	41	61.2
triazine, triazine	7	10.4
triazine, uracil	7	10.4
triazine, urea	5	7.5
urea	3	4.5
urea, urea	2	3.0
uracil	2	3.0
dinitroaniline	1	1.5
dinitroaniline, urea	1	1.5
oxiadiazole, amide/triazine	1	1.5
triazine, dinitroaniline	1	1.5
uracil, urea	1	1.5

Percentage figures have been derived using 67 as the denominator. The frequency totals 72, reflecting the five growers who use different residual herbicides in separate parts of the orchard. Of these 72 applications 56 (78%) are made with herbicides from one chemical group.

The grower who used norflurazon, a phenylpyridazinone, applied it with a triazine, then with a urea and a triazine. He was the only grower who applied three residual herbicides in a season. Because this material was under trial, it has been excluded from Table 16.

Combinations of residual herbicides from the same group were applied in 9 instances. The herbicides involved were simazine, terbumeton/terbuthylazine and linuron/diuron. In all but one of these cases where simazine was followed by terbumeton/terbuthylazine, the herbicides used were the same, e.g. simazine, simazine.

Further analysis of herbicides used by chemical group is given in Table 17. Each chemical group used has been listed and the instances of use scored for each one. Where growers have used herbicides from the same chemical group twice this is scored as two.

TABLE 17: Frequency of herbicides used in a chemical group.

Chemical group	Frequency	Proportion of use %
triazine	69	70
urea	14	15
uracil	10	10
dinitroaniline	3	3
oxadiazole	1	1
amide/triazine	1	1
TOTAL	98	100

Growers are depending heavily on triazine herbicides, and are not using combinations of herbicides, or extending the range of herbicides used, to reduce the selection pressure on any one herbicide. The nine growers who applied two residual herbicides from the same group in one season are compounding "selection pressure", with much of this pressure acting to increase the incidence of C_4 grasses. However the application of knockdown herbicides in combination with the residuals is counteracting this to some extent, i.e. there are combinations, of residual and knockdown herbicides. The reason that simazine is used so frequently is it's low solubility (5ppm), its broad spectrum activity on germinating weeds, high safety factor for crops when correctly used, and it is relatively cheap.

A numerical analysis of herbicide applications applied during the 1989/90 season is given in Table 18 (excluding the use of special purpose herbicides). The major application periods were from dormancy to bud movement and over summer.

TABLE 18: Number of herbicide applications in 4 application periods and in total.

Time period	Number of orchards applying herbicides	Proportion of orchards surveyed %
Autumn	35	46
Dormancy to bud-movement	60	79
Green-tip to fruit set	37	49
Summer	68	89
Special purpose herbicides	21	28
TOTAL	221	

4.3.2 Changes to season's herbicide programme

Growers were asked if they would be using the same herbicide programme next season (1990/1991). Anticipated changes in chemicals, rates or timings were recorded. Multiple answers were permissible. The growers responses are presented in Table 19. Two growers gave responses that were not included. One of these growers was waiting to see how the current season's herbicide programme worked, whilst the other grower claimed he would only change his programme if the relative costs of herbicides changed dramatically.

TABLE 19: Herbicide programme changes anticipated for the next season of 75 pipfruit growers.

Anticipated programme changes	Number of growers.
No Change	28
Change type of residual herbicide	19
Use more glyphosate over growing season (by rate or increased applications)	8
Add in a residual (period not specified)	6
Add in an autumn knockdown herbicide	5
Rotate amitrole and glyphosate	3
Add in a residual (dormancy to budbreak)	2
Reduce amount of glyphosate used	2
May not use a residual	2
Delay application of residual	1
Use safer residuals around young trees	1
Increase rate of simazine used	1
Use less amitrole	1
Not use terbumeton/terbuthylazine	1
Not use simazine	1

Over one third of the growers claimed that they would not be changing their herbicide programmes.

Of the 19 anticipating changing their residual herbicide next season, six had not decided what to change to; seven were changing from a triazine to another chemical group (e.g. to linuron/diuron (urea), or pendimethalin (a dinitroaniline)); and six were considering interchanging simazine with terbumeton/terbuthylazine. Since these are both triazines there is unlikely to be much benefit as label claims for weeds controlled are similar, though terbumeton/terbuthylazine claims to control clover better than simazine (O'Connor 1989). Two specifically stated they would not use either simazine or terbuthylazine/terbumeton. No growers indicated that they were changing residual or knockdown herbicides as part of a planned regular rotation, but are changing to either save money, i.e. reductions of use,or improve the present state of weed control. Dissatification with current herbicides was present, but some of this is illfounded. The six growers who indicated that they were going to include a residual herbicide in their weed control programme had not used one previously.

In most cases growers are changing residual herbicides without fully appreciating the implications, as the above paragraph highlights. Growers blame a residual herbicide for not working rather than blaming poor timing of application or underdosing. They also expect control of species that the herbicide does not control at recommended rates according to the label, e.g. many grass weeds are not controlled by simazine at rates of 2-5 ℓ/ha.

The approach to changing their herbicides appears to indicate a lack of knowledge. Not one grower was going to add oryzalin or terbacil to triazines to increase the range of weeds controlled. Some growers stated they would try new herbicides following recommendations from friends.

Addition of a knockdown herbicide in autumn (5) was either amitrole (1) or glyphosate (4). Likewise rotations of the amitrole or glyphosate revolve around the autumn or spring period. The two growers who were changing to use less glyphosate did so in two ways. One was going to reduce the rates applied per hectare but he did not indicate by how much. The other grower was going to reduce the number of applications. This grower was the only one applying 5 knockdown herbicides (all glyphosate) in a season, and thus could probably afford to miss one.

Overall, intended herbicide use for next season would appear to increase since additions of residual and knockdown herbicides outweighed intended reductions of total herbicide use.

4.4 Herbicides and Weeds

4.4.1 Weed species on orchards

Growers were asked to list the "worst" three weeds on their orchard. "Worst" was defined as the weeds that they, as growers, were most concerned about and thus was not quantified or qualified by number, size, difficulty to kill, management impediment etc.

Not all growers listed three species, some listed more, some less. An analysis of these responses is presented in Table 20.

TABLE 20: Number of weeds indicated as "worst weeds" when asked for three.

Number of weeds recognised as worst	Number of orchards indicating as "worst"	Proportion of growers (%)
1	2	2.7
2	14	18.7
3	27	36.0
4	20	26.6
5	6	8.0
6	6	8.0
TOTAL	75	100.0

Two growers were not included in these analyses. One grower was in his first year of establishing herbicide strips after years of cross mowing, and did not have any major problem weeds as yet. The other grower's response was "couch and a range of annuals", and thus could not be constructively used.

An analysis of species that growers claimed to be their first choice worst weed, is analysed by region in Table 21. Growers regularly confused couch and Indian doab and thus these two species are placed together.

Mallows are difficult to identify, with differences between dwarf mallow French mallow, small flowered mallow and large flowered mallow being minor. Most growers identified mallows as mallow or small flowered mallow. For the purpose of this survey, mallows will be considered as Malva spp, and henceforth referred to as mallows.

Table 21 summarised responses from a total of 71 growers as the 3 Manawatu growers, the grower in Nelson who had just established herbicide strips, and two Hawkes Bay growers who answered that their worst "weed" was grass, Indian doab, couch and barnyard grass were excluded. The 3 Manawatu growers all ranked black nightshade as their single worst weed. Table 21 lists the single worst weed on growers orchards, whereas Table 22 lists all worst weeds mentioned by growers.

TABLE 21: **Single worst weed identified by 33 Nelson and 38 Hawkes Bay pipfruit growers.**

Weed species	Number of growers		
	Nelson	Hawkes Bay	Total
paspalum	12	5	17
couch and/or Indian doab	1	6	7
tall willow herb	5	0	5
mallow(s)	2	3	5
summergrass	2	2	4
barnyard grass	0	4	4
creeping mallow	1	2	3
amaranthus	3	0	3
oxalis	3	0	3
Californian thistle	0	3	3
bristle grass	0	2	2
asparagus	0	2	2
fathen	0	2	2
black nightshade	1	1	2
dock(s)	2	0	2
cocksfoot	1	0	1
yarrow	0	1	1
Jersey cudweed	0	1	1
"convolvulus"	0	1	1
thorn apple	0	1	1
creeping buttercup	0	1	1
oxtongue	0	1	1
TOTAL WEED SPECIES	12	18	23
TOTAL GROWERS	33	38	71

Altogether, grasses made up 37 of the 76 responses, or just under half of the pipfruit orchards surveyed. Hawkes Bay and Nelson growers had seven weed species in common as their worst weed: paspalum, couch and/or Indian doab, mallows, summergrass, creeping mallow and black nightshade. Over half of the species listed were the worst weed on only one or two orchards. Only four growers from Nelson, five from Hawkes Bay and one from Manawatu did not list a grass as one of their worst weeds.

Table 22 lists all the worst weeds that growers from all regions mentioned, including their single worst weed. The grower who had just established herbicide strips has been excluded from analysis leaving a total of 76 growers.

No differentiation was made between narrow-leaved plantain and broad leaved plantain, as growers generally had both and did not distinguish between them. Barnyard grass is highly variable in growth form (erect to prostrate): and plant size (20 - 120 cm tall) (Lambrechtsen 1986). Some confusion ocurred between it and bristle grasses, but growers with one often had the other.

TABLE 22: Worst weeds listed by pipfruit growers.

Weed species	No. of growers indicating as a "worst weed"	% of growers considering as worst weed
paspalum	39	51
Indian doab and/or couch	28	37
mallows	23	30
black nightshade	16	21
summergrass	15	20
Californian thistle	14	18
tall willow herb	14	18
docks	13	17
barnyard grass	12	16
"convolvulus"	10	13
amaranthus	10	13
creeping mallow	9	12
bristle grass	8	11
fathen	7	9
oxalis	7	9
white clover	6	8
asparagus	5	7
creeping buttercup	4	5
ryegrass	3	4
yarrow	2	3
storksbill	2	3
cocksfoot	1	1
plantains	1	1
brambles	1	1
phalaris	1	1
prairie grass	1	1

continued on next page

TABLE 22: continued...

Weed species cont...	**No. of growers indicating as a "worst weed"**	**% of growers**
hawksbeard	1	1
fennel	1	1
Jersey cudweed	1	1
thorn apple	1	1
groundsel	1	1
oxtongue	1	1
creeping yellow cress	1	1
TOTAL 34 weed species		

Of the weed species listed in Table 22, 12 species were mentioned by only one grower. Of these, five have already appeared in Table 21, being the growers single worst weed. A comparison of Tables 21 and 22 shows that black nightshade, docks and convolvulus have increased in importance as weeds.

Observations in the orchard suggested that the species listed by growers had been correctly identified. Weed species noticed as been prevalent, but not troublesome enough to make the "worst 3" listing were observed. In the Nelson region the following species were recorded once on seperate orchards: wild carrot, yorkshire fog, scrambling speedwell, wireweed, pennyroyal and gorse. In the Hawkes Bay region the following species were recorded once on seperate orchards: mercer grass, sheeps' sorrel, catsear, wild portulaca and on two orchards, fleabane.

4.4.2 Weed buildup and herbicide failure

Growers were asked to indicate how the weeds they mentioned in 4.4.1 had built up and which herbicides had failed to control them. The results gained in this section were very diverse. Answers given also conflicted, with one grower claiming a herbicide worked for one specific weed and another claiming it did not.

Over half the growers (38) claimed simazine had failed on one or more of their weeds, whilst another seven felt that all herbicides or pre-emergents had failed to control their weeds. One grower claimed that 10ℓ/ha of simazine (50% active ingredient) did work. (Simazine is registered in New Zealand for use at 2 to 5ℓ/ha in pipfruit.) Of the knockdowns, growers claimed amitrole failed to control paspalum, whilst glyphosate was claimed to not controll tall willow herb. Plate 9 shows a clump of paspalum growing after application of amitrole. The photo was taken in December, some 12 weeks after application. The grower claimed that 2-3 weeks after application the grass was completely white.

Plate 9: Paspalum showing recovery following application of amitrole.

Two growers admitted that they had used low rates of glyphosate, whilst another two cited herbicide failure being caused by applying residuals too late or onto rank weed growth.

Alleged reasons for spread of weeds included dispersal by birds (black nightshade, asparagus etc) less frosts, disperal by sheep, spread from mown alleyways, and poor control of weeds in a neighbouring orchard.

Table 23 shows weeds that will not be adequately controlled by the herbicides used at the given range of rates. Extensive use of Matthews (1975) and O'Connor (1987; 1989) has been made in preparing Table 23. Only those species listed in Table 22 as worst weeds have been included and are listed in that order for convenience. Glyphosate was a relatively new herbicide at the time that Matthews (1975) work was written, and his book contains little information on it. The manufacturers' of glyphosate claim that there is no weed it will not control - its simply a matter of rate. Weed species listed are compiled from growers responses, literature, and personal knowledge.

Matthews (1975) lists terbumeton and terbuthylazine separately, and his findings have been combined. In some respects findings cannot be fully compared to that of simazine as the major formulation of these herbicides Caragard, uses 5kg ai triazine/ha whereas simazine at 5ℓ/ha is 2.5kg ai triazine/ha. Linuron and diuron are also treated differently in Matthews book. Results for oryzalin have come purely from O'Connor (1989).

The herbicides listed in Table 23 have been limited to those used by over 95% of growers. (See Tables 14 and 16.)

TABLE 23: Weed species listed in Table 22 not controlled by the herbicide used.

Herbicide	Weed species
simazine, 3-5ℓ/ha, 50% ai	all those in Table 22
paraquat/diquat 2-6ℓ/ha. 20% ai	all weed species in Table 22 except summergrass and groundsel.
amitrole 8-10ℓ/ha 40% ai	paspalum, couch, Indian doab, mallows, Californian thistle, docks, "convolvulus", creeping mallow, oxalis, asparagus, creeping buttercup, yarrow, plantain, fennel, Jersey cudweed, creeping yellow cress.
glyphosate 2-4ℓ/ha. 36% ai	established paspalum, Indian doab, couch, established Californian thistle, tall willow herb, dock, convolvulus, creeping mallow, bristle grass, oxalis, white clover, asparagus, creeping buttercup, yarrow, Jersey cudweed, creeping yellow cress.
terbumeton/ terbuthylazine 8-10ℓ/ha. 50% ai	paspalum, Indian doab, couch, Californian thistle, tall willow herb, docks, barnyard grass, "convolvulus", amaranthus, oxalis, asparagus, storksbill, plantains, fennel.
terbacil 2-3kg/ha. 80% ai	paspalum, Californian thistle, established docks, amaranthus, creeping buttercup.
linuron/diuron 4-8ℓ/ha. 46.5% ai	paspalum, Indian doab, couch, summergrass, Californian thistle, docks, barnyard grass, "convolvulus", oxalis, asparagus, yarrow, storksbill, plantains, fennel, docks.
oryzalin 6-9ℓ/ha 50% ai	established paspalum, black nightshade, Californian thistle, docks, "convolvulus". oxalis, asparagus, yarrow, groundsel, oxtongue, creeping yellow cress.

The cost of alternative residual herbicides to simazine may be posing an economic barrier to change. The cost of treating a hectare in 1989 for the herbicides given in Table 23 is given in Table 24. (FruitFed Supplies 1989). These prices reflect the cost paid by growers for residual herbicides in the winter of this survey. Oryzalin was not available in a flowable form in 1989, and the equivalent cost of ai/ha for the wettable powder (75% ai) form has been used.

Table 24: Cost of residual herbicides in 1989.

Herbicide	Rate per hectare of formulation used	Cost per treated hectare $
simazine	3-5*l*	29-48
terbacil	2-3kg	200-300
oryzalin	4-6.25kg	180-280
linuron/diuron	4-8*l*	90-180
terbuthylazine/ terbumeton	8-10*l*	198-245

Not suprisingly none of the herbicides used will control all of the grower's worst weeds. Good decisions can be made within the range of registered herbicides available (not all listed in Table 24) to aid control of these weeds. Growers are compounding problems by using, or having used triazines too often, and not adding terbacil or oryzalin with them, which aids control of germinating grasses and other annuals. To overcome these problems growers need to rotate their residual herbicides amongst the chemical groups to improve the control of annual weeds and increase their broad-acre and spot spraying with herbicides that have label recommendations for orchard use. Higher rates of glyphosate will control all annuals, grasses, docks, "convolvulus", yarrow, Californian thistle, or weaken them to an extent where a second application will control them. This second application can be timed in early summer when annual weeds such as amaranthus, black nightshade, groundsel, summergrass etc emerge. These weeds will be seen for two reasons. Firstly they are late germinating, and secondly the strength of the residual applied in spring may have weakened to no longer control germinating weeds at the reduced rate now resident in the soil. Application of a residual herbicide together with a knockdown herbicide can be applied before the weight of fruit brings branches down, and weeds that survived any spring application get too much larger.

Lawson (1984) recommends that better utilisation of existing label recommendations should be made, using programmed weed control and rotation of herbicides to prevent the buildup of resistant weed problems. He also states that it is important that existing herbicides with label recommendations do not lose these due to product rationalisation by chemical suppliers.

4.4.3 Solutions to problem weeds

Growers were asked what they were doing in regard to their problem weeds. In some respects part of the possible solutions are covered in Section 3.3, by changes in herbicides programmes.

Specific examples of growers responses were:

- better timing of knockdown herbicides to control weeds at an earlier growth stage than usually done;
- to improve the control of paspalum graminicides such as fluazifop-P-butyl were going to be used, or rates of glyphosate in excess of 4ℓ/ha;
- more use of asulam for control of docks, which is selective to this weed (and bracken) allowing spot-spraying, rather than spraying all herbicide strips;
- use of linuron/diuron on tall willow herb which is not controlled by triazines (Bailey and Hoogland 1984) and regrows following applications of glyphosate and amitrole (Atkinson 1976). One grower was hand hoeing this weed out;
- the timing of residual herbicides was going to be improved to apply it to near bare soil, rather than waiting until late spring and applying it with a knockdown herbicide. In some cases a second residual may be required in early summer.
- one grower was going to use 2,4,5-T on mallows;
- improvement of irrigation to ensure that the herbicide strip is kept moist, but not continually leached, allowing residuals to work longer;
- one grower was going to add oryzalin to current residual herbicides used, to aid control of summer germinating grasses.

Only one grower indicated that he was seeking advice, that for the control of Jersey cudweed which he claimed was a weed recently introduced to his orchard.

The rest of the growers solutions involved herbicide changes detailed in section 4.4.2, and continuation of their current programmes. However, the emphasis on controlling these weeds is post-emergence, with 50 growers mentioning the importance of glyphosate in improving control of problem weeds.

The use of special purpose herbicides was reiterated by growers and this, in conjunction with the common mention of increased vigilance with glyphosate, shows a curative attitude rather than preventative. Thus I believe that lack of information is probably a problem, and too few growers know the correct or better ways of overcoming problems, and are probably also very aware of the costs, which may not meet their financial objectives. For example, most growers do not:

- add terbacil or oryzalin to triazine herbicides;
- use glyphosate at high enough rates to control paspalum in autumn;
- rotate residual herbicides to reduce selection pressure;
- control weeds when they are smaller;
- control weeds as they emerge after the "spring" application of a residual herbicide has weakened and lost its effectiveness.

4.4.4 Use of herbicides in a manner not according to label recommendations

Of the 77 pipfruit growers surveyed 86% of them (66) claimed that they had not applied any herbicides in a manner contrary to label recommendations. It is important to note that these results do not directly relate to the season of survey (1989-90), but also include past applications. In all but one case the growers did not relate the results in the format set out in Question 4.4, and answered without consulting any records. Results are thus going to be presented in an anecdotal form, though a summary of these results is given in Table 25 and 26.

Six different unregistered herbicide formulations were identified. Dicamba/2,4-D was used by half of the 11 growers who used herbicides not reigstered for pipfruit. The six growers were all from Hawkes Bay and used the material for control of "convolvulus". One of the six growers indicated that he had not used 2,4-D/dicamba for 3 years. In terms of application the herbicide was applied through side-booms, weedwipers, handguns and knapsack sprayers, mainly over the summer. On a 32ha property one orchardist indicated that he used 2,4-D/dicamba at a low concentration with surfactant added, using approximately 100ℓ over the whole orchard.

Clopyralid was used by four growers. For two of these growers it was the only herbicide they indicated whilst the others each used another herbicide, with one also using dicamba, the other 2,4-D/dicamba. Target weeds for clopyralid are yarrow, Californian thistles and clover. One Nelson grower indicated that once in the past he used 2,4,5-T under apples at bud movement, aiming to control fennel and mallow.

TABLE 25: Number of growers from the 77 respondents that admitted to using herbicides not registered for use in pipfruit.

Herbicide	No. of growers in this category
dicamba/2,4-D	6
clopyralid	4
dicamba	1
metolachlor/terbuthylazine	1
2,4,5-T	1
TOTAL NUMBER OF GROWERS INVOLVED	11

Another Nelson grower indicated in question 4.3 that he was using 2,4,5-T on mallow, which he considered a problem weed, yet he responded negatively to questions 4.4 and 4.5. Results gained in Section 4 were compared with those gained in Section 3, (where growers' current and intended herbicide programmes were recorded), to investigate further the accuracy of replies given about unregistered herbicides. In question 3.2, 19 growers were recorded as using materials that do not have orchard registration. However only one of the 19 growers declared the use of a non-registered herbicide (metolachlor/terbuthylazine) when asked in section 4.4.4. The grower that indicated he had used 2,4-D/dicamba, "but not for three years", neglected to detail the use of dicamba in the 1989 August-September period. The 18 growers who did not admit to this use may not have realised that the materials they were using did not have orchard registration, or knew, but felt uncomfortable disclosing the information. Growers spot spraying clopyralid or 2,4-D/dicamba were not concerned about the safety of their pipfruit trees because of the limited use within the orchard.

In addition to detecting use of herbicides not registered for use in pipfruit, the survey also identified cases of herbicides which are registered but not applied according to label recommendations. In Table 26 the results from Table 25 have been collated with those from previous tables and sections, to present a summary of all herbicides used in orchards contrary to label recommendations.

A small number of growers in the Nelson region were being advised to apply simazine at more than 5ℓ/ha up to 10ℓ/ha. (Simazine only has registration for use at 2-5ℓ/ha.) The advice came from one company of pesticide merchants, based on a memo received from a manufacturing company. I contacted the reseach division of this company and was given the following reason. Simazine is a triazine formulated with 50% active ingredient. Caragard is formulated with 50% active ingredient comprising two triazines: terbuthylazine (25%) and terbumeton (25%). Caragard has registration for use in orchards at 10ℓ/ha. Since simazine has a lower solubility (5ppm) than both terbuthylazine (8.5ppm) and terbumeton (130ppm), it was reasoned that 10ℓ/ha of simazine would be as safe as 10ℓ/ha of Caragard (Harris 1990).

TABLE 26: Summary of herbicides used in a manner not according to label recommendations from a survey of 77 pipfruit orchards, collated from all questions.

Herbicide	Frequency
clopyralid	14
2,4-D/dicamba	11
simazine > 5 *l*/ha	3
dicamba	3
amitrole (after fruit-set)	2
2,4,5-T	2
terbuthylazine/terbumeton (young trees)	2
terbuthylazine	2
amitrole (young trees)	1
picloram/2,4-D	1
2,4-D	1
metolachlor/terbuthylazine	1
oxyfluorfen (applied after dormancy)	1
terbacil (on pears)	1
TOTAL	44

Table 26 shows that the usage of 2,4-D/dicamba and clopyralid is much more common than indicated in Table 25. This usage is predominatly in Hawkes Bay with 28% of all Hawkes Bay growers surveyed admitting that they use either dicamba/2,4-D or clopyralid. Careful cross checking of these results indicates that the herbicides detailed in Table 26 were applied in 35 orchards, by 46% of growers, with nine orchards using more than one non-recommended herbicide. Most of these applications are spot-spraying.

However, the picloram/2,4-D, metolachlor/terbuthylazine, and terbuthylazine were all boom-sprayed over the whole herbicide strip. Terbuthylazine (trade name Gardoprim) is one of the active ingredients of the herbicide Caragard. Caragard does have orchard registration. Growers are using Gardoprim because it is approximately a quarter of the price of Caragard. Presumably application rates not exceeding label recommendations should be safe.

Four growers added clopyralid to glyphosate to improve the control of clover, thistles and yarrow. These applications were also boom-sprayed over the herbicide strips. One of these applications was in the period of August-September (dormancy to budmovement), two were applied in October-November (greentip to fruitset), and the final put on over summer. Dicamba was boom sprayed with both amitrole and glyphosate on one orchard in mid-September.

Only one of the 11 growers using 2,4-D/dicamba applied it throughout the herbicide strip. This grower was treating "convolvulus" with glyphosate and 2,4-D/dicamba at rates equivalent to 1.3, 0.71 and 0.35 kg ai/ha respectively. For the cost of the 2,4-D/dicamba the grower could have increased his rate of glyphosate to control or suppress the "convolvulus", which is also much safer from a residue point of view.

In the Nelson region 2,4,5-T was recorded as being used to control mallow on at least two properties in past years. Presumably the mallow had got to the semi-woody stage prompting this action. On the whole, the mallows are not readily controlled by most herbicides, especially mature or perennial plants (Matthews 1975). My experience is that glyphosate will control mallow when it is small, but requires rates over 3.6kg ai/ha when large. The key is thus timing of application and/or the use of a residual that will prevent germination of mallow, such as oxyfluorfen.

Lawson (1984) suggests that the best remedy for off-label uses is to make them on-label if at all possible. He states that many herbicides are fully cleared under the British system for a wide range of crops, but not as yet for several minor fruit crops. Fruitgrowers have access to a chemical because a company has already developed a major arable market. New Zealand examples of this are 2,4-D, dicamba, picloram, clopyralid and their mixes. Legisation does not prohibit the sale of a herbicide until all potential uses have been cleared. There is a world of difference between off-label recommendations which growers should not be using <u>yet</u>, because of timescale problems with product development, and those which they should not be using <u>at all</u> for toxicological reasons. Pesticide legislation needs to sympathetically cover this from all sides.

Anomalies like this do exist in New Zealand. Amitrole can be used in kiwifruit up to nine weeks before harvest, (O'Connor 1989) but not after fruitset in pip and stonefruit. From a growers' point of view spot spraying white clover in apples in amitrole may be seen safe compared with broad-acre application which is registered for kiwifruit.

Recent advice in the New Zealand Orchardist seemed to endorse off-label use. Wilton (1990) suggests that sometimes real problem weeds occur which are difficult to bring under control within the recognised (i.e. those with label recommendations) selection of orchard herbicides. He goes on to state that "if this happens it is essential to eliminate them before they begin to spread very far. Spot treatment of the problem weed patches with the most effective herbicide for their control is the best course of action. In my view it is better to risk damaging a tree or two to wipe out potentially hazardous weeds before they take over than run the risk of an orchard full of them later on".

The advice given to growers is not always good advice. It is important to control problem weeds while they are small. However, the residue risks must be taken into account. Use of a herbicide without label recommendation whilst the trees are dormant should not pose a residue risk to fruit, but may affect the health of the tree.

Apart from the above exceptions the bulk of these unregistered herbicides were carefully directed "spot" applications used to control "troublesome" weeds in the orchard.

Education about herbicides and fruit safety could improve many of these practices. Dicamba could be replaced by amitrole (before fruit set only) or glufosinate for clover control, 2,4-D could be replaced by asulam or higher glyphosate rates for dock control, whilst rates in excess of 6ℓ/ha of glyphosate will also suppress "convolvulus". However a few growers such as those boom-spraying picloram/2,4-D and dicamba/2,4-D will probably only respond to an individual request to stop these practices.

4.4.5 Herbicide damage to pipfruit trees

Growers were asked if they knew of any trees on their orchard which had been damaged by herbicides in the past. Growers did not always relate perceived herbicide damage in the form as laid out in the questionnaire, which was worded to include current and past experiences. The results are presented in Table 27.

Out of 76 growers, 22 indicated that they had never noticed herbicide damage on their orchards. There were 79 cases of herbicide damage declared: 41 in Nelson, 35 in Hawkes Bay and 3 in Manawatu. Nearly half of the orchardists related more than one case of damage.

TABLE 27: Herbicides claimed to be responsible for damage on 76 pipfruit orchards. Multiple answers were acceptable.

Suspected herbicide	No. growers claiming this herbicide involved
No herbicide damage	22
glyphosate	40
amitrole	16
terbuthylazine/terbumeton	5
simazine	5
paraquat/diquat	3
linuron/diuron	2
terbacil	2
glufosinate	1
metsulfuron	1
oryzalin and terbuthylazine	1
oxyfluorfen	1
2,4,5-T	1
13 herbicide formulations	**79 cases of herbicide damage**

The majority of herbicide damage experienced was caused by glyphosate. This is not really surprising as this survey found it was used more often than any other herbicide, especially when trees are in leaf. Of these cases 68% (28 out of 41) were localised damage which can be best described as "little leaf syndrome". The growers experienced this on both young and old trees; pears and apples. All acknowledged entry of the herbicide following drift or direct contact with green bark, suckers or lower limbs. Some growers prune these damaged parts off, whilst others leave them as they usually recover. One grower added that he considered the apple variety Fuji to be more susceptible to glyphosate than other varieties. Examples of herbicide damage related during the survey are given below.

A severe case of glyphosate damage occurred in Nelson in which several Gala trees were killed (Plates 10 to 13). The trees were originally planted 2.5m apart in the row and, on advice from a NZAPMB Field Officer every second tree was removed. The advice also included painting the stumps of removed trees with a mix of glyphosate and diesel in July 1989. It is likely that the roots of the adjacent trees had, during their development, grafted together. Thus the glyphosate was translocated to adjacent trees, and the severity of damage depended on the amount of root grafting and amount of active ingredient translocated.

Root grafting is not unknown and has been investigated. In experiments with oak wilt control Kuntz and Riker (1950) documented spectacular transport of several poisons from treated to non-treated oak trees. Disodium hydrogen arsenite, Na_2HAsO_3, moved to seven non-treated trees over a maximum distance of 15m, with other poisons moving to two or three trees over 8m. Boyce (1957) noted movements of copper sulphate ($CuSO_4$) over distances from 3 to 8m between poisoned oak stumps and nearby intact trees. Of the seven instances four were intraspecific and three were interspecific.

Fenton (1965) reported selective thinning using 2,4,5-T to 14 year old natural stands of sweet gum in southern New Jersey. Ultimate mortality of untreated crop trees was estimated at 3 to 6% and he observed damage to about 20% of the dominant trees. Root grafts were confirmed by excavation of two of the crop trees.

Self grafts, intraspecific and interspecific grafts are known to occur in forest trees. Occurrances of such fusions have been reported in more than 150 woody species (Graham and Bormann 1966). Although no published reports of root grafting with apple trees could be found, there is general acceptance among horticultural researchers that root grafting is common in orchards (Warrington 1991). Thus root grafting was probably responsible for the glyphosate damage found in the Nelson Gala trees.

Plate 10: **A stump that was painted with glyphosate and diesel, following removal of every second tree down a row.**

Plate 11: **Tree death from glyphosate poisoning, adjacent to painted stumps.**

Plate 12: View of glyphosate damage, including three dead trees on left and symptoms on adjacent trees. Note stumps removed between dead trees.

Plate 13: Close up of less severe symptoms of glyphosate poisoning.

Other reported mishaps with glyphosate resulting in tree damage included a burst spray hose, drift from poorly directed handgun and knapsack applications, and splash from a herbicide tank (on the back of the tractor that did not have a lid) affecting a lower teir. Another incident involved a grower who sprayed with a boom out either side of his tractor, lifting one boom up to pass the pump shed, and turning the wrong side off, spraying glyphosate into the lower branches. Death of young trees and grafts due to glyphosate damage was claimed by four growers. One lost trees in an interplant situation, where dormant budded trees had been put in. All but one of these growers recognised drift or direct contact with glyphosate as the cause of damage. As Plate 14 illustrates one grower believed that glyphosate was washed down cracks in the soil and translocated to the aerial parts of the tree via root absorption. The trees did express symptoms of glyphosate damage.

Plate 14: Grower beside glyphosate damaged tree showing cracks in soil where he believed herbicide travelled down to be taken up by roots.

Due to a very wet 1989 spring in Nelson, trees planted that winter had soil with sunken hollows and had dried out with many cracks. The grower was quite adamant that glyphosate was moved into the soil in rain, down the cracks and absorbed up by the young trees. (See Plate 15 and 16.) The grower in question was using herbicides for the first time after years of cross mowing. Thus the glyphosate was applied by a grower who had no previous experience with herbicides. Glyphosate is rapidly deactivated by adsorption following contact with soil particles, and there is no evidence suggesting root uptake. Thus foliar uptake was a more likely cause.

Plate 15: Three young damaged trees in a row.

Plate 16: Example of young trees expressing typical symptoms of "little leaf syndrome" due to uptake of glyphosate, through green tissue.

Plate 17: Close up of severe symptoms of glyphosate damage.

Another case of herbicide damage occurred when glyphosate was mistaken for winter oil and was applied to trees at the green-tip stage to control mites, mealy bugs and aphids.

Characteristics of amitrole poisoning are very distinctive. Leaves turn white (bleaching), with severe chlorosis and often pink colourations mainly on younger leaves (Ministry of Agriculture, Fisheries and Food 1981). Marginal necrosis is also common. Amitrole is a foliar applied translocated herbicide that can be absorbed by roots and has a 4-6 week residual life (O'Connor 1989). Occurrence of these symptoms on lower tier leaves and branches was recorded by 14 growers. Damage was recorded on apples, pears and nashi of all ages. Growers identified drift as the major cause of contact, but also indicated that they had applied it too late, used rates exceeding label recommendations, and that young trees in interplant situations suffered the most (note Plate 7). Suckers also expressed symptoms.

In one reported case a grower applied amitrole prior to 72mm of rain. He indicated that the herbicide successfully controlled the weeds but that his apple trees had a white margin on their leaves for a while. Amitrole leaked from a herbicide tank parked under an apple tree overnight, causing damage to trees around the puddle. Another case of amitrole damage involved young trees. A mix of amitrole and simazine was applied in a mature orchard, but also around replants. The trees did not grow and the leaves closed up. Figures 18 to 20 show amitrole symptoms expressed in apple trees photographed during the survey.

Plate 18: Amitrole damage where the herbicide has been applied under young apple trees.

Plate 19: Amitrole damage on fruit bearing wood.

Plate 20: Low hanging branch showing amitrole damage.

Simazine was implicated in four other reports of damage. Two of the reports involved damage to young trees and grafts. In one case the symptoms were described as a marginal necrosis, from which the trees recovered. Symptoms expressed on mature apples were described by growers as "white-tips on the odd branch". As an inhibitor of photosynthesis, triazine damage has symptoms of chlorosis and necrosis tending toward the tips and margins of the leaf. Older leaves are usually the worst affected (Ministry of Agriculture, Fisheries and Food 1981). A Hawkes Bay orchardist growing fruit on a sandy soil claimed that simazine had caused his leaves to yellow - "like mosaic virus". This symptom is not unlike those shown for apple by Ministry of Agriculture, Fisheries and Food (1981). Hogue and Neilsen (1988) conducted trials with various herbicides at above recommended rates. They used 1.5kg ai/ha "(x)" as the recommended rate. This equates to 3ℓ/ha of the 50% formulations used in New Zealand, except Simatox, a 90% formulation. In New Zealand, orchard label recommendations are for up to 5ℓ/ha (2.5kg ai simazine/ha). They found that foliar symptoms of toxicity were mainly evident at the 4x level (12ℓ/ha of New Zealand 50% formulations), and described simazine damage as an interveinal chlorosis and marginal necrosis throughout the season, agreeing with symptoms of Ministry of Agriculture, Fisheries and Food (1981). All growers claimed that simazine damage was a result of root uptake, which is the chemical's main mode of action, rather than foliar uptake during application.

Another triazine residual herbicide claimed to be causing damage was terbuthylazine/terbumeton. Symptoms recorded were more severe with death recorded on 2 year-old Granny Smith trees, following application to a dry soil, followed by rain washing the herbicide down cracks to the roots. Label recommendations are that this herbicide should not be applied to trees under 3 years old. Terbumeton is much more soluble (130ppm) than both simazine (5ppm) and terbuthylazine (8.5ppm). Mature pears suffered "yellow leaves all over, for the whole season, getting progressively worse". The terbuthylazine/terbumeton is claimed to have leached too quickly in the wet. The grower indicated that the fruit was alright, but this seems unlikely. Stunting and yellowing were the damage symptoms of this herbicide on two separate orchards. Young apple trees replanted between older trees were damaged, whilst on another orchard 7 year old apple trees were affected when the herbicide was washed in during a rain storm. Another grower described the symptoms as being like a deficiency, a yellow chlorotic leaf spot. All of the growers agreed that the damage was the result of root absorption, usually due to leaching after heavy rain.

Direct contact of paraquat/diquat with tree leaves caused superficial burns in two orchards. In 1982 one grower was using the same tank for both crop and herbicide spraying. A mixed up solution thought to be captan (a fungicide) was actually paraquat/diquat. The sprayed trees "dropped their leaves but later cropped well". The grower now has separate sprayers.

In 1977 a grower used terbacil under pears contrary to label recommendations as a spring residual. The trees' leaves and fruit went yellow, and he indicated a yield loss of some 600 bushels. Terbacil, like other uracils, cause a chlorosis along the veins that later turned necrotic (Ministry of Agriculture, Fisheries and Food 1981). One orchard in Nelson had used terbacil over a number of years. The grower did not indicate that he had any herbicide damage. Comments taken in the orchard were "young interplants with very weak growth, leaves small and grey, with marginal necrosis and chlorosis", probably terbacil damage. Hogue and Neilsen (1988) described terbacil damage as scorching, which could be interpreted as marginal necrosis.

When glufosinate was new on the market a Nelson grower intentionally sprayed an apple tree to assess its safety. This resulted in tree death.

One instance of late application of the herbicide oxyfluorfen (Goal) caused extensive damage in mature pear trees. The growers described the symptoms as burnt off leaves, like a blow torch. Branches above 3m recovered but the lower tiers were unthrifty for the whole season. Oxyfluorfen is not absorbed by roots nor foliage but damages shoots (Worthing and Walker 1987), and is extremely resistant to leaching. The label recommendations for this herbicide are that it be put on whilst fruit trees are dormant, onto moist soil. The grower did not follow the recommendations and applied this herbicide over late flowering, which on pears coincides with leaf emergence. Damage was probably caused by a volatile fraction of the herbicide.

Only one of the herbicides without orchard registration applied was claimed to have caused herbicide damage. This is an important finding indicating that growers using dicamba, clopyralid and 2,4-D did not experience any damage to crop trees, supporting growers' views that careful spot-spraying of herbicides is relatively innocuous. The grower who indicated that he had used 2,4,5-T on mallow and fennel in Question 4.4 indicated damage from this herbicide stating that the herbicide had no visual leaf effect, but that he had small fruit for two years. He suspected that this occurred when drift from gorse spraying reached the apple trees. Symptoms from hormone damage, vary with dose, plant species and herbicides. The most common is leaf distortion with a tendency to parallel veining, leading to a characteristic "fern leaf" symptom (Ministry of Agriculture, Fisheries and Food 1981). Lobb and Woon (1983) found that grape and kiwifruit showed strong symptoms eight weeks after application of auxin-type herbicides (including 2,4,5-T at 1/10th and 1/100th dilutions of commercial rates). Thus in this case, the symptom of small fruit is unlikely to be caused by the 2,4,5-T, without strong symptoms seen on the leaves of the apples. This case has too many contradictions to be credible. Plates 21 and 22 display damage from hormone herbicides.

Plate 21: **Dead willows in the background were treated with 2,4-D/picloram. Apples in the bottom left are expressing hormone damage symptoms. It is suspected that intraspecific root grafting is involved.**

Smith (1991) reported on growers whose kiwifruit vines had been affected by hormone sprays. 2,4,5-T was claimed to delay fruit maturity, over one month after it is usually picked. Drift from 2,4-D was claimed to have reduced total yield and distorted fruit and leaves. Pears grown on the same orchard were not affected.

Plate 22: **View of apple showing characteristic distortion of leaves, indicating contact with hormone herbicide in this case having come up from the roots.**

One other case of damaging spray drift was recorded. A Nelson grower claimed that 25 apple trees were killed by metsulfuron, probably from the herbicide leaching onto the property from adjacent areas. The symptoms were likened to that of a flame thrower with bark peeling. However it was strongly suspected he applied it under the trees.

Herbicide damage in a Hawkes Bay nursery accounted for the death of 15 to 20% of dormant budded stock, at leaf emergence. The grower was using a mixure of terbuthylazine and oryzalin. He shortened the spray width of the boom, thus concentrating the chemical. The soil remained bare for 18 months. This was the only case where a grower indicated that overdosing was the probable cause of herbicide damage.

Herbicide damage is widespread, and in all probability can be found on every orchard. Their exists then a probability that herbicides are reaching the fruit. Plates 19 and 20 show fruit subtended by afflicted leaves. The question arises about the fate of this fruit. Small or blemished fruit will not make export, but does it get into fancy or No.1 grade, gate sales or process?

Contact with materials such as paraquat/diquat and glufosinate would disfigure the fruit, not unlike russets, and branches severely affected by glyphosate and amitrole would not be able to carry fruit to harvestable size. Glyphosate and glufosinate are herbicides of very low mammalian toxicity. (O'Connor 1989.)

Lobb and Woon (1983) found that grapes and kiwifruit showed no visual effect from spraying with amitrole at 1/10th and lesser dilutions of commerical rates. Growers and harvesting staff then may not be able to identify fruit from localised areas previously affected by herbicides. For knockdown herbicides, drift or direct contact is the major problem rather than root uptake. Residual herbicides are suspected by growers as being taken up by roots particularly terbuthylazine/terbumeton, following leaching in heavy rain, and or because of applications applied after leaf emergence on the crop. Young trees in all these situations are more susceptible than older trees. Damage to these young trees planted as replacements or interplants was common from both knockdown and residual herbicides. Overdosing, or high rates of residual herbicides was mentioned by one grower. Soil uptake by young trees is recorded as causing extensive damage.

Although damage is common it is not so bad as to be reducing production. Having grown up on an orchard and later managed them, this much damage was not expected, with only a little ever been seen. Growers can diagnose herbicide damage and are able to indicate which herbicide caused it. The frankness and amount of results given indicate that they are not overly concerned, unless death is involved. In Nelson the wet spring of 1989 meant that many growers were applying herbicides later than usual and in less than ideal conditions. This region was where most of the amitrole damage was sighted in mid-December, but as Hawkes Bay was surveyed some 3-5 weeks after Nelson, Hawkes Bay trees may have recovered and not be expressing the symptoms.

The problem is widespread and although not production orientated is very much quality orientated. The next section of this thesis unfolds just how this occurs.

It is the potential translocation of materials into the fruit that is of most concern. The most prevalent of these would appear to be amitrole, but clopyralid, 2,4-D, dicamba and picloram are also possibilities. Damage from residual herbicides (terbacil, simazine, terbuthylazine/terbumeton) are generally restricted to young non-bearing trees. Further work is needed to examine this.

4.5 Herbicide Spraying Equipment

Information was gathered on the equipment used by growers for applying herbicides, including the manufacture of boom and tank, nozzle arrangement on boom, mounting and adjustment, and the way the spray discharge turned on and off at the boom.

4.5.1 Tank manufacture, size and age

All growers spraying equipment was examined. However not all were in their orginal chassis and carried on the 3 point linkage. Tanks that were commerically made specifically for herbicide spraying were identified on 42 orchards (55%) out of 77 orchards.

Two thirds of these tanks (28) were made by two companies, Croplands (14) and Winstones (14). The next most common tanks were made by Sprayrite (8), GIMCO (5), and Pearce Engineering (1).

Sprayers constructed on the farm (45%) were made from metal 44 gallon drums or plastic drums orginally used for carrying materials like drench, or spraying oil. These were carried on trailers, on pallets in scoops or put into frames. (Plates 23 and 24).

The age of the commercially made tanks was recorded for 32 of them, and for 6 of the non-manufactured spray tanks (Table 28). Growers may have an old tank with a new boom, or a boom that they are continually modifying and thus Table 28 relates mainly to the age of the equipment as the grower sees it. Ages over 5 years were occasionally given as a range, i.e. 8 to 10, 7 or 8 and these age groups are presented together.

TABLE 28: **Distribution of age of equipment (mainly tanks) by growers.**

Age in years	Number of equipment this old	Distribution %
1	1	2
2	0	0
3	3	8
4	4	11
5	5	13
6 to 7	9	24
8 to 10	14	37
> 10	2	5
TOTAL	38	100

Thus one third of equipment is less than 5 years old and two thirds of it more than 5, but most of this is over the age of 8. This would also hold true for that equipment which is not scored here.

Of the 42 commercially made tanks 41 had a capacity of 500ℓ and one of 450ℓ. The non-manufactured tank arrangements were made up predominantly two sizes, 100 gallon (described by growers as such or 400ℓ, 450ℓ or 500ℓ), and 44 gallon (around 200ℓ). Two very large tanks were used. One was an old 500 gallon petrol tank that was dug up and mounted on wheels, whilst the other was a 1500ℓ crop sprayer tank. The distribution of all tank sizes is given in Table 29. The 100 gallon size was recorded as 450ℓ, the 44 gallon size as 200ℓ.

Plate 23: Tank placed on pallet. Note use of string by right hand to lift boom up and down. Boom mounted on front.

Plate 24: Spray tank mounted on a trailer.

TABLE 29: Distribution of tank sizes of 68 sprayers.

Tank size (ℓ)	No. equipment	Distribution %
160	1	1.5
200 (44 gal)	11	16.1
300	1	1.5
400	1	1.5
450 (100 gal)	7	10.3
500	44	64.7
800	1	1.5
1500 or more	2	2.9
TOTAL	68	100.0

Tank size is thus dominated by three sizes, manufactured 500ℓ tanks and 44 gallon or 100 gallon "tanks". Pump sizes were not accurately recorded, but most were in the 30-40ℓ/min range.

4.5.2 Nozzle tip type, manufacturer, and composition

Nozzle tips were used by all growers (except for one who used a handgun only).

Spraying Systems (USA) Teejet nozzles were used by 68 out of 76 growers (90%), whilst the Lumark range was used by four growers (5%), with four growers (5%) using nozzles from both companies. Thus 95% of growers used Teejet nozzles and 10% used Lumark nozzles.

All of the growers used nozzles manufactured from plastic or brass. All of the Teejet nozzles were brass, and brass only nozzles were used by 66 growers (87%). Most of the Lumark nozzles were plastic, but only one grower used all plastic nozzle tips on his boom. The remaining nine growers (12%) used combinations of brass and plastic.

Many growers did not know about the screening meshes or had long since taken them out. For those growers that had them in their booms a wide array of types was found: 50μm meshes, plastic types, brass strainers with slots, and antidrip gauze strainers were recorded for 21 growers, with four growers indicating that they didn't have them or took them out - because they blocked up.

4.5.2.1 Arrangement of nozzles on booms

Two distinct methods of spraying were used. Sprayers either sprayed one row (left or right) at a time or had a boom out each side doing both sides of a row at once. The number of nozzles on these booms was recorded, along with the type, fan or off-centre. Out of 76 growers 57 sprayed one side at a time, the remaining 19 spraying two sides at once with the nozzle arrangement on each side being the same. For a given side the arrangement of their nozzles is given in Table 30. Off-centre nozzles are abbreviated to OC.

TABLE 30: Analysis of nozzles used and type on orchard herbicide booms.

No. nozzles per side	No. booms like this	1	2	3	4	5	6	7	%
1	8	4	4						10.5
2	45	5	12	28					59.2
3	20	2			15	3			26.3
4	3						2	1	4.0
TOTAL	76	11	16	28	15	3	2	1	100.0

Key: 1 = Fan only; 2 = OC only; 3 = Fan/OC; 4 = 2 Fan, 1 OC; 5 = 1 Fan, 2 OC; 6 = 3 Fan, 1 OC; 7 = 2 Fan, 2 OC

Of the 68 growers who used more than one nozzle 72% used combinations of off-centre and fan nozzles. The actual arrangement of these nozzles is not standard. Each boom was sketched at the time of survey to show the arrangement of these nozzles in space, and to identify any novel pieces of equipment. Diagramatic representations of these booms along with their popularity are presented in Table 31.

TABLE 31: Arrangement of nozzles on booms.

No. growers	Nozzle arrangement	Proportion of distribution %
15	FAN OC	19.7
13	FAN OC	17.1
12	FAN FAN OC	15.8
7	OC OC	9.2
5	OC OC	6.6
4	OC	5.3
4	FAN	5.3
3	FAN FAN	4.0
3	FAN FAN OC	4.0
2	FAN FAN	2.6
2	FAN FAN FAN	2.6
2	OC FAN OC	2.6
2	FAN FAN FAN OC	2.6
1	OC FAN FAN OC	1.3
1	OC FAN OC	1.3
TOTAL 76	15 arrangements	100.0

With two types of nozzles and up to four nozzles per boom growers have arranged them in 15 different ways. Obviously some growers are using the same boom arrangement but are interchanging nozzles. A summary of this is given below, in Table 32.

TABLE 32: Summary of arrangements of nozzles on booms.

No. growers	Boom silhouette	Type	Proportion of distribution %
8		A	10.6
24		B	31.5
21		C	27.7
16		D	21.0
4		E	5.3
3		F	3.9
TOTAL 76	6 boom "types"		100.0

The double headed fitting on boom types B and E can be easily purchased and put on a boom. In Growers Guide Bulletin 14 and 14B (New Zealand Fruitgrowers Federation Ltd 1982; New Zealand Fruitgrowers Federation Ltd 1983) boom types A, B and C were recommended and able to be purchased. Two thirds of the growers use these types. Unfortunately these bulletins are no longer produced or updated. The actual nozzle combinations used by the growers shown in Table 32 were not limited to the three recommended arrangements. Types D and F are simple extensions of type C. Type E is a combination of types B and C. Plates 25 to 28 depict examples of booms photographed during the surveys.

Most booms (87%) were mid-mounted between the front and rear wheels. Three booms were attached to the tank chassis at the back, and the height adjustment was controlled by the hydraulically operated tractor three point linkage. Seven booms were mounted on the front of the tractor.

Plate 25: Single nozzle boom (brand new) and a Croplands herbicide spray tank.

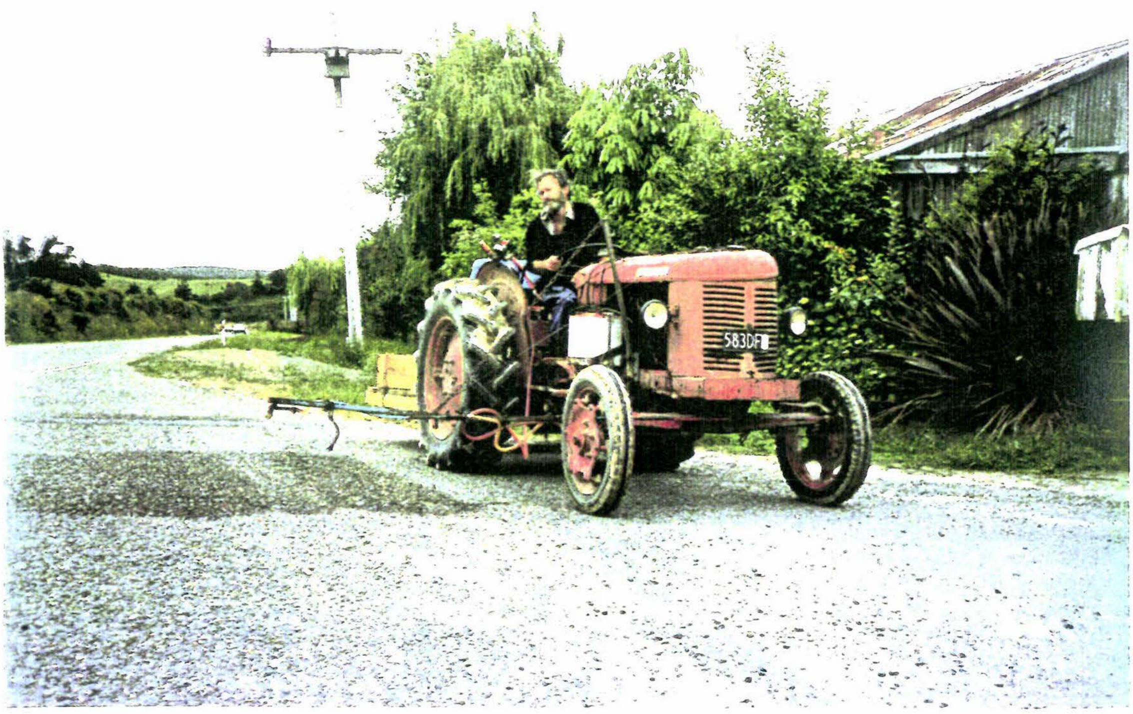

Plate 26: Homemade boom with two nozzles. Note very wide spray width (1.9m).

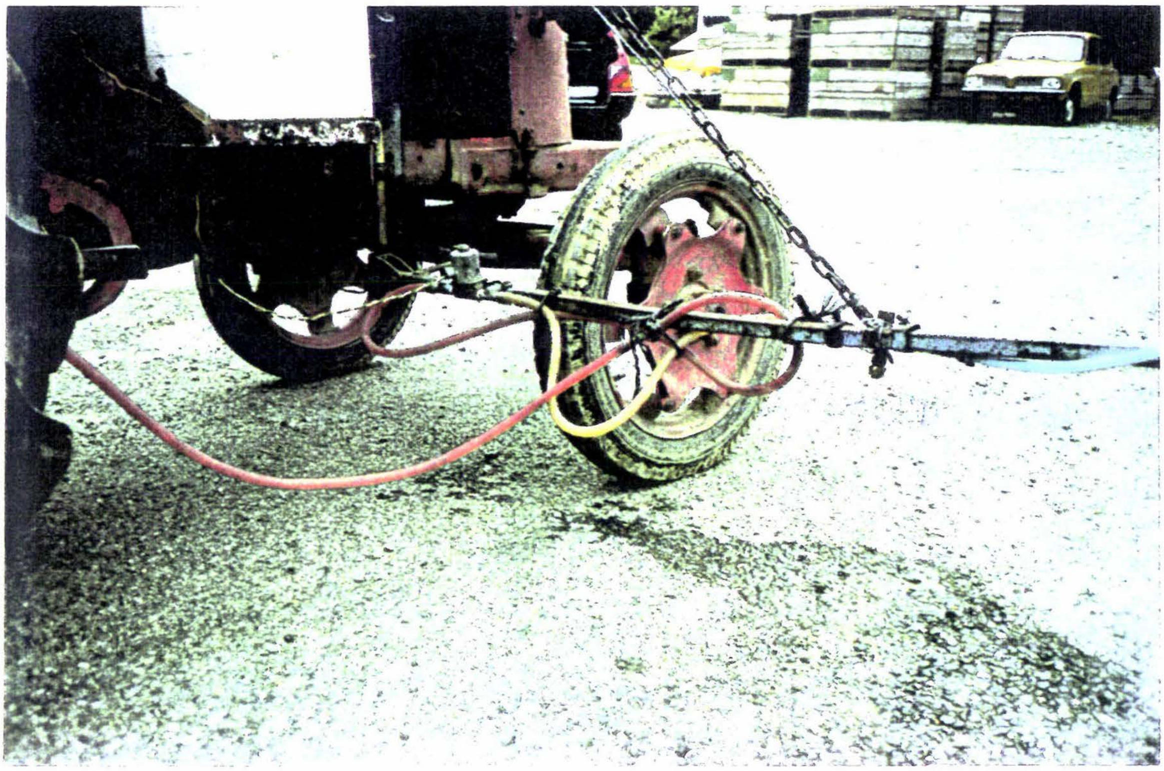

Plate 27: Close up of pipe plumbing of boom shown in Plate 26.

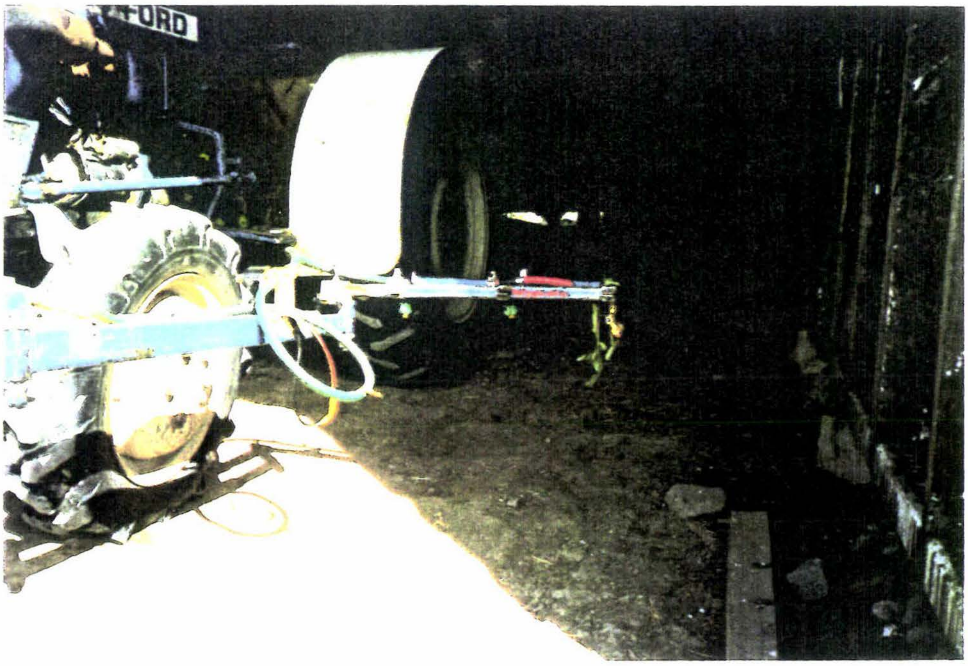

Plate 28: Multi nozzle boom, depicting double head at end of boom.

Seven growers had covers or shields that went over the boom, protecting the nozzles from pruned wood and live branches and also to reduce wind drift (Plates 29 and 30). Many other minor modifications were found that are not worth reporting at length, but have been retained as a data base for improving the boom design.

In terms of controlling the nozzle discharge from the seated position the method of achieving on/off was recorded. Each one of these was also rated as to the ease of reach, with "1" being good or easily accessible "2" being fair and "3" being poor/difficult and based on practical experience of the author. This would affect the reaction time in being able to turn the boom or nozzles off for suckers or lower branches etc. Good or easy to reach was deemed as being on the "dashboard" or close at hand to the driver i.e. on the mudguards. Mechanisms requiring reaching were deemed fair, and those requiring reaching and turning, or leaving the seat deemed poor or difficult. Three methods of turning booms off were found: a shut-off tap where the spray solution to the boom was halted by a simple valve closed by turning a handle through 90°; solenoid(s) to cut off flow in the supply hose to the nozzles; or disengaging the power-take-off drive to the pump, thus causing pressure and flow to drop and the nozzles to (eventually) turn off. (In all cases the p.t.o was independent of the tractor thus not requiring the tractor to be stopped.) This method is very inaccurate, and although the p.t.o lever may be easily reached it is not recommended. Summaries of both the method of spray control and ease of reach are given in Table 33.

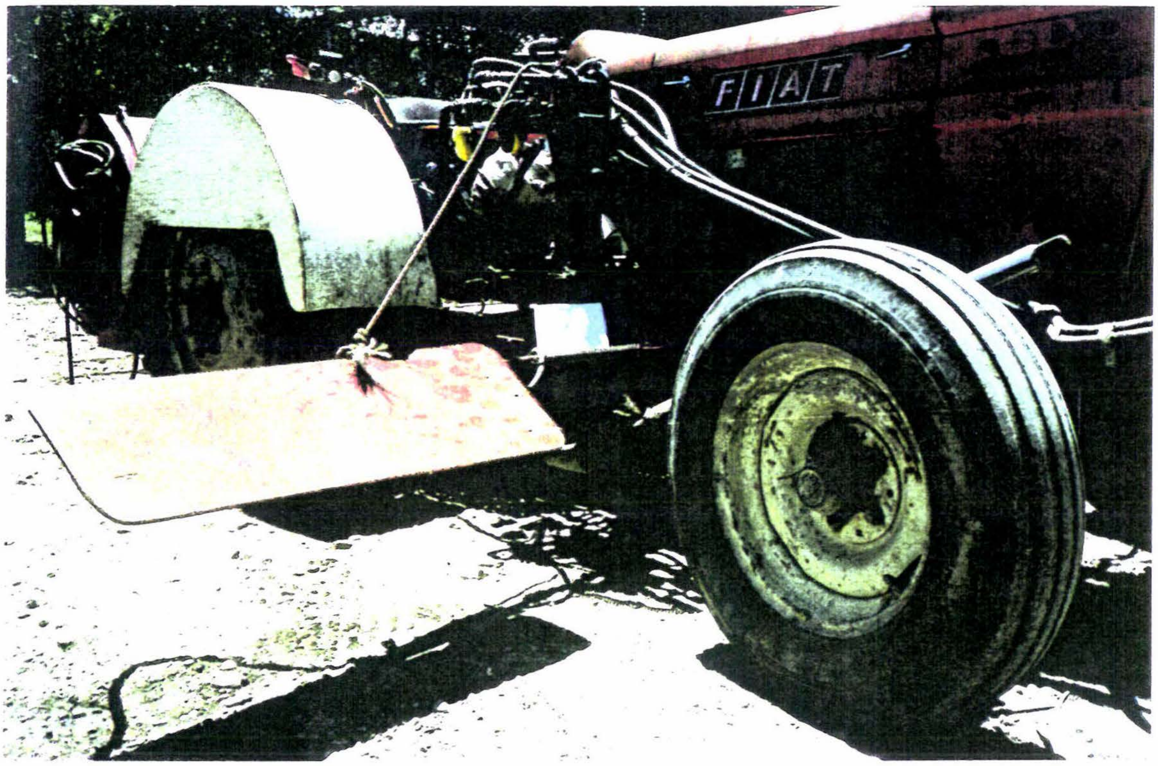

Plate 29: Sheild to protect nozzles from pruned wood, branches and other obstacles.

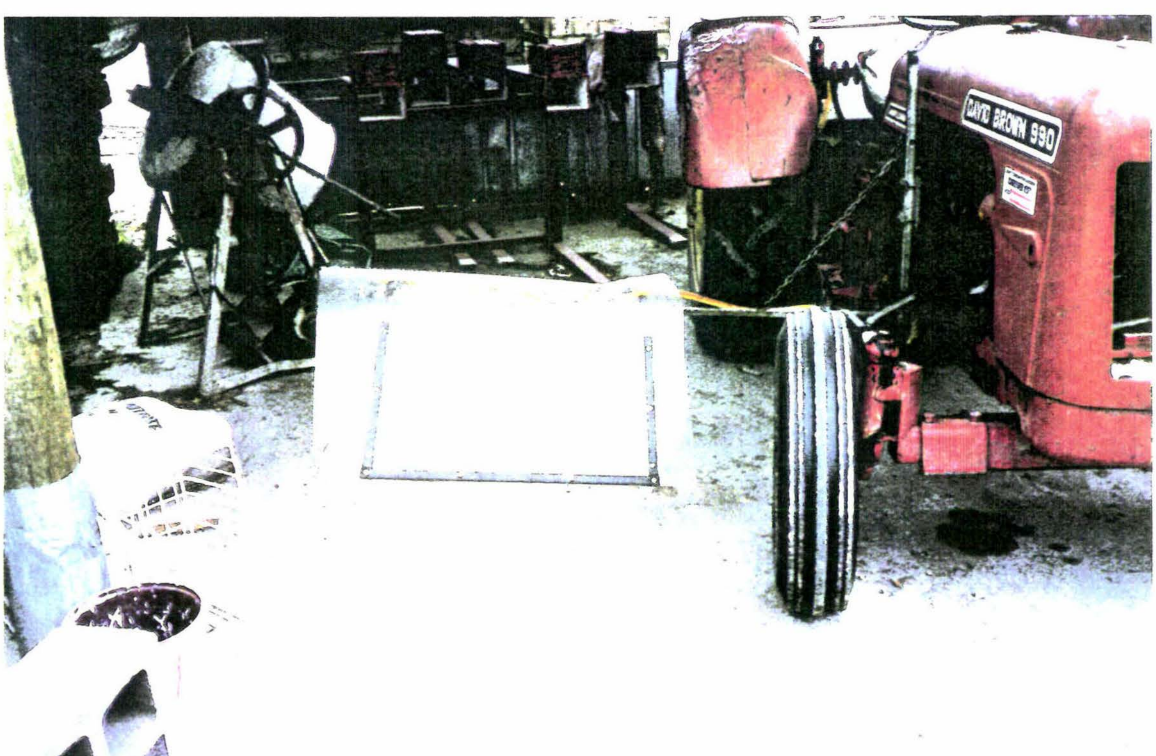

Plate 30: Sheild to reduce wind drift.

TABLE 33: **Mechanism of spray control (on/off) and ease of reach.**

Type Rating	Number of growers with this type				TOTAL
	Solenoid	Shut-off tap	p.t.o	TOTAL	
Good	28	30	3	61	80
Fair	1	8	0	9	12
Poor	0	4	0	4	5
Not recorded	0	2	0	2	3
TOTAL	29	44	4	76	100
% distribution	4	58	38	100	

At least 80% of the growers could easily reach their shut-off mechanisms although the p.t.o system is rather slow. The four growers whose ability to reach their shutoff taps was considered poor or difficult used the tap on the pressure regulating valve, having to leave their seat, turn and reach over the top link to turn it off. The quickest and cleanest method of turning off the spray solution to a nozzle is by using a well operating solenoid with anti-drip gauze filters. The anti-drip filters contain a spring and ball bearing which seals the flow to the nozzle tips off at around 100kPa (15psi). The solenoid also achieves a quick clean start to spraying when turned back on.

Three growers had a combination of both solenoid and shutoff tap in easy reach. In addition three growers had two solenoids on one side of a boom to turn the end nozzle on and off independently of the inside nozzle, allowing suckers not to be sprayed but some of the width still getting covered. One grower with four nozzles had a three way switch allowing all nozzles to be on, three inside nozzles on, or everything off.

For the spray booms that were inspected the height of the nozzles above the ground was measured. (All of the booms that were calibrated were measured, plus any more that were convenient.) The lowest nozzle height recorded was 220mm and the highest 550mm. The distribution of heights is given below:

10 booms below 400mm off the ground;

7 booms between 400 and 449mm off the ground;

12 booms between 450 and 499 mm off the ground;

14 booms between 500 and 549mm off the ground;

4 booms at 550mm off the ground.

None of these heights were considered excessive, although the lower the better in terms of reducing drift and the risk of spraying low hanging foliage. Note that all spray leaving the nozzles is directed down, usually perpendicular to the ground for fan nozzles, and booms with more than three nozzles, but off-centre nozzles are usually tilted out toward the crop tree trunks. Thus this height is the maximum height of spray discharge and is directed toward the ground.

4.5.3 Basic maintenance of sprayers

Growers were asked how often they cleaned their nozzle and pump filters. Responses were gained from only 50 growers due to a logic flaw in the questionnaire. After answering question 6.6 of the survey (Appendix 1) the interviewer was directed to Section 7 of the survey, before asking two questions on basic maintenance. All growers who did not calibrate their sprayers missed questions 6.8 and 6.9 of survey, (Appendix 1).

Commercially made pumps usually have a gauze filter on the suction side. This can get clogged with detritus reducing both pressure and flow. A finer filter can be placed immediately above the nozzle tips. Again if these are not regularly cleaned flow and pressure can be affected or detritus can upset the spray pattern. Given clean water, the only problem herbicides are residuals in both wettable powder and flowable liquid form.

Growers were asked how frequently they cleaned nozzle and pump filters. Responses such as "not often" and "occasionally" were taken to be the same, as were "regularly" and "often". Growers answers are presented in Table 34. One grower indicated that he had taken the nozzle filters out and another growers' pump did not have a filter. One grower had to remove the nozzle tips each day and flush the spray boom out bumping the pipe to remove rust on the inside.

TABLE 34: **Frequency of nozzle and pump filter cleaning.**

Occurrence	No. growers taking action	Proportion of distribution %
Often/regularly	18	36
After each tank	7	14
Not often/occasionally	7	14
Once a day	6	12
Keep tank clean	3	6
Never have	2	2
When pressure drops or tips blocked	2	4
Once/year	2	4
When change nozzles	1	2
Every 2 tanks	1	2
Every 3 weeks	1	2
TOTAL	50	100

Maintenance that can be identified as "regular" (i.e. after each tank, once a day, every two or three tanks) was carried out by 30% of the growers. Depending on just how frequently "often" or "regularly" is, this would cover in total 70% of the growers. Those that clean them "not often" or "occassionally" may also be doing this sufficiently often, as these criteria are very subjective. However, in at least two cases it has got to the stage when the pressure has decreased or tips have been blocked. Because of the subjective nature of this information it is less accurate. However it is very important. Yates (1989) stated that poor chemical performance is often the result of poor sprayer maintenance. Blocked and partially blocked filters are a major cause of inaccurate application, and even though individual nozzle filters may prevent nozzles from blocking, unless they are cleaned out at least daily, they can cause considerable variations between individual nozzle output, which are not apparent visually.

Growers were asked if they had ever replaced worn spray nozzles. Responses were gained from 55 growers, with 31 growers (56%) indicating that they had. Six growers indicated that they changed their nozzles at the time of calibration every 1 to 2 years, and 20 growers indicated that the last time that they were changed was when the sprayer was calibrated 3-5 years ago. At least one grower has used the same nozzles for 10 years. Growers also indicated how long they expected a nozzle to last: 3-5 years, 2-3 years, 2 years and 4 years. One grower had to replace plastic nozzles often as he finds they break. Yates (1989) suggested that if nozzles used for cereal spraying were not changed every season, then the chances are that within a set of nozzles variation will be between 10 and 30%. He suggested annual replacement.

However its a bit like respirator cartridges - its a function of materials and time involved, and maintenance or care in use. No one will give a fixed answer. Checking nozzle flow variation and pattern is the only answer, discarding those nozzles with uneven patterns and checking nozzle spacing. No growers have access to spray patternators and it is not enough to simply look at nozzle output variation. (Ozkan 1987; Couch 1988.)

4.5.4 Accuracy of operation during herbicide spraying

Growers were asked six questions (Appendix 1, 5.8 to 5.13) about boom movement, spray drift and actions taken if crops are accidently sprayed, in a means to identify a pathway in which herbicides get to leaves and/or fruit.

During herbicide spraying the target(s) are the soil that comprises the herbicide strip and any weeds growing in this strip. Leaf and fruit contact with herbicides could occur in many ways (outlined in survey questions) and the survey questions recorded the frequency of these events.

With regard to boom movement, growers were asked, if on uneven ground the spray boom moved or bounced up and down altering the spray spread. From 76 responses, 60% of the growers (46) indicated that their booms did not. When all growers were then asked if they considered there was any risk in occasionally spraying some lower tier leaves, 72% of growers (54) indicated that there was a risk. One grower was excluded because he felt his apple trees were too young for him to comment on, giving a total of 75 responses.

The fifty four growers who did consider that there was a risk of spraying lower tier leaves were questioned more closely on how this occurred. Their responses are given in Table 35, (which includes the criteria from the question). Four growers who answered negatively to the previous question but could see this question whilst they were being interviewed also added in an answer. Multiple answers were acceptable and were recorded.

TABLE 35: **Responses from 58 growers to reasons for occurrence of risk in occassionally spraying some lower tier leaves.**

Criteria	No. Growers	Proportion growers %
a) Ground uneven	7	12
b) Nozzles too high	1	2
c) Lower leaves and fruit too low	51	88
d) Obstacles bump boom up such as:		
- weeds	4	7
- pruned wood	6	10
- branches	5	9
e) Pressure surges from pump, i.e. filter blocked	0	0
f) Wind drift of droplets	15	26
g) Lines break or rupture	1	2

Although 30 growers indicated that their booms did move up and down during spraying, only 7 felt that this was a problem that could lead to lower leaves being sprayed.

Criteria (b) and (c) were similar. If the spray boom could be lowered and still provide the desired swath of control then the lower leaves and fruit would not be too low, as 88% of the growers have indicated. However only one grower felt that the nozzles were too high. Adjustment to booms is limited and currently the equipment used limits the potential for reducing the height above the ground, leading to growers using pulley and string systems.

When asked specifically whether they could see spray droplet drift (not necessarily going onto the crop) 75% of growers (55) said that they had. Responses were not gained from 2 growers giving a total of 74 responses. The condititions under which drift occurred are summarised in Table 36. Of the growers who had never seen wind drift, two further qualified their answer. One grower said he had never seen damage from drift, whilst the other indicated that he was always spraying into dense weeds. Of the growers who had seen wind drift, nine did not describe the conditions under which drift occurs. One of the growers felt drift was "O.K as it is only Roundup" (glyphosate).

TABLE 36: Conditions or situations in which growers see spray droplet drift.

Condition/situation	No. growers	Proportion of growers
Wind - not quantified	31	67.4
End of nozzle pattern	4	8.7
Draught from exhaust and or tractor engine	3	6.6
In some light angles	2	4.3
Heat rising from ground	2	4.3
Wind and too high on operating pressure	2	4.3
When using Pulse with glyphosate	1	2.2
At low application rates	1	2.2
TOTAL	46	100.0

As expected wind was claimed to be the main cause of drift, implicated in over 70% of conditions. Drift caused or from the ends of offcentre (OC) nozzles and draught from tractor engines and exhausts is likely to be present at all times when these growers are spraying, as opposed to drift caused by wind, which can be limited by spraying in calmer conditions, or stopping when the wind gets up to an unacceptable level. Drift occurring at low application rates is probably a function of pressure which is very difficult to control with the low output nozzles required to put on 100-200ℓ/ha.

Elliott and Wilson (1983) indicated that windspeed is the main influence on the number and size spectra of drops which become 'airborne' to form drift. Strong winds are usually more predictable in direction than light winds. When there are only slight variations in barometric pressure in the horizontal plane, the wind is light and tends to be variable - a very important factor to consider in crop spraying. With regards to wind, Pasquill (1974) offers this advice "spraying in the presence of an appreciable wind has at least the advantage that the direction of travel of spray will usually be definable."

In the field, there are nearly always movements of air up, down, along and across the mean direction, superimposed on the mean air flow, causing atmospheric turbulence. (Elliott and Wilson 1983). Spray drops will tend to drift further with increased turbulence. Sunny days with light winds increase thermal turbulence, where warm air in contact with the surface is rising, and cool air sinking. Turbulence is also caused by surface friction where the air moving over a surface overturns and mixs near that surface. The four growers seeing spray droplet drift in some light angles and heat rising from the ground (Table 36) are likely experiencing this kind of turbulance. The drift situation is considerably simplified in that drops of diamter less than 100μm are most unlikely to be reflected from even the most unwettable surfaces (Brunskill 1956). Thus, the drops of the size range most likely to cause drift are unlikely to become airborne again once they have hit the surface. Schotland (1966) showed a major exception to this in the case of drops hitting a surface that is already covered with a film of water, which could easily occur if spraying is started too soon after a heavy rain shower, on a crop whose foliage is easily wetted by water. It may also occur if very high volumes of spray are applied so that the target foliage is saturated to beyond liquid runoff conditions.

With regards to strip spraying of herbicides in orchards, use of, for instance, 500 ℓ/ha equates to 0.05mm of water over the sprayed hectare. Previous wetted surface can occur in another way not mentioned by other authors. In strip spraying the second pass down a row is overlapping in part some 100-300mm. However, this is a slim risk because volume at the edge of the spray pattern is at least half of the calculated volumes in ℓ/ha, and less than 0.025mm of water does not accurately depict a wetted surface. Elliott and Wilson (1983) also presented an argument that surfactants in most spray cause a considerable increase in the hysteresis of the contact angle of the aqueous solution on leaf surfaces, preventing spray droplets being reflected. Sprays based on oils have a low surface tension ($\approx$ 30mN/m) and their excess energy after initial spread on contact is insufficient for them to be reflected.

Growers do see drift then, and although none of them specifically mentioned gustiness, the above shows that this phenomena could be a factor. The key question is "just how bad is this drift?" The survey broke up the questions in this area so as not to seem to dwell on the potential for herbicides to reach the crop, but make sure that it is well covered.

With regards to more obvious drift growers were asked if they ever got spray drift onto their body or face. Responses were gained from 71 growers, of whom 35% claimed they did. Actions taken by 19 of the 25 growers were recorded. Most of the growers (13 out of 19) claimed they would stop, and another grower said he would stop only if he was in constant contact with the spray. The rest of the growers (4) said that they would continue to finish the tank, with only one grower going to wash off drift that had reached him. Of the growers who indicated they never got spray drift, 4 said they would stop if they did, one said he could smell the spray whilst another said that his handgun leaked but he wore gloves.

One grower reported an unfortunate incident when he shut off a hose, causing it to burst. He happened to be yawning at the time and got some spray in his mouth.

Growers were then asked if they took any action if they thought lower branches may have come into contact with herbicide (Table 37). Responses were not gained from 12 growers and two growers claimed it doesn't happen, leaving a total of 62 answers. Note that the way this question was worded and placed in, seemingly out of order should lead to a direct answer. Thus those that have responed admitted it does happen despite any prior answers to the contrary.

TABLE 37: Growers' actions after they thought lower branches of pipfruit crop may have come in contact with herbicide spray.

Action taken	Number of Growers	Proportion of growers %
None - carry on	24	38.7
Prune or snap off	20	32.2
Carry on, but cut off young trees	10	16.0
Cut off later when symptoms seen	3	4.9
Only prune off if severely sprayed	2	3.3
Only remove if glyphosate or amitrole	2	3.3
Turn nozzles off and aim with handgun	1	1.6
TOTAL	62	100.0

Some justification for carrying on, or not taking any action, given were: "it doesn't worry them (the trees)"; "I only use paraquat/diquat"; "wood should not be that low on old trees"; and that "you would have to spray the whole tree to cause any damage".

The results given in Table 37 conflict with those gained previously where 54 growers indicated there was no risk of spraying lower tier leaves. Table 37 indicates that at least 62 of these same growers have actually seen lower leaves of the crop come in to contact with a herbicide whilst they were spraying.

It is no wonder then that the incidence of glyphosate damage was so common (see 4.4.5), and thus Table 37 would seem to be the more accurate results. The common occurrence of trees expressing symptoms of contact with knockdown herbicides would indicate direct contact rather than drift, although 25% of growers questioned indicated that drift in some circumstances could be sufficient to reach their person, and thus even more likely to reach the crop.

Lower branches are the major site of contact with herbicides as opposed to drift or soil uptake. Tree crop foliage is below the height of nozzles for the latter part of the growing season. In some orchards an attempt is made to apply summer herbicides before these branches come down too low. But as early as mid January branches were observed touching the ground. (Plate 31.)

In 26 orchards (34%) low branches were recorded as impeding herbicide spraying. Obviously growers need to control weeds that have survived or established since residual herbicides were applied in spring. Improvement of current weed control programmes with rotation of residuals and greater use of complementary combinations would see a reduced need for summer herbicides, although a second application of a residual may be merited in late November once the initial residual herbicide has stopped controlling weeds.

Growers who had covered their booms were able to spray in dense blocks as the shield guided the crop away from spray nozzles, and no problem should occur if the crop foliage does not come into contact with sprayed weeds.

Plate 31: **Low branches and poor weed control in January which may lead to another herbicide being applied.**

The attitude is basically that a little bit of spray will not harm a large or mature tree, and over 50% of the growers do not take any action. Another 50% of growers will prune sprayed wood off all trees, including a small proportion of growers who would only remove wood if it was severely sprayed, or if the herbicides being used were contact translocated such as amitrole and glyphosate. Thus this lack of action is a clear pathway for herbicides reaching the crop and for those that can be translocated (i.e. amitrole, glyphosate, dicamba, 2,4-D, clopyralid) to reach the fruit. Glufosinate and paraquat/diquat are only weakly translocated under low light conditions (O'Connor 1989) and direct contact with fruit of sufficient quantities would cause russets or blemishes probably exluding those fruit from export.

4.6 History of sprayer calibration

Sprayer calibration done in the past by growers and/or other parties was the focus of questions in Section 6 of the survey. The grower who used a handgun only was excluded from this section.

4.6.1 Historical calibrations

Growers were asked if since they bought their sprayers they had ever calibrated them. From 76 responses 13 growers (17%) said they had not. These 63 growers were then asked how frequently they calibrated their sprayer. Results are given in Table 38. The format used for recording this question is detailed in Appendix 1, question 6.2. However, since growers were not usually applying more than one spray in a seasonal period i.e autumn or summer, most defined "beginning of each seasonal application" as being annually, with the season being defined as the bud break to harvest period. These two were recorded together.

Not all growers had a fixed frequency and 18 Hawkes Bay growers answered by responding with the last time the sprayer was calibrated, without actually indicating the regularity - i.e. done three years ago, but not if it was actually done every three years. This would indicate that no regular calibration was carried out. Some growers gave more than one answer, i.e "I calibrate annually and when new nozzles are put in."

TABLE 38: Frequency of sprayer calibration from 63 pipfruit growers.

Time calibrated	No. of growers	Proportion of growers %
Before every spray application	5	7
Beginning each seasonal application (annually)	23	32
Only when new nozzles are put in	3	4
Only when new tractor or sprayer	3	4
Others - every 2 years - every 3 years	5 1	7 2
No regular pattern	32	44
TOTAL	72	100

One grower indicated that he only calibrated his sprayer when he used a new residual herbicide (frequency of this not given). Results given of a specific time, i.e. 3 years ago were carried forward to the next question.

Other answers not of this nature but included in Table 38 as "no regular pattern" were

- just once;
- twice in 7 years;
- used to every year but as I got same results I no longer bother; and
- not specified (two growers).

Table 38 shows that only 48% of growers regularly calibrate their sprayers - before each spray application, annually, biannually or triennially. Another 6 growers relate calibration to alterations to the sprayer, i.e nozzles, the tractor or sprayer itself. These are also irregular occurrences. These frequency of calibration results for the 76 growers can further be simplified and is presented below.

- 13 growers (17%) have never calibrated their sprayers.
- 28 growers (37%) calibrate their sprayers at least annually.
- 35 growers (46%) calibrate their sprayers irregularly.

Growers were asked when was the last time their sprayer was calibrated. Some growers had already answered this in the previous section. Results are presented in Table 39.

As the survey was carried out in December of 1989 and January of 1990, 1989 was used as the reference years. Growers in Hawkes Bay were surveyed in 1990, but if they answered that they calibrated their sprayer 4-5 years ago their answer was deemed as 1985 (i.e. 1989 = 4 years ago or 1990 = 5 years ago). All of the sprayers calibrated in the last two years were done in spring and thus 4½ years, i.e. 4-5 years from January 1990 would be spring in 1985. This is accurate enough for the results required and information gained. Growers results are given in Table 39, exluding the one Manawatu grower who calibrated his sprayer that summer (1989). Results for Nelson and Hawkes Bay have been separated. Two growers from each region did not indicate when the sprayer was last calibrated. Thus Table 39 should be read with the summer of 1989/90 as the reference point, not the present. Beyond the winter of 1989 no growers specified a season or date and thus the column purely records the year, although it was probably spring.

TABLE 39: Last time herbicide sprayer was calibrated for 58 pipfruit growers.

Last time calibrated	Number of Growers		
	Nelson	Hawkes Bay	TOTAL
Spring 1989	13	9	22
Autumn 1989	1	0	1
Spring 1988	2	8	10
Winter 1988	0	1	1
1987	2	5	7
1986	2	3	5
1985	2	0	2
1984	1	4	5
1983	0	2	2
1982	1	1	2
about 10 years ago	1	0	1
TOTAL	25	33	58

Tables 38 and 39 complement each other, with Table 39 showing just how long ago those who irregularly calibrated did so. One grower commented that liquid formulated herbicides cause little wear and thus the application rate changed little, negating the need for regular calibration. For the half of growers who did not regularly calibrate their herbicide sprayers this recalibration was done only if the amount of water used per hectare markedly changed from one application to the next. After four years or so most growers would of put on 12-16 applications. Variation of 1-2% each time would not be noticed, but by over three years it could compound to over 10%. Nozzle wear is going to increase water applied per hectare. Slight changes in pressures, forward speed, reflexs in turning booms off at the end of rows, and combinations of all three are likely to vary total water used more than nozzle wear, further complicating the issue. No doubt a grower would only be concerned if he was inconvenienced by having to make up a part tank to finish a job.

Growers were then asked who does the calibration. One of the 63 growers who said that they had calibrated their sprayers did not respond, giving 62 growers whose answers are presented in Table 40 below. Rep. is used as an abbreviation for company representative.

TABLE 40: Person carrying out calibration of sprayer (when done).

Person	No. growers sprayers calibrated by this person	Proportion of distribution %
Grower	24	38.7
Chemical Rep.	18	29.1
Grower and Rep.	7	11.3
Grower and Staff	6	9.7
Orchard Staff	2	3.2
Spray Equipment Rep.	2	3.2
Orchard Staff with Rep.	1	1.6
Grower and Consultant	1	1.6
Consultant	1	1.6
TOTAL	62	100.0

In Nelson the chemical company representatives were FruitFed Supplies Ltd (4) or a private company Tasman Chemicals (6). One grower used people from both companies. In the Hawkes Bay area, FruitFed Supplies Ltd was used by 12 growers, and Williams and Kettle, Turners, and Bayer and Bayer once each. Consultants and a spray equipment company representative were only used in Hawkes Bay. One orchardist had his neighbour, also a grower, calibrate his sprayer. This is recorded as "grower". One grower measured all his sprayer settings and took the figures into FruitFed Supplies Ltd for their staff to work out his application rate.

Growers or their staff were involved in two thirds of the calibrations, but in all probability would also be present in the 21 cases of either representatives or consultants calibrating their sprayers. Chemical company representatives calibrating sprayers for over 30% of the growers is good, as they should be confident making product recommendations, now knowing how accurately they would be applied.

Growers were asked what parameters were checked during the calibration process. Results were split in two ways, those that the growers calibrated themselves and those that company representative or consultants did. From the 26 responses from growers, 15 (58%) measured forward speed, nozzle output, spray width and checked the pressure. Nozzle output only was the sole setting measured by 7 growers (27%), whilst four (15%) measured spray width and nozzle output but not forward speed. Information gathered by the last two groups of growers was put back into formulas using readings gained previously to fill the blanks where readings had not been taken.

For those sprayers not calibrated by the growers, the growers were asked what the person doing the calibration measured. From 24 responses, 20 (83%) measured forward speed, nozzle output, pressure and spray width; two only checked the nozzle output only; and for two growers who received their advice by phone; one checked only his nozzles and speed, whilst the other grower was simply advised to drive at x speed with these nozzles to equal y ℓ/ha.

A summary of the parameters measured during calibration is given in Table 41.

TABLE 41: Sprayer settings measured during calibration process.

Sprayer setting	No. growers having this done	Proportion of growers %
forward speed, nozzle output, spray width, pressure checked	35	70
nozzle output only	9	18
spray width and nozzle output	4	8
assistance given over the phone	2	4
TOTAL	50	100

Thus only 70% of growers do a full check on their sprayer settings. Checking the forward speed is commonly not done, probably on the assumption that in a given gear and rpm it should not change from year to year. Nozzle output is considered the most important sprayer setting to measure, and done by most growers, except for those receiving advice over the phone. One of these cases was very poor, with the grower being advised of all the settings to aim for, to reach a known application rate.

Growers were then asked who they turned to for help if they ran into problems during the calibration process. All of the 24 growers who calibrated their sprayers gave an answer. Of these 10 growers (41%) said that they had no problems. The remaining 14 growers turned to FruitFed Supplies Ltd (9), a spray equipment company (3), Williams and Kettle (1), and the last grower used a study guide from Massey University. It was further revealed that at least one of these growers received help over the phone.

4.7 Accuracy of herbicide application

4.7.1 Components of sprayer utilization

Growers were asked to state their intended output/area in litres per hectare or gallons per acre. Only one grower responded in gal/acre which was subsequently converted to ℓ/ha. Growers' intended application rates are given in Table 42. Five growers answered giving the water use over a given area e.g. 500 litres over 1.4ha. In these cases the area of herbicide strips for that orchard was calculated to obtain output/area, e.g. 500 litres over 1.4ha equated to 715ℓ/ha. Seven growers indicated an application rate prefixed by "approximately". The grower using a handgun around the base of trees claimed to use 0.3-1.5ℓ/tree per application. His results were excluded from this section.

Six growers claimed they used two application rates depending on the herbicide being applied, e.g. glyphosate in 300ℓ/ha of water or simazine in 600ℓ/ha of water. Each rate has been recorded separately in Table 42.

TABLE 42: The water rates claimed to be used by 76 pipfruit growers for applying herbicides.

Intended application rate l/ha	No. growers claiming this rate	Proportion of growers %
"Don't know	15	18
less than 200	3	4
200 - 250	6	7
251 - 300	7	9
301 - 350	3	4
351 - 400	10	12
401 - 450	6	7
451 - 500	16	19
501 - 550	1	1
551 - 600	7	9
601 - 650	1	1
650 +	7	9
TOTAL	82	100%

Of the 61 growers who were intending to apply a specific application rate, over 50% of them claimed to use between 301 to 500l/ha of water, with the same number of growers above and below this range of rates. 301 to 500l/ha suits most knockdown and residual herbicides.

Growers were also asked for information on their nozzle output, forward speed, gears and engine speed, spray width and operating pressure. This information was primarily gathered to compare with that gathered in Section 8 of the survey, dealing with the accuracy with which growers set up their equipment, but also to find the range of parameters growers intended to use. A herbicide sprayer of the nature surveyed can be calibrated with a knowledge of forward speed, spray width and total nozzle output. In finding out the current intended ranges more accurate recommendations can be made in the preparation of a calibration manual.

With regard to nozzle output growers responded quoting figures in litres per minute (l/min). Growers responses are given in Table 43. For growers using more than one nozzle the individual outputs were summed. In regard to total nozzle output 51 out of 76 growers did not know how much they were applying. Seven growers gave answers to two decimal places, i.e. 2.16ℓ/min, whilst 13 growers gave answers to one decimal place, the final five growers giving single figure answers. I was to find out later in the calibration questions that some of these growers were quoting figures from manufacturers or suppliers charts, i.e. nozzle OC04 applies 1.58ℓ/min at 300kPa. (Spraying Systems.)

TABLE 43: Claimed total nozzle output of herbicide sprayers.

Claimed rate ℓ/min	No. growers claiming this output	Proportion of growers %
Don't Know	51	67.1
< 2.00	3	3.9
2.00 - 2.99	9	11.9
3.00 - 3.99	3	3.9
4.00 - 4.99	4	5.3
5.00 - 5.99	4	5.3
6.00 - 6.99	1	1.3
7.00 - 7.99	0	0
8.00 - 8.99	0	0
9.00 - 9.99	1	1.3
TOTAL	7	100.0

The range of outputs is quite narrow with 80% of nozzle output values falling between 2.00 and 5.99ℓ/min.

These results were not expected as most growers indicated that they measured nozzle output during calibration (Table 41).

Growers were much more certained about their forward speed. Just under 80% of the growers gave an answer of their intended forward speed. Some results are given in miles per hour (mph), and these were converted to kilometres per hour (km/h). Just under 80% of the growers reported their intended forward speed to one decimal place i.e. 5.2km/h. Two growers indicated their speed to two decimal places.

Results are given in Table 44.

TABLE 44: Intended forward speed of herbicide sprayers.

Forward speed km/h	Number growers	Proportion of growers %
Don't know	17	23.6
2.0 - 2.9	3	4.2
3.0 - 3.9	16	22.2
4.0 - 4.9	17	23.6
5.0 - 5.9	10	13.9
6.0 - 6.9	6	8.3
7.0 - 7.9	1	1.4
8.0 - 8.9	1	1.4
9.0 - 9.9	1	1.4
TOTAL	72	100.0

Five growers gave results that did not neatly fit into Table 44. Their answers to question 5.3 were 5 to 7km/h, 2 to 3mph (3.2 - 4.8km/h), 4 to 4.5mph (6.4-7.2km/h) walking speed, and one grower who changes speed "until the water rate looks right for the weeds being sprayed".

Thus for growers whose speed was given, Table 44 shows that 78% of them spray in the speed range of 3 - 5.9 km/h. Speeds over 8.0 km/h should be discredited as being incorrect, as in my opinion and experience this is too fast, but are shown as they were recorded.

Engine speed or revolutions per minute (rpm) is required for two simultaneous things when herbicide spraying. The first is to provide enough power in the given gear to maintain a constant forward speed, the second to supply power to a pump to maintain constant nozzle output and pressure. Correct selection of engine speed and gear is more important around Nelson than in Hawkes Bay due to the sloping terrain on which many orchardists grow their crops. The tractor needs power to go up slopes and engine brake on the way down, maintaining constant speed.

The responses gained for this question are given in Table 45. Some growers used petrol run tractors that do not have engine revolution counters, and some of these tractors did not have hand throttles, with the engine speed being set on a fast idle by adjustment at the carburettor. One of these petrol run tractors had a hand throttle which the grower set at "the third notch". Another grower set his engine speed to give 300 rpm at the p.t.o. Five growers answered that they did not know the engine speed. These seven responses are excluded from Table 45.

TABLE 45: Engine speed set for herbicide spraying for pipfruit growers.

Engine speed	Number of growers	Proportion of growers %
900	4	5.8
1000-1100	22	31.8
1101-1200	21	30.4
1201-1300	4	5.8
1200-1400	1	1.5
1400	2	2.9
1500	8	11.6
1600	1	1.5
1700	1	1.5
1800	5	7.2
TOTAL	69	100.0

Nearly two thirds of the growers (62%) in Table 45 set their engine speed between the narrow range of 1000 and 1200 rpm. Even taking into account the range the tractors orchardists use, these growers are running the pumps at around half of the capacity rated at 540 rpm (maximum p.t.o speed).

The results from Table 43, 44 and 45 need to be linked together. Most pumps in use were rated between 30-40ℓ/min at 540 rpm. Yet 80% of the growers only require 2 - 6ℓ/min. The rest of the pumps' capacity is bypassed to give hydraulic agitation in the spray tank, but when the pipe size or suction filter restrict flow, pressure increases, and is difficult to control, leading to excessive drift, and frothing in the tank. Specifications for nozzles may be exceeded. Controlling pressure at engine revolutions over 1800rpm proved difficult for two growers. One grower ran the tractor at 2400rpm causing pressure to be at 140psi, whilst another grower set his tractor at 2000rpm, giving pressure gauge readings of 75 to 80psi (520 - 550kPa), and up to 100psi (670kPa). This is the direct result of the manufacturers putting in pumps over-rated for the job, and growers running them at or near 540rpm at the p.t.o and being unable to control the pressure from a 30-40ℓ/min pump whilst applying 3-6ℓ/min. The power needed to spray herbicides is much less than that needed for other tractor work such as mowing or crop spraying. Reducing engine revolutions to below 540 at the p.t.o reduces the output of the pump but still allows, in the appropriate gear, a constant forward speed to be maintained in the desired range of around 3 to 6km/h.

The final aspect required for complete calibration is that of the spray swath width. This is defined as the width that the growers were aiming for weed control over. All growers sprayed rows from each side, and thus the spray swath is half of the total herbicide strip for any one row. (See Figure 2.)

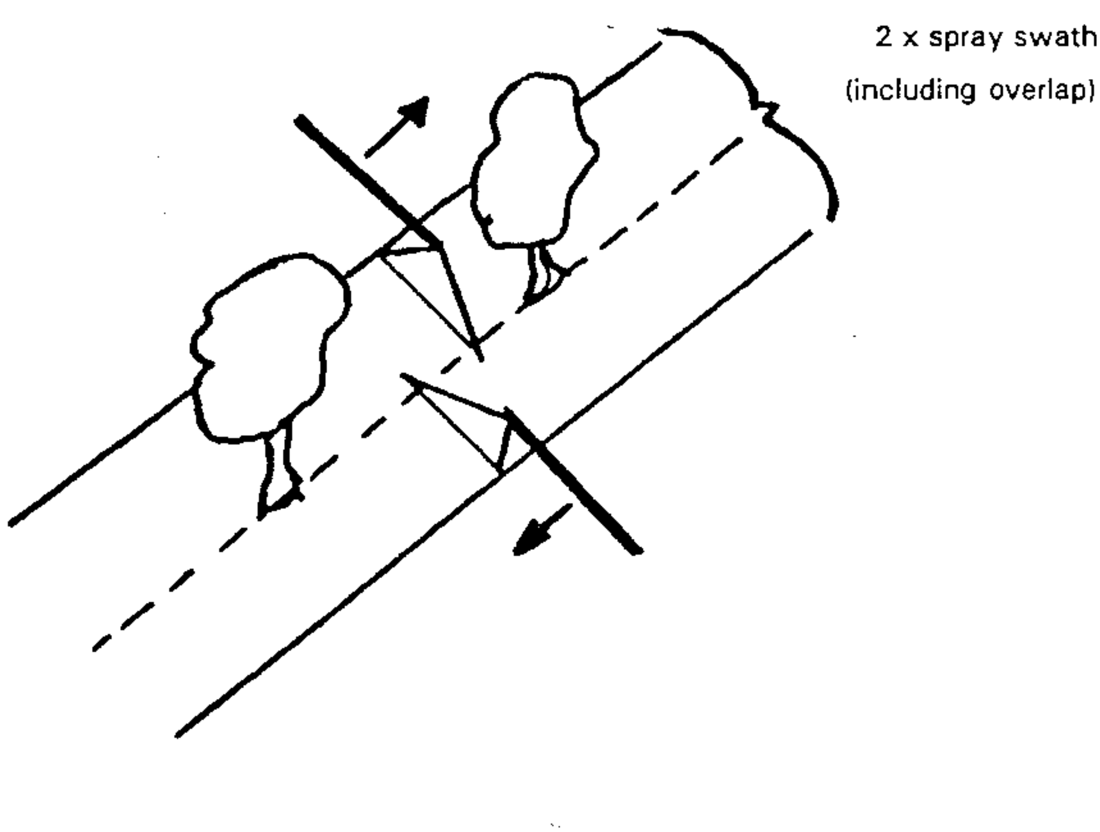

Figure 2: **Spraying practice to produce desired herbicide strip width. From Berry (1987).**

The spray swath from one pass excludes overlap, as this is done on each side and does not increase the total width of control, i.e. a 1.5m spray width with 200mm overlap will produce a 3.0m spray strip (2 x 1.5m). Growers intended spray swaths (for one pass) are given Table 46. Two growers gave answers that couldn't be constructively used - "very wide" and "full cover", the latter due to interplanting with sweetcorn. These results have been excluded.

TABLE 46: Claimed spray swath for one pass excluding overlap for 74 pipfruit growers.

Claimed spray swath (m)	No. of growers	Proportion of growers %
Don't know	2	2.7
< 1.0	6	8.1
1.0	32	43.2
1.1	2	2.7
1.2	12	16.2
1.25	6	8.1
1.3	3	4.1
1.4	2	2.7
1.5	6	8.1
> 1.5	3	4.1
TOTAL	74	100.0

Of the 74 growers who knew their spray swath 52 of them aim for 1.0 - 1.25m. Thus 70% of the growers are aiming to have an established herbicide strip of 2.0 - 2.5m in width. The grower who used a handgun only sprays around the trunks in a circle of about 0.5m in diameter (0.2 m^2/tree).

Growers and their spray operators overlap the spray swaths to ensure coverage is complete. This overlap, if large, is a potential area for overdosing, directly over the crops root system. This will be discussed later. Growers responses are given in Table 47. One grower indicated that his overlap was insufficient, whilst three growers indicated that they measured their overlap by the distance sprayed up the trunk - 100, 150 and 450mm in each case. These growers were excluded from

Table 47. 450mm up the trunk (given as 1 ½ feet) is an exaggeration, but if it is not constitutes poor and risky practice.

TABLE 47: Overlap in spray swath for 74 pipfruit growers.

Overlap (mm)	Number of growers	Proportion of growers %
Don't know	11	15.3
< 100	1	1.4
100	21	29.3
100 - 150	3	4.1
150	3	4.1
200	16	22.2
250	1	1.4
300	11	15.3
350	1	1.4
500	1	1.4
> 500	3	4.1
TOTAL	72	100.0

Of the 61 growers who knew their overlap 70% of them indicated that their intended overlap was between 100 and 200 mm, and only 5 growers indicated that they applied their herbicides with more than a 300mm overlap. Sitting on a tractor and trying the gauge the amount of overlap is difficult and for practical purposes, the 89% of growers that have an overlap of 100-300mm can be considered as having a similiar practice - 100-300mm of overlap fits nearly 90% of growers.

Growers were also asked to indicate the operating pressure of their herbicide sprayers. All pressures given in pounds per square inch (psi) were converted to kilopascals (kPa). Growers responses are given in Table 48. Growers who responded "don't know" either had sprayers with no pressure gauges, faulty gauges, or the gauges were in units that could not be understood. Most growers indicated that they operated their sprayers in a range, i.e. 40-50psi, thus Table 48 shows both ranges and specific answers.

TABLE 48: Claimed operating pressure of 76 pipfruit growers.

Operating pressure kPa (psi)	Number of growers	Proportion of growers %
Don't know	5	6.6
>200 (>30)	7	9.2
200-280 (30-40)	30	39.5
281-350 (41-50)	15	19.7
351-420 (51-60)	5	6.6
421-490 (61-70)	4	5.3
491-560 (71-80)	3	3.9
561-620 (81-90)	1	1.3
<620 (<90)	6	7.9
TOTAL	76	100.0

The wide range of pressures used was larger than was expected. The nozzles that growers are using are rated for use at 150-400kPa (Spraying Systems). Below this pressure less than ideal droplet formation and spray distribution occurs, and spray width would also narrow. It is my experience that 150kPa is too low and 200kPa is a minimum.

Table 48 shows that of the growers that knew their operating pressure 70% of them claim to apply their herbicides in the range of 200-400kPa (30-60psi). The 14 growers (20% of those surveyed) who are spraying at pressures over 420kPa are greatly increasing the chances of herbicide damage from drift, and are outside manufacturers' recommendated range. Droplets become smaller as pressure increases from any level, but 420kPa has been determined as the cut off by manufacturers.

A summary of the results from this section are given in Table 49. For the components or settings of spraying that were questioned, the range in which the majority of growers (who gave a useable figure) is given, and a percent figure of growers represented in this range.

TABLE 49: Summary of range of claimed or intended application figures from Tables 38 to 44.

Sprayer setting	No. growers supplying usable data	Range	Percentage of growers in this range
Nozzle output ℓ/min	25	2.0 - 4.9	60
Forward speed km/h	55	3.0 - 5.9	78
Total spray swath, 2 passes (m)	72	2.0 - 2.5	72
Application rate ℓ/ha	61	301 - 500	57

Using all the minimum figures i.e. 2.00ℓ/min, 3.0km/h and a 1.0m spray strip, the application rate calculates to 400ℓ/ha. Using all the maximum figures, i.e. 4.99ℓ/min, 5.9km/h and a 1.5m spray strip, the application rate calculates to 338ℓ/ha. Note these are not extreme ranges because a grower driving at the slow end of the scale putting on a high water rate over a narrow strip would apply nearly 1000ℓ/ha. However in the survey no grower claimed to be using these sorts of rates. Thus the tables complement each other. The actual settings that growers used were checked during the calibration process.

4.8 Herbicide sprayer calibration

To determine how accurately growers calibrated their sprayers, each grower was given the opportunity to have his herbicide sprayer calibrated and the spray distribution measured. Sprayers were calibrated at 40 of the orchards with two settings calibrated at one orchard. All parameters of application - forward speed, nozzle output, and spray width were checked. In many cases advice was given to growers on how to correct poor patterns, solve calibration problems, identify weeds and select herbicides. Two growers in Hawkes Bay had broken equipment at the time of the initial visit and were revisited in April and July of 1990, to conduct calibrations.

For growers who gave a specific answer for Question 5.1 of the survey (Appendix 1) and whose herbicide sprayer was calibrated, a percentage error in application rate was calculated. Application rate for this section is defined as the total water and diluted herbicide applied per hectare. Results are presented in Table 50.

Of the 41 sprayers calibrated six growers did not know their initial rate and thus their errors could not be calculated. Three growers did not give their rates in the conventional form of $x\ell$ of water/ha. One grower answered as 50 gal/acre (= 560ℓ/ha). Two growers gave the total water used over a given area. For each of these growers, measurements of spray width and row width were used to estimate their application rates. Thus for a total of 41 sprayers calibrated, 35 could be used for error comparisons. The results given in Table 51 were obtained from 15 Nelson growers, 17 Hawkes Bay growers and 2 in the Manawatu. Appendix 5, Table 5A.1 lists the errors more fully.

TABLE 50: Actual application rate of 41 pipfruit herbicide sprayers.

Actual application rate ℓ/ha	No. of growers calibrated at this rate	Proportion of growers %
< 200	3	7.3
200 - 250	3	7.3
251 - 300	7	17.1
301 - 350	6	14.6
351 - 400	4	9.8
401 - 450	5	12.2
451 - 500	2	4.8
501 - 550	3	7.3
551 - 600	0	0
601 - 650	4	9.8
> 650	4	9.8
TOTAL	41	100.0

A mean was calculated from the results. However there is a bias as some growers aim to apply around 200ℓ/ha for glyphosate. There are also growers who aimed to apply over 500ℓ/ha but their errors drop them closer to 200ℓ/ha. In total the results were: $n = 41$, $\mu = 403$ℓ/ha, $\sigma = 165$ℓ/ha.

Application rates showed a wide variation with 95% of growers applying herbicides between 80 and 726ℓ/ha.

A comparison of actual results compared with intended results is given in Figure 3. The large proportion of growers significantly under applying is reflected in the distribution.

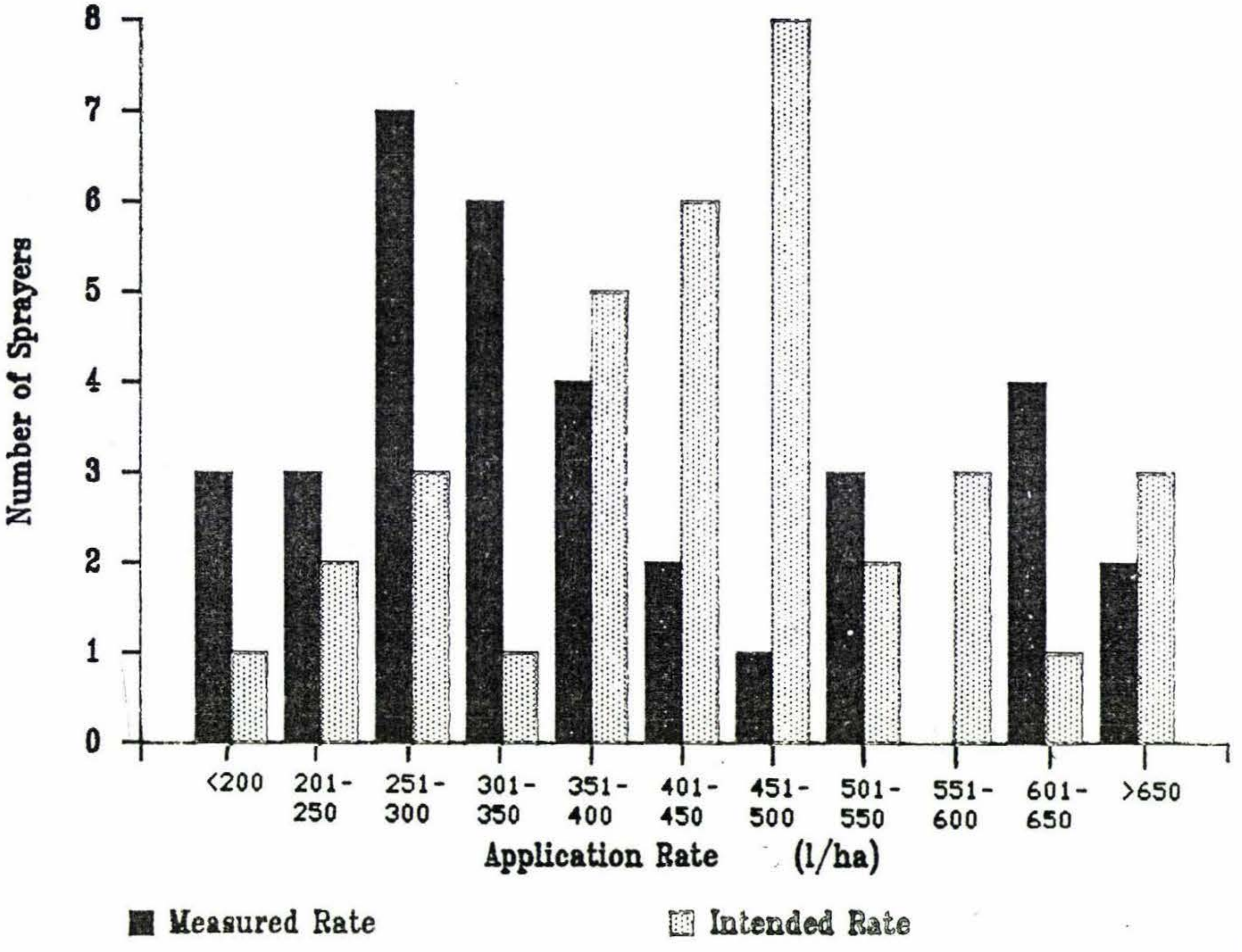

Figure 3: **Measured application rates vs. intended application rates of 35 pipfruit herbicide sprayers.**

Note that the measured application rates (in red) do not typify a normal population. The graph has two peaks. This was also borne out during statistical analysis when a large standard deviation was calculated ($\mu = 403 \ell$/ha, $\sigma = 165 \ell$/ha).

TABLE 51: Differences between intended application rate and measured application rate for 35 herbicide sprayers.

Error %	No. sprayers calibrated with this error			Accum TOTAL
0	2			2
	- ERROR	+ ERROR	TOTAL	
0 - < 5	1	1	2	4
5 - 10	3	3	6	10
11 - 20	3	2	5	15
21 - 30	6	2	8	23
31 - 40	3	1	4	27
41 - 50	4	0	4	31
> 50	3	1	4	35
TOTAL	23	10	33	35

Of the 35 sprayers calibrated with given intended application rates:

6% were correctly calibrated;

6% had an application error of ± 5%;

17% had an application error of ± 5-10%;

14% had an application error of ± 11-20%;

57% had an application error in excess of ± 20%.

Table 51 shows that of the 33 sprayers with an application error, 23 sprayers (66%) were found to be underapplying and 10 (31%) overapplying. The word "dosing" should not be used as growers using more than the intended water rates/ha but lower rates of herbicides can still be within the safe limits of application.

The average error of the 23 sprayers underapplying was 37%, and of those who were overapplying 18.1%. Thus underapplication of herbicides is a larger problem, and of a larger magnitude.

Figure 4 illustrates these errors for the 35 sprayers.

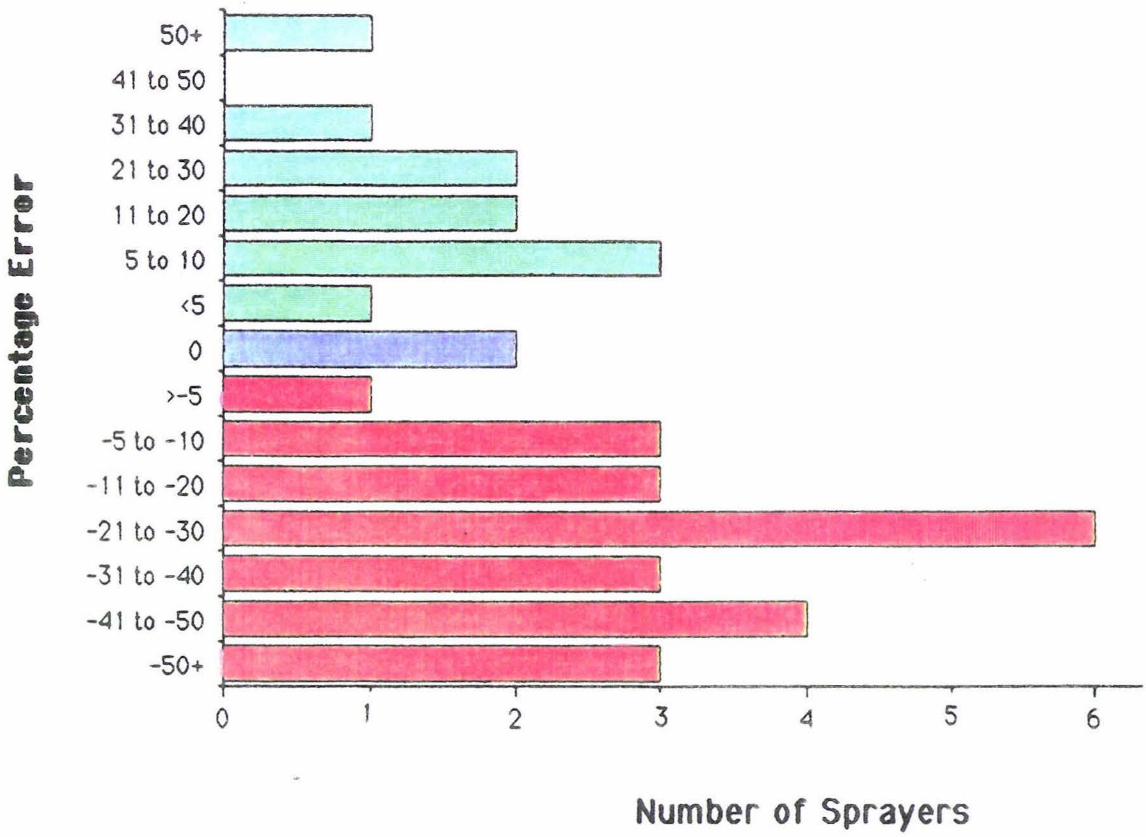

Figure 4: Application errors of 35 orchard herbicide sprayers.

Four sprayers calibrated had booms spraying left and right, allowing two rows to be sprayed at once. Three of the larger errors of -41%, -60%, +55% arose from this equipment. Instances occurred where the growers or their advisors added together the application rate from each side to get the total ℓ/ha.

For example a grower with an intended rate of 800ℓ/ha was found to be applying 320ℓ/ha on the left side and 315ℓ/ha on the right. The grower or his advisor had calculated these incorrectly then added them together. Another two sided sprayer calibrated in Nelson at 205ℓ/ha had an intended rate of 350ℓ/ha. The output from one side only was measured. The grower was not happy with the figures given as the sprayer had recently been calibrated by a chemical company representative with different results. It was found that the representative used a formula incorporating a measurement of distance between nozzles, as per long multi-nozzle booms to measure the spray width. Unless by chance that distance equaled the full swath width for both nozzles, this was incorrect. This example shows a poor understanding of the basic logic involved, even by advisors.

Growers whose sprayers were calibrated were given a copy of the completed calibration calculations for future references.

Petrol powered tractors caused some difficulty when measuring forward speed of tractors in the Moutere hills, Nelson. For example the speed of one tractor was 6.2km/h uphill and 8.0km/h downhill. This altered the application rate from 310 to 400ℓ/ha. The brakes could not be applied as his foot was resting on a string connected via a pulley to the boom (Plate 32). He used this arrangement to alter the height of the boom for ground contour changes and large weeds. On another Nelson property, two speeds recorded were 4.05km/h on the flat and 3.25 km/h uphill. A downhill speed was not recorded - but it would probably exceed 4.05km/h giving a difference of over 25%.

One grower had a boom on either side spraying different widths, and, depending on his turning pattern, this gave three widths of spray strip: wide, narrow, or wide on one half and narrow on the other. Differences in nozzle output for pairs of nozzles spraying to the left and to the right can be seen in Appendix 5, Table 5A.3.

Plate 32: Grower's foot resting on string to control height of boom, to spray large weeds and smooth out changes in ground contour.

Dirty nozzles were found at several locations. On two properties these nozzles were put back in before cleaning them to demonstrate to growers the problem. An OC03 nozzle was measured at 0.75ℓ/min, to give 139ℓ/ha. Upon cleaning the filters this rose to 1.05ℓ/min to give 195ℓ/ha (+40%). Similarly a grower using two nozzles had a total flow rate of 3.45ℓ/min rising to 3.75ℓ/min (+19%) after cleaning. This supports Yates (1989) who stated that errors of up to 30% may occur. Both growers discarded their filters after this demonstration. One pump was found to have no oil in it and no air in the compensator. The lack of pressure in the compensator caused the spray discharge to pulse.

4.8.1 Error in individual sprayer settings

To identify which portion of the calibration process was causing the most error, growers' intended speed, nozzle output and spray width were compared to those measured.

4.8.1.1 Forward speed

Forward speed measurements are summarised in Table 52, with full details in Appendix 5, Table A5.2.

TABLE 52: Actual forward speeds of 40 pipfruit sprayers during operation

Forward speed km/h	No. growers	Proportion of growers %
2.0 - 2.9	2	5.0
3.0 - 3.9	13	32.5
4.0 - 4.9	11	27.5
5.0 - 5.9	7	17.5
6.0 - 6.9	7	17.5
TOTAL	40	100.0

Table 44 showed that 78% of growers intended to operate between 3-5.9km/h, and measurements confirmed this (Table 52), but from a smaller sample (40 vs 72). Note that the three growers who claimed to exceed 7km/h did not have their sprayers checked.

The average speed of these growers was calculated. On advice from Brook (1991) the grower who went one speed uphill and another downhill, had these speeds averaged, so as not to bias the sample. This was done for growers spraying left and right.

Results were n = 40, μ = 4.53km/h, σ = 1.21km/h.

Thus 95% of growers spray at a forward speed of between 2.16 and 6.90 km/h. This agrees well with Tables 44 and 52.

Thirty growers had a specific intended speed compared with the measured speed (Appendix 5, Table 5A.2). Results are given in Table 53. Errors under 5% were taken as zero given the variability in field operation.

TABLE 53: Forward speed errors of 30 herbicide sprayer tractors comparing intended rate to that measured.

Error %	No. tractors calibrated with this error			Accum Total
0	12			12
	- Error	+ Error	Total	
5 - 10	- 2	5	7	19
11 - 20	- 1	2	3	22
21 - 30	- 2	0	2	24
31 - 40	- 2	1	3	27
41 - 50	0	1	1	28
> 50	0	2	2	30
TOTAL	7	11	18	30

Speed was more accurately measured by growers than total spray application, with 63% of growers being within ± 10% of their intended speed. However, speed is only one of three major sprayer settings that determine total application error and thus any errors in speed can be cancelled or exaggerated by errors in other settings.

4.8.1.2 Nozzle output

Results from nozzle output readings are given in Table 54. One grower who was spraying the whole row width for sweetcorn, applying 8.95 ℓ/min was excluded as this will not be a normal practice as the apple trees mature.

TABLE 54: **Actual nozzle output from 39 sprayers.**

Actual rate ℓ/min	Number of growers	Proportion of growers %
< 2.00	3	7.7
2.0 - 2.99	15	38.6
3.0 - 3.99	9	23.0
4.0 - 4.99	5	12.8
5.0 - 5.99	3	7.7
6.0 - 6.99	2	5.1
7.0 - 7.99	2	5.1
TOTAL	39	100.0

Table 54 correlates well with Table 43, where 25 growers knew their intended rate, and 80% of nozzle outputs were between 2.00 and 5.99ℓ/min. Table 54 from a larger sample shows over 80% in this category, and a narrowing of the range. The grower who claimed to apply 9.5ℓ/min/side was found to be applying 7.2 and 7.7ℓ/min/side, and thus 8.00ℓ/min defines the end of the range for sprayers calibrated.

The errors of these growers are given in Table 55. Complete calculations can be found in Appendix 5, Table 5A.3. The statistics regarding total nozzle output were: $n = 39$, $\mu = 3.58$ℓ/min; $\sigma = 1.57$ℓ/min.

Thus 95% of growers applied 0.50 to 6.65ℓ/min. However, some of this wide variability was due to two growers applying more than 7ℓ/min. One grower put in an extra nozzle to establish abnormally wide herbicide strips (3.8m) (see Table 56) whilst the other growers total application rate approaches 700ℓ/ha. To check this influence two growers were excluded and μ recalculated to get 3.35ℓ/min and σ = 1.28ℓ/min. Thus for this calculation 95% of growers apply between 0.85 to 5.85ℓ/min, which better fits the data presented, as 0.85ℓ/min is a more accurate lower limit.

Table 43 showed 68% of growers didn't know what their nozzle output was, and for the 41 sprayers calibrated only 14 growers knew their intended nozzle output. Of these, four growers had booms out left and right. These four booms each differed by at least 5% from the other side and were recorded separately, giving a total of 18 readings.

TABLE 55: Nozzle output errors of 14 pipfruit growers from 18 booms.

Error %	No. sprayers measured with this error			Accum Total
0	1			1
	- Error	+ Error	Total	
5 - 10	3	1	4	5
11 - 20	1	5	6	11
21 - 30	3	1	4	15
31 - 40	1	2	3	18
TOTAL	8	9	17	18

Due to the small sample size that could be used, very little can be inferred. Only one in 14 growers had their nozzles applying with ±5% of what they intended or expected the nozzles to be applying. Errors were evenly spread, nearly as many under as over, but the amount of errors was high with over 60% of the growers having errors of over 10%.

4.8.1.3 Spray width

The final aspect required to calibrate sprayers was that of spray width. This was measured by measuring the width of estabished herbicide strips acheived by the sprayer and boom being calibrated. Actual spray widths measured (excluding any overlap) are given in Table 56. The grower spraying the whole width (2.85m/side) was excluded from this analysis as it is not usual practice.

TABLE 56: Actual spray widths of 39 pipfruit growers.

Actual spray width (m)	Number of growers	Proportion of growers %
< 1.0m	4	10.2
1.0m	5	12.8
1.1m	3	7.7
1.2m	4	10.2
1.25m	8	20.5
1.3m	10	25.7
1.35m	1	2.6
1.4m	2	5.1
1.5m	1	2.6
> 1.5m	1	2.6
TOTAL	39	100.0

Actual spray width measured agree relatively well with intended widths, considering that the difference between a 2.5m strip and a 2.6m width is not significant. However, comparing Tables 46 and 56 growers actually spray over a wider than intended width, with many more growers getting weed control over a width of 2.5-2.6m when they were intending for a total width of 2m. The errors that this encompassed are given in Table 57, with full details in Appendix 5, Table 5A.4.

The average width sprayed by these 39 pipfruit growers was calculated. The statistics for spray widths are: $n = 39$, $\mu = 1.21$m, $\sigma = 0.20$m.

Thus 95% of growers spray over a width of 0.82 to 1.6m, giving an overall established width of 1.64 to 3.2m under the trees assuming the spray meets at the centre of the rows. The grower establishing 3.8m widths was outside three standard deviations, so would represent less than 0.13% of a normal population. Excluding his result of 1.9m gives $\mu = 1.19$m, $\sigma = 0.17$m, narrowing 95% of the growers to a range of established strips of 1.7 to 3.0m.

TABLE 57: **Spray width errors of 38 pipfruit growers.**

Error %	No. spray widths measured with this error			Accum Total
0	7			7
	- Error	+ Error	Total	
5 - 10	2	3	5	12
11 - 20	4	9	13	25
21 - 30	0	11	11	36
31 - 40	0	2	2	38
TOTAL	6	25	31	38

Most growers (65.8%) are getting weed control over a wider width than intended, whilst 15.8% achieved a narrower width. The final 18.3% being with 5% of their target width. Two thirds of growers had errors of 11 to 40%. Wider widths than intended decrease the overall application rate in ℓ/ha but increase the proportion of the area in herbicide strips under the crop trees.

4.8.1.4 Effects of sprayer setting errors

Due to the lack of knowledge by some growers of all or some of their sprayer settings, complete data was available for only 14 out of 40 sprayers calibrated. Results from these sprayers obtained from the calibration were compared with the growers' quoted parameters and the differences are presented in Table 58.

TABLE 58: **Known errors of all sprayer settings for 14 pipfruit growers.**

Grower	Error in forward speed %	Error in spray width %	Error in nozzle output %	Error in spray application %
A	5.7	-7	-27	-41
B	10	20	-22	-29
C	0	-13	-9	-22
D	1.9	-4	-6	-4
E	-12.3	17	11	8
F	0	20	19	12
G	-21.7	35	-32	-33
H	3.8	25	15	-44
I	7.2	19	7	0
J	10.4	0	7	11
K	-20.6	25	35	-6
L	-4.7	-17	-22	0
M	-37	-17	-6	-15
N	3.3	4	4	5

The calibration check identified errors in all three major sprayer settings. The intention was then to see whether forward speed, nozzle output or spray width had the largest influence on the overall application error. The errors calculated for each sprayer setting and the overall application error calculated are listed in Appendix 5, Table 5A.5.

Cumulative errors in settings can reduce the overall application error. For example, going faster than intended could reduce the application rate by say 10%, but having a lower nozzle output of 8% less than intended would compensate to some extent so that the overall application error would be smaller than either of the single errors alone. Errors in settings can also compound the overall application error, i.e. spraying over a narrower width than intended with a higher nozzle output than intended will increase the total application error.

Of the 14 growers, 10 (70%) had a spray application error less than any component error (from applied width or nozzle output). For example Grower L had sprayer setting errors of -4.7, -17 and -22% respectively which cancelled out to give an accumulative calibrated error of 0%. It is more by luck than any other reason that this grower was applying herbicides in the target rate. Grower K with three large errors over 20% had a total error of only -6%. Because of the flexibility in the strip width, the error in litres of water applied per hectare overall may be small, but the proportion of orchard land in herbicide strip can be altered significantly. In conventional boom sprayers with many nozzles the spray width is fixed, and for air blast sprayers spray "width" is defined by the orchard rows, irrespective of volume.

The four growers who had compounded errors (A,B,C and H) were all significantly under applying.

To further analyse how these errors were occurring the application rate that these 14 growers should have calculated from their intended settings, was compared with what they claimed as their application rate and that calibrated (Table 59). For example grower A intended at a rate of 350 ℓ/ha. Using the settings stated he would have theoretically applied 275 ℓ/ha but when measured the sprayer was only applying 205 ℓ/ha.

TABLE 59: Comparison of application rates (ℓ/ha) intended, recorded and calibrated from 14 pipfruit growers.

Grower	Rate calculated from stated intended settings	Intended rate recorded from grower	Actual calibrated
A	275	350	205
B	216	360	255
C	295	400	310
D	370	370	355
E	490	490	530
F	181	160	180
G	555	270	360
H	300	450	266
I	420	416	416
J	625	550	608
K	409	600	570
L	660	660	656
M	277	500	427
N	600	600	630

Table 59 shows that only growers C, E, I, J, L and N had measured their spray settings correctly arriving at a similar figure to that calibrated during the survey.

The reality then is much more complicated than it first looks. In-depth analysis showed that growers had not accurately measured sprayer settings of width, forward speed and nozzle output, and also do not use these figures correctly to derive their application rate. Luck has favoured some to smooth the total error to an acceptable level, but with others it has exaggerated the error. Given that only 14 out of 40 growers could quote all their sprayer settings, which is commendable, the other 26 growers were not expected to be any better.

4.8.2 Results from portable spray patternator

At the completion of calibration 35 sprayers had their spray distribution across the width measured by the patternator. A photographic record was taken.

The use of the patternator added a whole new dimension to the calibration process. Growers enjoyed the speed and ease at which results were obtained. Over the survey period it was also used for diagnosis work, correcting faults in spray patterns, detecting nozzle wear, and correcting distances between nozzles on booms.

The ideal spray pattern should be even across the whole width, (Plate 33) with a small fall off at the extreme ends that can be covered by overlap in the middle and is not of great significance at the interface between the mown alleyway and herbicide strip.

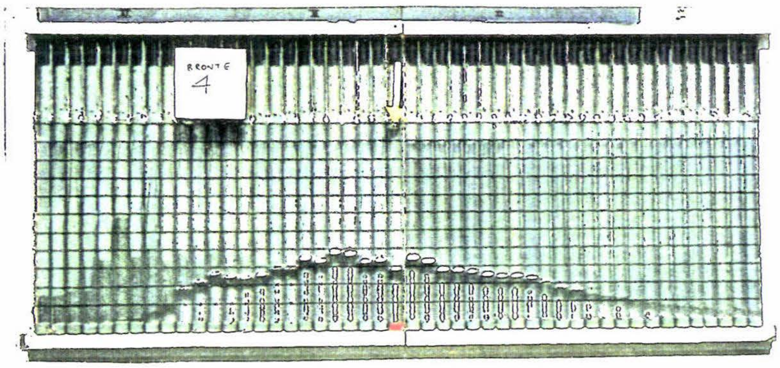

Plate 33: **This pattern, achieved by a single fan nozzle in this instance, produced an even distribution across the spray width, when overlapped (on the right).**

Growers using at least two nozzles or more set apart, were unable to ensure that the pattern produced would be even. Attempts to watch the spray swath dry on concrete to give an indication of evenness are crude at their best. The patternator quickly diagnosed any deficiencies. Plate 34 shows the pattern recorded from a two nozzle boom. The arrows show the position of the nozzles over the patternator when collection took place.

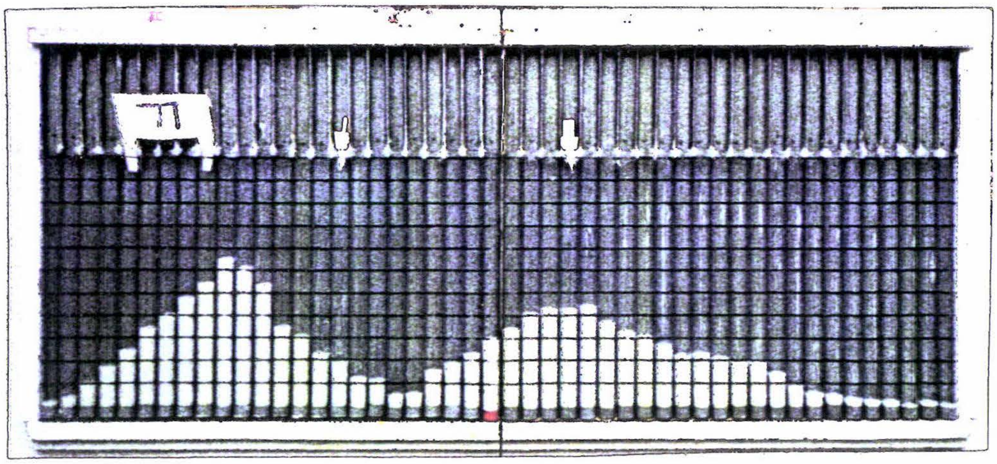

Plate 34: **An uneven distribution pattern due to poor nozzle spacing and poor selection of nozzles with different outputs.**

Nozzle wear is also an unknown factor for growers, and nozzles are usually only discarded when the application rate from one period to another increases significantly enough for the grower to observe a difference.

Nozzle wear leading to unevenness in application is something that cannot be seen by eye (Yates 1989). Plate 35 dramatically shows a two nozzle combination with five distinct peaks caused by nozzle wear.

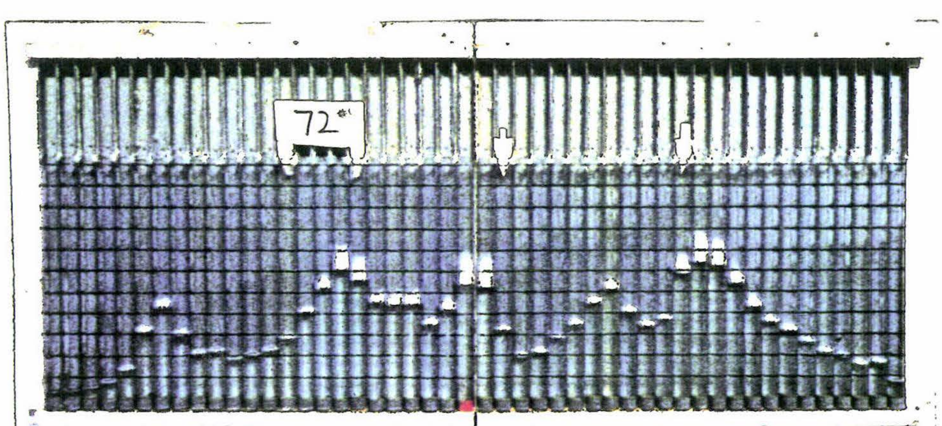

Plate 35: **A spray distribution pattern for two nozzles that were badly worn and spaced too far apart.**

The results from a boom fitted with four nozzles is given in Plate 36. The third nozzle from the left was not the same as the two extreme left nozzles causing this distinct pattern. The left half of the pattern was applying spray at about 400ℓ/ha, whilst the right half at about 600ℓ/ha. The sprayer was calibrated and shown to be applying 540ℓ/ha.

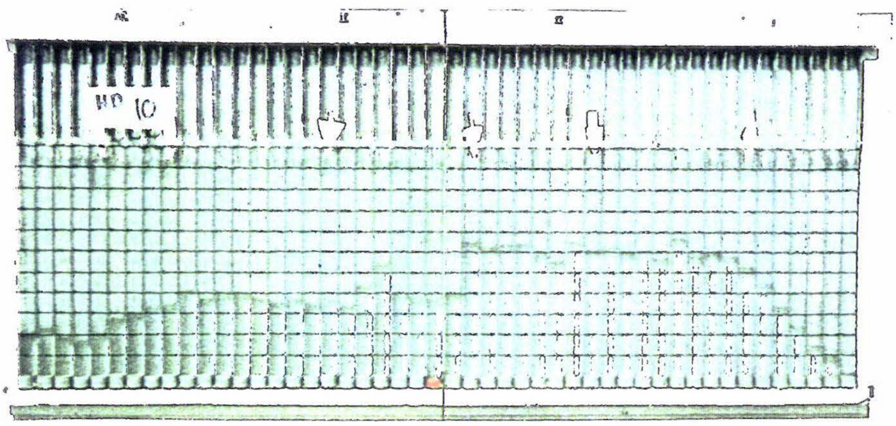

Plate 36: Boom with four nozzles. The third nozzle from the left has a higher output that the other three, as it was different.

Booms with nozzles spraying side by side in an inverted V shape, nearly all gave the same result depicted by Plates 37 to 39. The pattern produced fell away sharply and concentrated the spray a short distance each side of the nozzles. These booms always produced poor patterns.

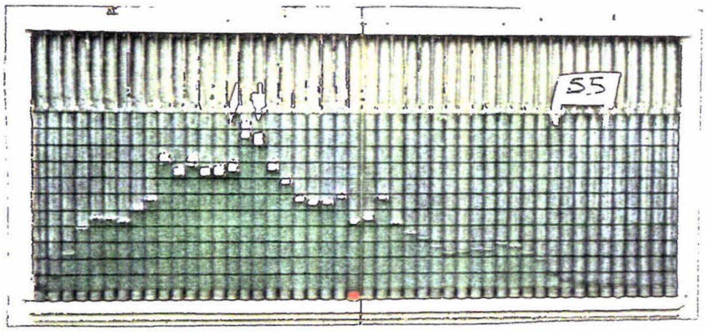

Plate 37

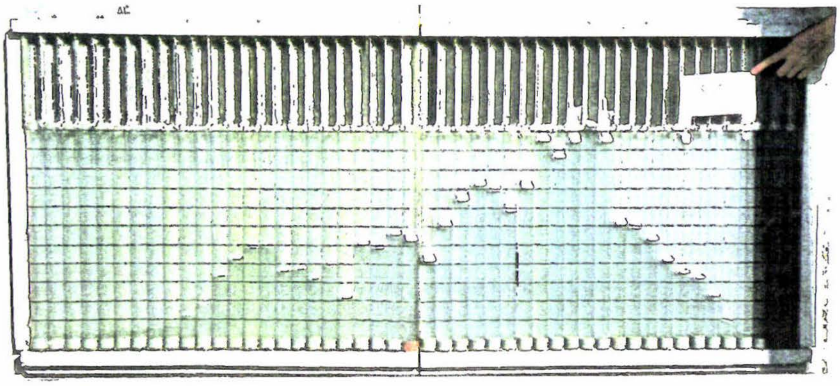

Plate 38

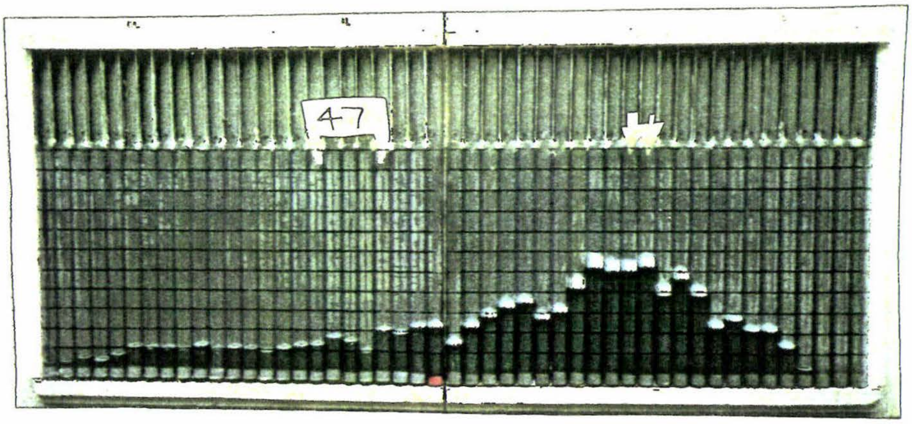

Plate 39

Plates 37 to 39: Pattern from booms with two nozzles side by side in a double head .

Poor distribution resulting from a dripping nozzle was highlighted by the patternator as shown by Plate 40. The leaking nozzle on the left disrupted the pattern, filling two tubes beneath it to nearly double the average application rate.

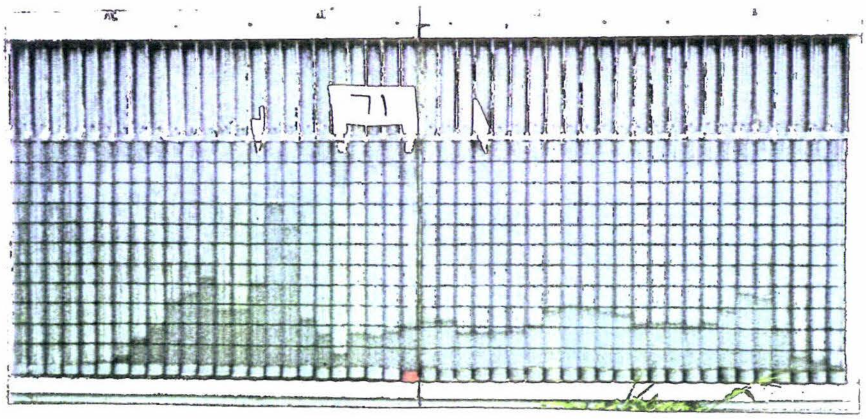

Plate 40: **Effects of nozzle drip on an otherwise near even pattern.**

Overall the portable spray patternator highlighted several major deficiencies in evenness of spray patterns. In some cases the error was larger than that of the error in the application rate, and further served to show just how much attention needs to be paid to correctly set up and calibrate an orchard herbicide boom.

The savings in wasted chemicals and reduced damage to trees and fruit contamination could make the effort worthwhile.

No economic analysis was attempted in this study but it was evident from several examples that improved sprayer design leading to more accurate chemical application methods would benefit from a reduction in chemical use and cost.

4.8.3 Correction of these problems: boom design

To improve both calibration and spray distribution across the width, a standardised boom needs to be designed. Width and nozzle output will need to be specified during the design stage. The boom needs to be closer to the ground than current booms to reduce the amount of tree crop foliage in direct contact with herbicides, which only half of growers removed immediately after contact.

The patternator has shown that to lower a boom more nozzles are required to give even coverage over the spray width. Off-centre nozzles should not be used at all. No nozzles should spray from a double fixture.

Time constraints and the size of this project meant that only preliminary work been done on boom design. However, the standardised boom would spray at no more than 300mm above the ground with at least three nozzles for spray swaths of up to 1.2m and four nozzles for those swaths desired to be over 1.2m. Nozzles would be even sprays', probably 125° spray angle.

With the knowledge that this study has provided, recommendations for the nozzles to use for the range of speeds travelled can be easily made. Such a boom could be made and tested using the portable spray patternator to ensure it works correctly. A shield may or may not be warranted to reduce the potential of spray drift.

A calibration manual needs to be prepared to accompany the boom, and for distribution to all growers using herbicides. The format could be similar to past FruitFed Grower Guide Bulletins, detailing the boom design and nozzle specifications for those who wish to make their own boom.

4.8.4 Orchard operation

Whilst calibrating sprayers in the orchard a check list of items was observed. (Section 9, Appendix 1.)

Nothing new came out of this section of the survey. Tractors not coping well with changes in terrain were picked up in speed measurement, and has already been mentioned, and no growers were found to have a complicated turning system at row ends. Boom movement was picked up in Section 5 of the survey. Nozzle drips, pressure surges and shut off speeds were seen during the calibration process, and picked up by the patternator.

During the process four tractors were considered to be operated too fast for the terrain giving poor boom stability. Two tractors were run at higher engine speeds than required for the contour and pump.

4.9 Water rates for applying herbicides

4.9.1 Utilisation of recommended water rates

Non-translocated contact herbicides, e.g. paraquat/diquat, must be applied in a sufficient water rate to cover all plant surfaces for a good control. Denser weed infestations require a higher water rate per hectare to ensure all plant parts are covered. Contact translocated herbicides, e.g. glyphosate, need only be applied at a sufficient rate to ensure each plant receives some spray, the herbicide then translocating to affect the whole plant. Soil acting residual herbicides, e.g. linuron/diuron, needs to be applied at a high enough water rate to ensure that a continuous uninterrupted layer is applied to the soil, ensuring each germinating weed comes into contact with the herbicide. High rates also aid runoff from any plant species present so that the herbicide quickly reaches the soil following irrigation or rain. A time lapse may be intended for those residuals with some knockdown action.

Herbicide manufacturers usually give a recommendation of both the amount of herbicide to apply per hectare and the water rate per hectare to apply it in. Examples of label recommendations for some herbicides are (O'Connor 1989):

- Paraquat/diquat (Preeglone):

  2-6ℓ/ha (depending on weed stage and type) in 200-600ℓ/ha of water

- Glyphosate (Roundup):

  1-6ℓ/ha (depending on weed stage and type) in 100-200ℓ/ha of water

- Linuron/diuron (Cohort):

  4-8ℓ/ha (depending on soil type) in 200-1000ℓ/ha of water.

Growers are expected to select the rate of herbicide and then apply it within the range given. Equipment set up at 500ℓ/ha of water for linuron/diuron, should not be (following label recommendations) used for applying glyphosate, where the maximum water rate/ha is 200ℓ.

The initial choice of herbicide and formulation, mode and timing of application, prevailing weather and other factors, all may influence the proportion of herbicide reaching the target and the effect it has when it gets there. For example, quite small differences in the droplet size spectrum, concentration of wetting agent or other adjuvant, or in air temperature or relative humidity before during or after spraying can all have profound effects on the retention of herbicide on leaves and subsequent uptake, movement and behaviour within the plant. With so many variables it follows that manufacturers' recommendations are a compromise aimed at achieving good weed control while avoiding crop damage or spray drift, but inevitably much spraying is done under suboptimal conditions (Stephens 1982).

To find out if growers adjust their water rate for the herbicide they are going to apply, they were asked if the output given in Question 5.1 was the only rate at which they applied herbicides. Responses were gained for all 76 growers who applied herbicides through a boom. Two thirds of the growers (51) used only the one water rate whilst the other third (25) indicated that they had another option. However, six of these growers did not know what the second application rate was, including two growers who did not know how much was applied at either rate. The options given by growers are listed in Table 60. The six growers who did not know their second rate were excluded.

Nearly half of the growers in the Nelson region (15 out of 33) used more than one application rate, whilst less than a quarter of Hawkes Bay growers (9 out of 40) were able to use more than one rate.

TABLE 60: Alternative application rates used by growers to apply herbicides in (litres water/ha).

Lowest rate ℓ/ha	Highest rate ℓ/ha	Absolute increase ℓ	Percentage increase over initial rate %
160	370	210	131
160	500	340	212
170	450, 650	304, 480	175, 283
182	474	292	160
190	380	190	100
200	360	160	80
200	300	100	50
200	500	300	150
200	600	400	200
209	417	208	99
215	440	225	105
220	660	440	200
250	500	250	100
261	580	319	148
270	848	578	214
200 - 300	490	190-290	63-145
300	400	100	33
300	600	300	100
350	500	150	43

When analysing the surveys a difference between Hawkes Bay and Nelson growers was perceived, between the regions and the alternative water rates used per hectare. Results of this are presented in Table 61.

Table 61: Number of water rates used by Nelson and Hawkes Bay growers.

Region	Growers with one rate		Growers with two rates		Total
	Observed	Expected	Observed	Expected	
Nelson	18	22.15	15	10.85	33
Hawkes Bay	31	26.85	9	13.15	40
	49	49	24	24	73

$X^2 = 4.32$

At one degree of freedom the 5% confidence level was 3.841. So being less than $X^2 = 4.32$ we can say with at least 95% confidence that the difference was significant.

This may be because Nelson growers are more confident at calibration or more conscientious when following manufacturers' label recommendations or more likely because water is short in the Moutere hills.

Many orchardists were crop spraying at 2 or 3 times concentrate in an effort to reduce water usage, and they if could apply this principle to herbicide spraying probably do. Their major aim was to apply glyphosate at lower rates than those used for residual herbicides and other contact herbicides to meet label recommendations. For glyphosate applications to be applied in 100-200ℓha of water/ha, 12 out of 76 growers (15%) were able to meet this criteria. In a practical sense the major benefit of using low water rates is that the tank needs refilling less often as a larger area is covered.

Applying glyphosate in more than 200ℓ/ha is not going to put the crop at any greater risk from spray contamination; indeed the coarser heavy drops will drift less. Spurrier (1973) who worked with glyphosate at its early stage of development, indicated that volumes up to 840ℓ/ha could be used for spraying high density vegetation. At optimum or slightly higher rates of diluent (186-465ℓ/ha) where rates of 1.0kg ai/ha or more are used (3.6ℓ/ha or more of formulation), the surfactant level in the formulation is quite adequate. Higher water rates than 465*l*/ha can still be effective if the total surfactant in the diluent approaches 0.5% by weight of total diluent. In a book dedicated to the herbicide glyphosate (Grossbard and Atkinson 1985), this information was not detailed, but Atkinson (1985) stated that most studies on the use of glyphosate in fruit crops in the United Kingdom have employed conventional high-volume sprays, of approximately 500*l*/ha.

Tank mixing glyphosate with triazines, ureas, uracils and other soil-acting herbicides generally reduces its activity. A review of other work in this area by Turner (1985) showed that the interaction only occurred in mixed sprays and not when simultaneous applications were made to different leaves, or a triazine to the soil and glyphosate to the foliage. Antagonism is due to the formulation ingredients, especially those in wettable powders, and that more glyphosate was absorbed when more concentrated spray mixtures were used.

Thus growers are not doing anything wrong, and on reflection using glyphosate in the water rates used will not do any harm, and with regards to drift and efficacy in mixes, is beneficial.

A small portion of the alternative application rates used were are not very practical and of doubtful benefit, where absolute increase in application rate was less than 150*l*/ha and the relative increase less than 50%.

The way in which growers adjusted their sprayer operation to achieve these different outputs was asked. From 24 responses, 19 growers claimed to change the nozzle tips. A further four changed their nozzle tips and also adjusted the pressure. The final grower adjusted his speed, pressure, and changed nozzle tips.

Altering application rates by nozzle tip and pressure changes is very simple, and allows growers to maintain simple procedures for spraying - the selection of gear and engine speed remain the same.

Growers were asked if, for the range of herbicides used throughout the seaon, manufacturers' recommended rates always fitted in with their sprayer setting.

Responses were gained from 72 growers.

Just over 60% of the growers (44) answered "no". As expected, 31 out of 40 Hawkes Bay growers answered no, as only nine of them changed application rates. The recommendation that is not being met is application of glyphosate in rates less than 200ℓ water/ha, because they use one setting, generally around 300-500ℓ/ha. This is not really of any consequence.

No growers chose chemicals because they could be applied at the setting they used. Of the 44 growers who did not always meet label recommendations only one grower was concerned, and he wanted to change the rates for applications of glyphosate. Nine growers commented that they preferred higher rates of water as it lowered the risk from drift, and increased coverage of the dilute chemical. Four growers commented that the herbicides still work at other rates and another three growers said that a single setting was convenient for their orchard staff. One grower stated that there were too many hassles to contend with in changing, so he uses larger output nozzles at a lower pressure and considered this safer for his crop. For droplets of equal volume, a droplet from a sprayer with 1 kg ai glyphosate in 200ℓ water/ha is twice as potent as that from a sprayer applying 1 kg ai glyphosate in 400ℓ water/ha. However the former droplet is more potent to the weed, and likely to be more effective. Growers' response when applying herbicides outside the manufacturers' recommended water rates was to adjust the dilution rate so that the chemical rate per hectare is correct, e.g. instead of 3ℓ in 200ℓ of water/ha, 3ℓ will be applied in 500ℓ/ha of water/ha.

Some commonly used herbicides do not have label recommendations specificially for orchard use, e.g. simazine labels state "use 2-5ℓ/ha" - but give no rates of water/ha (O'Connor 1989; O'Connor 1987). Simazine is used at 200-300ℓ/ha in lucerne and 300-400ℓ/ha in forestry. This is also the case for terbacil. Growers using mixes could not always satisfy the criteria for both herbicides. Recommendations for the herbicide Caragard are that it be applied "in a minimum of 200ℓ of water/ha for bare ground and up to 400ℓ of water/ha depending on the density of weeds, with a knockdown herbicide, e.g. glyphosate" (O'Connor 1989). Thus the grower is being given conflicting advice to apply glyphosate in rates exceeding 200ℓ/ha. Label recommendations for Goal are very specific for example and should be applied at 3*l* in 300-400*l*/ha of water to bare soil but advice changes for when weeds are present similiar to that for Caragard.

Thus, for many cases where mixtures are used the criteria of use is not rigid, and for some herbicides no rates are given. Logic would show that a mix of 5*l* simazine and 4*l* of glyphosate in 100-200*l* of water would be very viscous and difficult to apply, due to filtration blockages, etc, through fine nozzles. The mix would and also reduce the efficacy of the glyphosate due to the high concentration of the triazine mix. There is no risk to the crop or toxicological implications from applying herbicides in a more dilute form than recommended, and little advantage to be had in increased timeliness as usually only 1-2 tanks of herbicide can be applied in any one day, usually early morning, reducing the sprayer "down-time" during mixing and filling.

4.9.2 Calculation of herbicides to go into spray tank

Growers were asked how they calculated the amount of herbicide to put into their tank, (Appendix 1, Question 5.21). Where full information was given each calculation was checked.

Responses were gained from all 76 growers. However, as with previous sections the growers did not always follow the format of the question, working out their chemical rates in different ways: 16 gave answers that were incomplete and/or difficult to understand, leading to doubt as to whether they could work their rates out correctly; and 15 growers worked purely on dilution rates and percentage mixes and did not know how much water they applied per hectare. These growers stated they were using herbicide dosage rates as follows: "simazine at 1-2% mixed with amitrole at 2-2.5%"; "paraquat/diquat at 1*l*/100*l*"; "glyphosate 1*l*/100*l*"; "simazine and glyphosate at 0.75*l*/100*l*"; "1% of everything"; using "dilution rates given on the label for handgun or knapsack rates", without knowing total water/hectare.

Thirteen growers indicated that the capacity of the spray tank equalled the amount of water applied per hectare. For example "I put on 450*l*/ha and therefore add the required herbicide rate/ha to 450*l* of water - always working on a tank basis".

Although this looks terribly convenient, cross checking showed that in each case the figure used as the usual fill up, i.e. 450ℓ was actually the intended application rate/ha (given in question 5.1). One grower stated he applied herbicides at 474ℓ/ha, but when applying Caragard at 8ℓ/ha and amitrole at 11ℓ/ha put 8^{+}ℓ and 11^{+}ℓ into 500ℓ of water. How much "+" was not indicated.

Another eleven growers calculated their herbicide dosages by working out rates/100ℓ. Two examples follow.

1. Glyphosate at 3ℓ/ha in 400ℓ of water/ha equals 0.75ℓ/100ℓ, 1.5ℓ/200ℓ etc.

2. Roundup 4ℓ/ha and Caragard 8ℓ/ha in 490ℓ/ha of water. Roundup = (4/4.9ℓ)/100ℓ, Caragard = (8/4.9ℓ)/100ℓ. Using a calculator he was able to work out part tanks.

Another seven growers related their tank size to the proportion of a hectare sprayed. For example when applying 209ℓ/ha a grower with a 500ℓ tank worked out that the 500ℓ will cover 2.5 ha (actually 2.39), and thus added 2.5x the herbicide rate/ha chosen to 500ℓ. Fractions were also given, i.e. apply 600ℓ of water/ha but fill to 200ℓ, and divide herbicide rates/ha by 3. All of these were correct except for minor rounding differences.

Formulas were used by 12 growers. Examples are given below. Some growers did not show full workings with herbicide examples but were assumed to be able to work these out correctly.

1. $$\frac{\text{Tank size or water to apply (ℓ) x rate/ha (herbicide)}}{\text{Application rate (ℓ/ha) of sprayer}}$$

2. $$\frac{\text{Herbicide rate x tank size}}{\text{ℓ/ha used}}$$

3. $$\frac{\text{2000ℓ spray tank}}{\text{rate/ha (580)}} = 3.4$$

Therefore herbicides into tank = 3.4 x rate/ha chosen.

Variations on this theme were given but they were minor, as shown above and all were correct, apart from rounding. Two mistakes in calculations were detected. These are given in Table 62.

TABLE 62: Error in calculations of herbicides during mixing process.

Intended herbicides and water rate	Water in tank	Growers calculation	Correct rate	Error %/ha
amitrole 7l/ha simazine 8l/ha in 300l/ha	500l	10l 11l	11.6l 13.33l	- 14 - 17
simazine 3.5l/ha glyphosate 6l/ha in 550l/ha	208l (44 gal drum)	1.2l 2l	1.32 2.27	- 10 - 13

No doubt both these calculations had been performed mentally and were thus rounded fairly roughly, all on the lighter side.

For the total of 75 responses, the way growers calculate the amount of herbicide to go into the tank is summarised below:

- 16 growers (21%) gave incomplete answers with poor knowledge of the process required.
- 15 growers (20%) used dilution or percentage rates, with no knowledge of total water applied per hectare.
- 14 growers (19%) filled their sprayer tank to the water rate per hectare and added the chosen rate of herbicide per hectare.
- 12 growers (16%) used formulae to work out rates for both full tanks and part tanks.
- 11 growers (15%) calculated their dosage rates to herbicide/100l, and made up part tanks.
- 7 growers (9%) related their tank size to the proportion of a hectare sprayed, adjusting herbicide volume rates accordingly.

Two growers had work sheets which included formulae used and workings. One was devised for the growers' staff to check nozzle flow before spraying and then use formulae to calculate water applied per hectare and the herbicides to go into the tank.

This sheet also recorded the blocks sprayed. The forms were correct and simple to follow.

Thus just over half of the growers (42 out of 75), were able to accurately calculate the herbicides to go into their tanks. A further two growers had the method right but made mistakes leading to underdosing errors of over 10%. Of the 15 growers who used dilution rates as their herbicide dose rates without knowing the total ℓ/ha of water applied, seven of their sprayers were calibrated. Five applied less than the 500ℓ/ha, and thus dilutions of 1-2% for the herbicides being used (simazine, amitrole, glyphosate, paraquat/diquat) would not cause overdosing to the soil and weeds, leading to increased crop uptake. The exception to this was simazine where potential exists for rates between 5-10ℓ/ha, though Harris (1991) suggested that up to 10ℓ/ha was safe. Two sprayers were calibrated at 687 and 750ℓ/ha. Both these growers applied to "1% of everything" and only used glyphosate or glufosinate - no residual herbicides. Essentially these programmes are relatively low risk with regard to herbicide residues in fruit as both are of low toxicity, not persistant, and rapidly deactivated by the soil. They are however still able to contaminate fruit via their spraying practice relating to direct contact of herbicides, as are all growers.

All growers apart from two used jugs and scales to measure herbicides going into the spray tank. One grower whose weed control programme was based on paraquat/diquat alone dipped a 600mℓ container into the 5ℓ herbicide container to get a rate of around 1ℓ/100ℓ, usually assessed by the colour of the tank solution. As the spray tank doesn't have marks or a sight glass, this required peering in to assess both total water and the rate of herbicide assessed by colour of the fluid in the tank. This is a very unsafe health practice.

Another grower mixed his herbicides into a 200ℓ drum, which acted as the spray tank. When applying terbacil at 0.25kg/100ℓ he requires 0.5kg/tank (200ℓ). Terbacil packaged into 1kg plastic bags was spread out on a board, patted and squashed flat by hand. He then halved it by eye and by hand, pushing half into a bucket, keeping the remaining half for the next load. He used jugs for the liquid herbicide formulations. The suction hose in this tank and the terrain that this grower travelled over meant that he could not use the last amount of water, estimated by the grower to be 20*l* - or 10% of the total mix. He used 11 tanks because of this, but really only needed 10. Occassionally the tank falls off and spills some herbicide as it gets empty and therefore lighter. However, in those runs where he doesn't spill anything out the next tank filled to 200*l* starting with 20*l* in the bottom is 10% stronger than the last. The permutation of this, given no spillages over 11 tanks is that the final tank could be up to 160% more concentrated than the first, being at least 50% stronger after the 6th tank. This is a large error, and very unsafe for the trees, particularly the pears, who according to label recommendations should not receive terbacil.

Overall accuracy of herbicides applied was rather lacking. Some of this stems from the broad ranges given on labels which often put growers in the position of choosing rates in ranges that differed by 5 fold. This may give the impression that it doesn't really matter.

Rates of herbicides applied were not grossly inaccurate, with one exception. The precise amount applied was variable, and if herbicides were required to be recorded in the manner of crop pesticides, then only half of the growers would be able to comply.

4.10 Grower Needs

Growers were asked a range of questions covering areas of training, literature, manuals and information about the process of weed spraying. All growers, but especially those that had a calibration conducted in their presence, were asked which aspects they found difficult. Boom designs were discussed to see if any more innovative ideas were being considered.

4.10.1 Grower training and information

Growers were asked if they had any training in the area of sprayer calibration and/or chemical weed control. Of the respondents 60% had not.

The training came from several sources, the major one was Universities. Ten growers had Diplomas in Horticulture; one had a Diploma in Agriculture (sheep); one was enrolled for a Weed Science paper extramurally; two growers had degrees, one in landscape design and the other in horticulture. Other formal qualifications included horticultural cadetships (2); fruit production courses at a polytechnic (1) or Technical Certificate Institute courses (1). Five growers rated their grower experiences as their training and others felt that contact with chemical representatives and consultants could be deemed as training. Overall, recognised qualifications and courses had been undertaken by only 25% of growers.

Growers were then asked if they found the current literature such as brochures and pamphlets sufficient. 50% were positive, 30% were not, and 20% were indifferent. Of the positive respondents, 14 out of 37 endorsed FruitFed Grower Bulletins, although many indicated that they needed updating. Six growers indicated that they had never seen any information on calibration, and ten growers indicated that they had some problem with the mathematics. Nine growers felt that the current deficiencies in the available information could be overcome by contacting a company representative.

Growers were asked if they saw a need for a field manual on herbicide spraying and calibration, with 80% indicating they would find it useful. Nine growers said they found the graphical method of calibration "good", "simple", "practical" and "useful". 14 growers requested a field manual be kept simple and not too technical.

Specific information that growers would like to see included in such a manual was:

- New Zealand data on nozzle outputs (as opposed to USA Teejet charts), for speeds and heights growers use;
- Simple charts on herbicide selection;
- Information able to be handed onto orchard staff;
- A table showing the various trade names of the same chemical.

For example there may be many growers under the illusion that Gesatop and Simazine are different materials. Many other synonyms occur in the pesticide world and companies purchasing in bulk a particular active ingredient have presented growers with different brand names. One New Zealand company Nufarm; uses the common name as the trade nomenclature for pesticides i.e diazanon (also brought by growers as Basudin or Gesapon).

Labelling is very important and often came up as being deficient. Labelling specifically for a narrower range of uses, i.e. orchards and vineyards only, with each label having more information on that specific use(s) would help.

Growers were asked what was the major problem they faced with their sprayer. The most common problem, that of pressure gauge, was indicated by 23 growers (30%). They break too easily or malfunction, and don't always accurately read in the range 200-350kPa (30-50psi). Problems with the boom and mounting were indicated by 16 growers (21%), mainly design faults, i.e. did not fold back, too high, mounting and chains obtrusive, often hitting branches (see Plate 40). Almost half of the growers expressed satisfaction with their equipment.

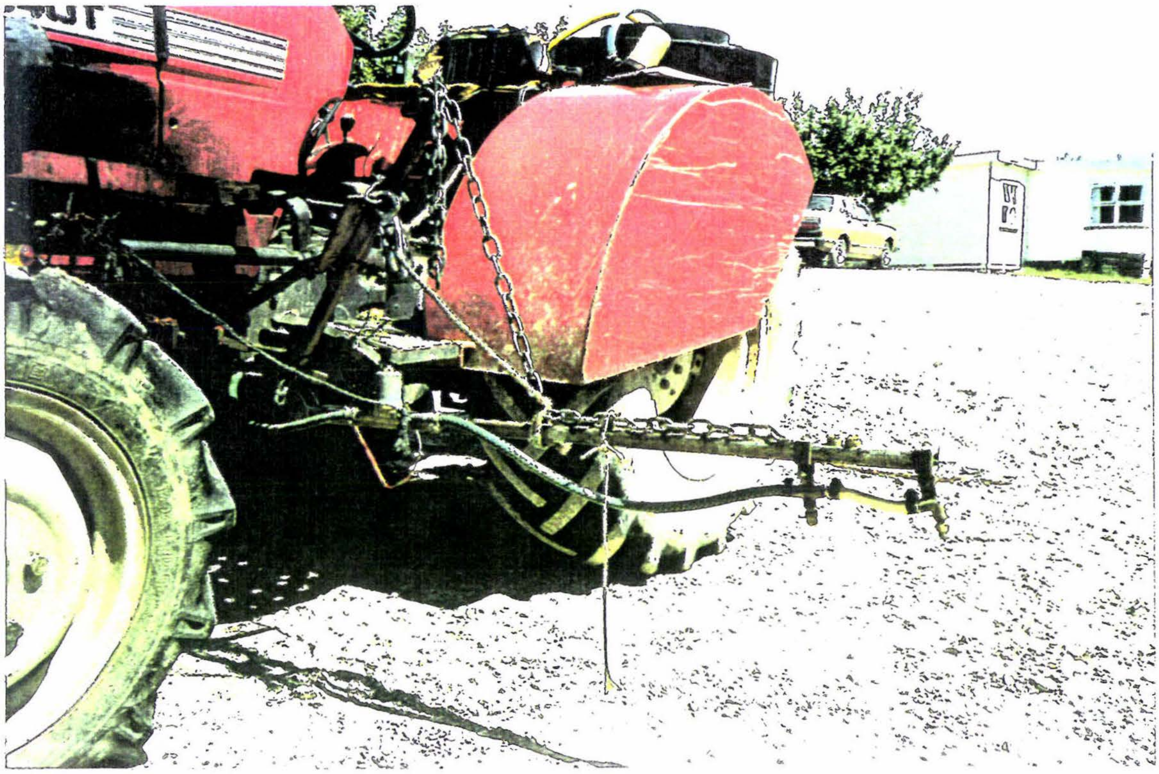

Plate 41: Obtrusive mounting system. Note branch scratches on mudguards, and extra strengthening put on fittings.

Nozzles were identified as a problem by 10 growers. Particularly the lack of spread, and misting. Several growers indicated they had no problems until the patternator highlighted deficiencies. Other miscellaneous items were mentioned such as taps, solenoids and filters, but generally with better performing pressure gauges, improved boom design and nozzle performance all growers would be satisfied.

Growers were asked which was the most difficult step they carried out in calibration. From the ten growers concerned with the whole process measurements of speed and width were troublesome, as was the mathematics and logic. Double sided spraying posed problems of calibration for those specifically doing it, and concern about even nozzle output was raised again.

In regards to the questions on sprayer design, most answers were based around fixing deficiencies in their current equipment, i.e. making it telescopic, able to swing back, less obtrusive mounting etc. Several growers suggested incorporating hydraulic height adjustment, rather than the current arrangement of chains, strings and pulleys.

CHAPTER 5: CONCLUSIONS

5.1 Herbicides and Weeds

Weed control rates highly in pipfruit growers' objectives, with most growers establishing weed-free strips beneath the trees, mowing between the rows.

Herbicides are an essential part of this management strategy that is unlikely to change in the forseeable future. There are flaws in individual grower strategies. Less than half of the growers use autumn herbicides, at which time good control of troublesome weed species can be obtained.

Many orchardists displayed a lack of knowledge about herbicides and weed control. This was indicated by the use of inappropriate mixtures of herbicides, and the lack of comprehension that their weed problems related to their poor choice of herbicides and poor application techniques.

Due to the failure of current chemical weed control methods for certain weeds, herbicides without label claims for orchards have been used. Alternatives are available for all of these materials, requiring more grower education in herbicides. Non-registered herbicides are unlikely to cause any residue problems as most are applied by careful spot-spraying. That said unsafe practices were highlighted were 2,4-D/dicamba and 2,4-D/picloram where applied over all of the herbicide strip.

Growers' responses to a probably worsening weed problem, is in the first instance to blame the herbicides. In most cases the herbicides selected at the rates used will never control the weed species present. This eventually leads to change in the weed control programmes, not always for the better. Two-thirds of the growers in the year of the survey were anticipating a change in their current programmes, and few changes were based on sound reason.

The narrow range of herbicides used by the majority of growers may lead to product rationalisation by manufacturers and importers, something that growers can ill afford.

Too few use glyphosate at sufficient rates to control paspalum in autumn, add terbacil or oryzalin to triazine herbicides, rotate residual herbicides to reduce selection pressure, or control weeds when they are smaller.

Widespread herbicide damage to pipfruit trees shows lack of respect for herbicides, and inaction in known cases of herbicides reaching the crop. In regards to contamination problems in or on fruit, amitrole is the likely to arise as a problem. Although it was observed at less frequency than glyphosate, it is of higher persistence and has known carcinogenic effects. Damage to trees rarely affects production but is very much quality orientated. Again education is needed, and anomalies in herbicide registration need to be corrected, i.e. the use of amitrole in kiwifruit up to nine weeks before harvest.

5.2 Equipment utilisation

The wide array of boom arrangements used is a key point to correcting current deficiencies in calibration, herbicide use and herbicide contamination.

A well designed boom will lower spray nozzles toward the orchard floor, greatly improve the evenness of application across the spray width and improve current calibration problems. The patternator also highlighted the current deficiencies in maintenance of sprayers, particularly nozzles and filters.

The lack of regular and complete calibration was borne out by the large errors measured in application rates.

Underapplication errors are causing a problem of poor weed control as less active ingredient is applied per hectare. Some of the larger errors were due to poor advice and calibration of company representatives, particularly with two sided sprayers. A basic understanding of the logic of calibration was lacking.

Indepth analysis of individual sprayer errors depicted even more uncertainty on the accuracy of growers ability to measure individual sprayer settings and accurately calibrate their equipment. Shortcuts taken during calibration by some growers worsened this scenario.

There is a clear need for more work in this field. There are six key areas.

1. Education about herbicides and weed control.

2. Education about sprayer calibration and its implications on weed control.

3. A code of practice for spraying herbicides, clearly defining products that can be used, at which times on which pipfruit crops.

4. Improvement and standardisation of the orchard herbicide boom.

5. Incorporation of measuring spray distribution as an essential part of calibration, and in the case of the patternator designed for this study, the only equipment that is required correctly calibrate a sprayer.

6. Production of a field manual embodying points 2 and 5 and possibly 1.

An alternative to education is to licence operators and issue "warrants of fitness" or "certified calibrated" tickets for orchard herbicide booms.

APPENDIX 1: SURVEY QUESTIONNAIRE

WEED CONTROL SURVEY

OF

BEARING APPLE, PEAR AND NASHI ORCHARDS

Weed control methods.
Herbicide application techniques.
Sprayer machinery utilisation.
Calibration of spray equipment.

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MASSEY UNIVERSITY
PALMERSTON NORTH

Project supported by the New Zealand Apple and Pear Marketing Board

1. Grower Identification

Date(s) visited: ..../..../...., .../..../....

Grower/company name(s):

:

:

Property location:

Contact Person:

....

Postal address:.......................

....

....

Telephones Work:......................

A/H:......................

1.1 Crops Grown

Ref	Species	Soil Type(s)	Crop Area (hectares)	Age (years)	Training/Density
A					
B					
C					
D					

2. Weed control objectives

2.1 For this orchard what best describes your overall objectives in weed control beneath the trees? Is it:

	tick
(i) Total vegetation control i.e. bare soil	[ ]
(ii) Try to achieve bare soil but tolerate some weeds if hard to control	[ ]
(iii) Don't mind occasional small weeds	[ ]
(iv) Not too worried about weedy patches	[ ]
(v) Weeds are acceptable	[ ]
(vi) Other. Describe	[ ]

2.2 How do weed control operations fit in with your other orchard priorities?

....

....

2.3 Does weed control ever conflict with other jobs and therefore not always get done, or do you always manage to fit it in around the optimum time?

Conflicts with other jobs [ ]

Comment: ....

Always fit it in [ ]

SECTION 3 - WEED CONTROL METHODS

3.1 What is your usual weed control method for the crops mentioned?

Herbicides using: tick

1. - Conventional hydraulic spray nozzles [ ]

2. - Knapsacks [ ]

3. - Wick booms [ ]

4. - CDA equipment [ ]

5. - Handguns (a) - trailed (+ individuals with 1-2 hoses) [ ]
   (b) - tractor mounted, driver spraying with gun [ ]
   (c) - tractor mounted and boom [ ]

6. - Mulches (a) - organic, i.e. bark, hay [ ]
   (b) - inorganic, i.e. plastic, matting [ ]

7. - Mowing [ ]

8. - Heat (a) - LPG rollers [ ]
   (b) - steam [ ]
   (c) - flame [ ]

9. - Animals grazing [ ]

10. - Cultivation using .... [ ]

11. - Other (description) [ ]

If (1), (2), (3), (4) or (5), fill out Herbicide Data sheet.

If none of (1) to (5), thank grower.

Data Sheet

3.2 Herbicide Programme for season

	Crop Reference			
Season	A	B	C	D
(1) Leaf-fall Autumn	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
(2) Dormancy - pre-spring	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
(3) Spring KD	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
(4) Summer KD's 1 2 3 4	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
Specifics	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate

3.3 **Will it be the same programme for next year?**

	Crop Reference			
Season	A	B	C	D
(1) Leaf-fall Autumn	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
(2) Dormancy - pre-spring	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
(3) Spring KD	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
(4) Summer KD's 1 2 3 4	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate
Specifics	Chem. Rate	Chem. Rate	Chem. Rate	Chem. Rate

If conventional nozzles continue to section 4. If wick or handgun only thank grower.

SECTION 4 – HERBICIDES AND WEEDS

4.1 **What do you consider to be the three (3) worst weeds on this property?**

"Help grower identify if required, use books if out of season. If possible be shown these weeds".

1.

2.

3.

4.2 **How has this weed built up, and which herbicides that you have used have failed to control it?**

1.

2.

3.

4.3 **What are you doing in regard to these problem weeds?**

1.

2.

3.

4.4 In your efforts to control these and other weeds did you apply any herbicides in a manner not according to label recommendations?

"I can assure you that this information will remain confidential if you feel uneasy in telling me. However it is important that this survey find out real problems growers face in regard to weeds"

	Case #1	Case #2
Herbicide used		
Rate/ha		
Large t(s)		
Application: boom		
Handgun		
Month applied		
On advice from:		
Results		

If more than two, fill out on herbicide data sheet, Section 3.2.
Tick [ ] if done.

4.5 In your mind are there any trees on the orchard that have experienced damage as a result of herbicide use in the past?

Suspected Herbicide	Crop and age involved	Damage Severity	How it happened

Limit to four worst if many.

SECTION 5 – Accuracy of Application

5.1 In the current set-up, what is your intended output in L/ha or gal/acre?

.... L/ha .... gal/acre

5.2 Do you have any idea of the total output of the sprayer?

.... L/min .... L/hr

.... g/min .... g/hr

If negative answer given:

"Don't worry because this and some of the following questions aren't necessarily required to calibrate your sprayer, or accurately apply herbicides".

5.3 What forward speed do you usually operate at?

.... km/hr ....mph?

5.4 Which gear do you use? ....

5.5 And at what engine revs .... rpm

5.6 What is your spray width for one pass? .... m

Does this include overlap when making two passes? Yes/No

If yes, what is the overlap? Approximately ...... m

5.7 Operating pressure? .... kPa, psi, bar

5.8 **On uneven ground does the boom move or bounce up and down altering the spray spread?** Yes ....

No ....

5.9 **Do you consider there is any risk of occasionally spraying some lower tier leaves?**

Yes ( ) .... - go to 5.10

No ( ) .... - go to 5.11

5.10 **Does this occur because:**

(a) Ground is uneven [ ]

(b) Nozzles are too high [ ]

(c) Lower leaves and fruit are too low [ ]

(d) Obstacles bump boom such as:

- weeds [ ]
- pruned wood [ ]
- branches [ ]

(e) Pressure surges from pump, i.e. filter blocked [ ]

(f) Wind drift of droplets [ ]

(g) Any other reasons record [ ]

5.11 **Can you ever see spray droplet drift?** Yes/No

If yes under what conditions?

....

5.12 **Do you ever get spray drift onto your body or face?** Yes/No

If yes do you stop, decrease spray pressure, or continue as before?

5.13 **If you think lower branches may have come into contact with the spray do you take any action?** Yes/No

If yes, describe. ....

....

5.14 **In question 5.1, you told me your output in L/ha. (or gl/acre)**

Do you spray all your chemicals in this set up?

Yes .... go to 5.18

No ..... go to 5.15

5.15 **What other options in L/ha are you able to change to if required (list)**

(a) ...... L/ha
...... gl/ha

(b) ...... L/ha
...... gl/ha

(c) ...... L/ha
...... gl/ha

5.16 **How do you achieve these other target outputs?**

	a	b	c
- changing nozzles or tips			
- changing pressure			
- increasing forward speed			
- by gear change			
- by changing rpm	do 5.17	do 5.17	do 5.17
- decreasing forward speed			
- by gear change			
- by changing rpm	do 5.17	do 5.17	do 5.17
- by increasing spray width			
- spread nozzles			
- lift boom height			
- by decreasing spray width			
- close nozzle gap			
- lower boom height			
- other (describe)			
....			

5.17 When you alter your rpm do you have to adjust the pressure?

5.18 **For your range of chemicals that you use through the year do the manufacturers' recommended rates always fit in with your sprayer in this setting? (add *"and the other settings you have"* if grower has more than one)**

Yes [ ] Did you choose them because of this? go to Section 6

No [ ] go to Section 5.19

5.19 **Does this concern you at all?**

No [ ] go to Section 6

Yes [ ] Why? Record comments.

5.20 **What do you do then if chemicals should be applied at a rate outside of your sprayer setting?**

- Borrow neighbour's sprayer .... [ ]
- Spray twice, etc. .... [ ]
- Adjust chemical rate .... [ ]
- Other .... [ ]

5.21 Chemical Practices

I would like to work through two examples of chemicals you have used to see how you worked out the rates.

Chemical(s)	Rate/ha chosen	Carrier rate	Rate/1001	Chem/usual full up
....	Manufac. Rec. Additives	Manufac. Rec.		Tank = ... L .... gl
....	Manufac. Rec. Additives	Manufac. Rec.		Tank = ... L .... gl

5.22 **Do you use scales and measuring jugs to measure these herbicides?**

Yes .... go to next page

No ..... go to 5.23

5.23 **How do you judge them then?**

SECTION 6 – Historical Calibration

6.1 **Since you have had this sprayer have you ever calibrated it?**

Yes [ ] - go to 6.2

No [ ] go to Section 7

6.2 **How frequently do you calibrate the sprayer?** It is:

- before every spray application [ ]
- beginning of each season [ ]

  When do you "start" your season? ....
- only when new nozzles are put in [ ]
- only when new tractor or sprayer [ ]
- others (state) .... [ ]
- ....
- .... [ ]

6.3 **When was the last time it was calibrated?**

Approximate date ______/_______/19__

6.4 Who does the calibration?

- Grower [ ] go to 6.5
- Orchard staff Yes [ ] go to 6.5

  No [ ]

Ask if key staff available to answer a couple of questions

Continue if possible, else go to Section 7

- Other orchardists [ ] go to 6.8
- Consultants Name: .... [ ] to to 6.8

  Company: ....
- Horticultural Reps Name: .... [ ] go to 6.8

  Company: ....
- Chemical Reps Name: .... [ ] go to 6.8

  Company: ....
- Students [ ] go to 6.8
- MAFTech personnel [ ] go to 6.8
- Do it by pamphlets, etc. [ ] go to 6.8
- Other (state) [ ] to to 6.8

6.5 When calibrating what do you measure?

- **Forward speed** ....
- **Nozzle output** ....
- **Spray width** ....

Do you adjust and check pressure? ....

- Anything else? ....

6.6 **If you run into problems when calibrating, who do you turn to for help?**

- No problems [ ] go to 6.9

- Other orchard staff [ ]

- Other growers [ ]

- Consultants Name: .... [ ]
  Company: ....

- Horticultural Reps Name: .... [ ]
  Company: ....

- Chemical Reps Name: .... [ ]
  Company: ....

- Students [ ]

- MAFTech personnel [ ]

- Sales introduction book/manual [ ]

- Do it by pamphlets, etc. [ ]

- Other (state) [ ]

How helpful were they? Any comments on the merits and/or otherwise in each case?

Record comments in space

Go to Section 7

6.7 **When calibrating what does he/she measure and check?**

- Forward speed [ ]
- Nozzle output [ ]
- Spray width [ ]
- Pressure gauge reading [ ]
- Other(s) .... [ ]

.... [ ]

.... [ ]

6.8 **How often do you clean nozzle and pump filters?**

6.9 **Have you ever replaced worn spray nozzles?**
+

Yes [ ]

No [ ]

Ask the grower or the key personnel if they will be available after the next two sections to answer some more questions. If not go to Section 10 now, then return to Section 7.

SECTION 7 - Equipment

7.1 **Manufacture of boom, pump and tank** tick

(i) commercial .... go to (iv) [ ]

(ii) homemade .... go to (v) [ ]

(iii) combination .... go to (iv) [ ]

(iv) make/manufacture ....

(v) age ....

(vi) tank size .....L .... gal

7.2 **Boom and nozzle arrangement**

(i) number of nozzles (circle) 1 2 3 4

		Composition type				
(ii) type -	(a) Fan	....	1	2	3	4
	(b) Hollow cone	....	1	2	3	4
	(c) Off centre	....	1	2	3	4
	(d) Other (state)	....	1	2	3	4

Composition (a) Plastic (b) Ceramic

(c) Stainless Steel (d) Brass

Meshes used where appropriate, no. and size

(a)

(b)

(c)

(d)

7.3 Nozzle manufacturer:

Excuse me while I make two rough sketches. *(Photo if interesting).*
Do last if grower allows machinery to be free.

7.4 **Diagram of arrangement**

(Include boom, nozzles, spacing, lengths)

7.5 **Mounting and adjustment (diagram)**

(note springs, freedom, height at both points, chains, boom shape)

7.6 Spray control (on/off) when seated and in operation

		ease of reach
- p.t.o. - live drive (clutch)	[ ]	....
- independent	[ ]	....
- solenoid	[ ]	....
- shut off tap	[ ]	....
- in-line valve	[ ]	....
- strings, chains	[ ]	....
- other (state)	[ ]	....

Ease of reach record as 1 - good
2 - fair
3 - poor/difficult

Ask "Is someone available to operate the sprayer whilst I record for calibration. I would also like someone to spray a dummy row or two while I watch. If not I can do it myself if the machinery is made available".

SECTION 8 - Calibration

In gear and rpm, as per 5.3 and 5.4.

1. (a) speed .... km/hr (use graph)

Post/Tree gap .... m

Distance .... m

Time .... sec

8.2 Output of individual nozzles

Adjust pressure as quoted. Pressure ...... from page 5.7.

Nozzle	Measurements for 1 minute	Average L/min
------	------, ------, ------	-------------
------	------, ------, ------	-------------
------	------, ------, ------	-------------
------	------, ------, ------	-------------

______________ L/min total

Where known, later compare nozzles to manufacturer's specifications

8.3 Run through patternator, get time from Chart A

Visually look for nozzle wear, streaks etc. Take a photo.

(d) Use these results to obtain a width, but also do by hand.

Spray width = ... m

If grower is interested, put figures in work sheet and work through graphs, etc. Show them patternator, adjust and rerun, where overlap may be improved.

8.4 Use these results to obtain a spray width, but also do by hand.

Spray width = ...m

Ask if someone is available to drive the sprayer as under usual conditions. If so observe and fill out section 8.5. If not ask for machine as per end of Section 7 and do yourself.

SECTION 9 - Orchard Operation

Note season ....

9.1 Whilst in operation, observe:	Good		Poor
(a) drivability	1	2	3
(b) boom stability	1	2	3
(c) nozzle drip	1	2	3
(d) pressure surges	1	2	3
(e) shut off speed *(Ask to be done)*	1	2	3
(f) rpm for pump and contour	1	2	3
(g) Orchard system passes/row			
- one per row	[ ]		
- two per row	[ ]		
(h) ability to turn at row ends	1	2	3
- miss a row	[ ]		
- turn inward on boom	[ ]) (for two pass system)		

Comments

(a)

(b)

(c)

(d)

(e)

(f)

SECTION 10 - Grower Needs

10.1 **Have you had training in the area of sprayer calibration and/or chemical weed control?**

Yes [ ] From where: ....

How long ago? ....

No [ ]

10.2 **Do you find the current literature sufficient?** Record comments.
Brochures, pamphlets etc

10.3 **Would a field manual to help you calibrate your sprayer be of any use to you?**

Yes [ ]

No [ ]

Record comments

10.4 **What are the major problems you face with the sprayer?**

Is it?

- none [ ]
- the boom [ ]
- nozzles [ ]
- mounting [ ]
- pump [ ]
- pressure gauges and taps [ ]
- other [ ]

Rank in order if more than one

10.5 **In calibration, which is the most difficult step or steps you carry out?**

Record comments

10.6 **Are you happy with your sprayer with regards to design?**

Yes ....   No ....

How could it be improved?

If grower hasn't tried worksheet in Accuracy Section, ask again if he would like to go over worksheets and graph. Follow through.

Ask "May I look around your orchard to measure your achieved width of control and height of lower tiers."

Thank you when finished.

Record other comments off the property.

SECTION 11 - Evaluation of success

		Crop Ref			
11.1 Overall control	- Full Vegetation	A	B	C	D
	- Patchy	A	B	C	D
	- Large bare areas/some weed	A	B	C	D
	- Very clean	A	B	C	D

11.2 List specific weeds, as I see it. Note this may differ due to season, and growers impression is more important.

11.3 Weed distribution - edges [ ]

- middle [ ]
- around emmiters/sprinklers [ ]
- under low branches [ ]
- close to humps, hollows, ruts [ ]
  (due to boom movements)

11.4 Width of control and lowest tier height

CROP REFERENCE							
A		B		C		D	
Spray Width	Lowest Tier Height	spray Width	Lowest Tier Height	Spray Width	Lowest Tier Height	Spray Width	Lowest Tier Height

Average

....

Work Sheet

Using graphs

1. Figure A = speed (km/hr) x swath width (m)

=

=

Repeat if different speeds and widths used

.... x .... =

.... x .... =

.... x .... =

Nozzle output(s) in L/min

(a)

(b)

(c)

(d)

So to calibration chart: Read off L/ha applied by finding intercept of figure A and total nozzle output in L/min.

Determine L/ha being applied

= Figure B

Chemical Application

1. Does calibrated L/ha meet manufacturers specifications?

(a) Yes, go to 2,

(b) No, go to 3.

2. Determine chemical to apply in tank:

Volume (from above) .... Figure B

Recommended Dose Rate .... Figure C

Your tank capacity .... Figure D

Each tank load covers $\frac{\text{Figure D}}{\text{Figure B}}$

= ....

= .... Figure E

[DID YOU DO SECTION 11?]

By Mathematics

Work rate = $\frac{\text{Speed x Spray width}}{10}$

= $\frac{\text{km/hr x m}}{10}$ = (...... x ......)/10

= ha/hr = ... ha/hr

Multiple nozzle output by 60 to give L applied/hour

= L/min x 60 ...... x 60

= L/hr ...... L/hr

L/ha = $\frac{\text{output}}{\text{Work Rate}}$ $\frac{\text{L/hr}}{\text{ha/hr}}$ ...... =

hours cancel = $\frac{\text{L}}{\text{ha}}$

Re-do for combinations of speed, width and nozzle output. Follow through section 2 of "graphical" way for rest of required information.

[DID YOU DO SECTION 11?]

Chemical required in each tank load

= C x E

=

=

To determine the total amount of tank loads required,

work out the total area of herbicide strip page 3, Figure F

No. tank loads to cover area:

$= \frac{\text{Figure F}}{\text{Figure E}}$

=

= .... Figure G

Time to cover whole area

$= \frac{\text{Figure F x 10}}{\text{Figure A}} = \qquad = \qquad \text{hrs}$

Not including filling and travel (field efficiency factor)

3. Adjustments

If your calibrated application rate doesn't fit the Manufacturers recommendation you have two options; considering that you with to keep the swath width fixed.

You may change the speeds to this effect:

- increase speed: decrease application rate
- decrease speed: increase application rate

Change nozzles

- higher or lower output

Remeasure output again.

N.B.: This may require recalibration of swath width.

Return to work sheet and work through until correct.

WORK RATE

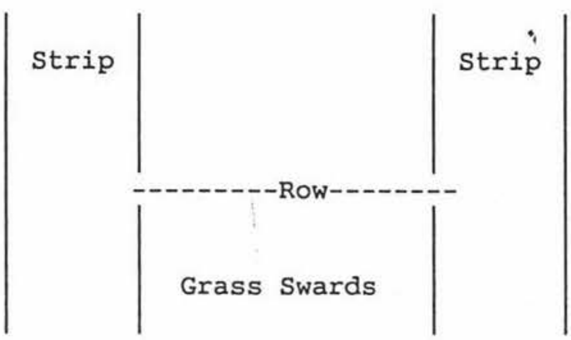
Your work rate is simply Figure A divided by 10, in ha/hr.

Remember the components of the work rate - your swath width and speed. Of these the speed is more important.

When you widen the spray swath for a given speed you do cover more ha/hr, but you are also spraying a larger proportion of your Orchard. It still takes 30 minutes to spray two blocks of apples, but the area sprayed in total rises.

In reality the work rate will be much less due to filling and mixing, travel and turning.

It is a good idea to get a rough estimate of the area you are going to spray b working out the percentage of herbicide strip in a given area:



$$\% \text{ Sprayed} = \frac{\text{Strip (m)}}{\text{Row (m)}} \times \frac{100}{1}$$

Remember to include correction for headlands and shelter.

Example:

20 ha Apple Orchard. 80% of land in crop, rest in road, headlands and shelter

Crop = 20 x 0.8
= 16 ha

Rows 6 m apart, spray strip 1.5 m.

% herbicide strip

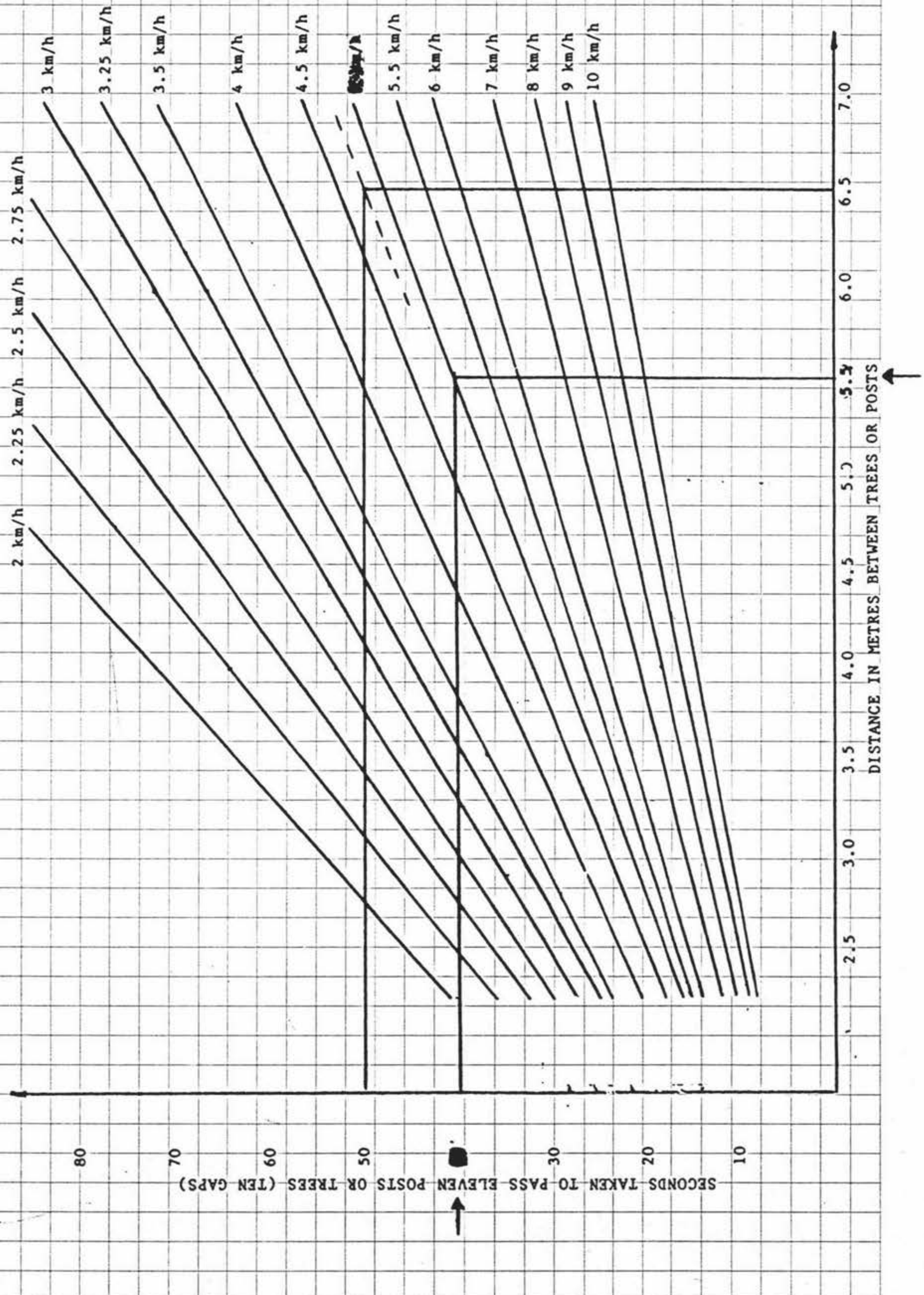
$$= \frac{1.5}{6} \times \frac{100}{1}$$

= 25%

Therefore total area of herbicide strip

= 25% of 16 ha = 4 ha = Figure F.

Chart A1.1: **Graphical derivation of forward speed for orchard herbicide sprayers used during survey. (Now needing modification based on study results).**



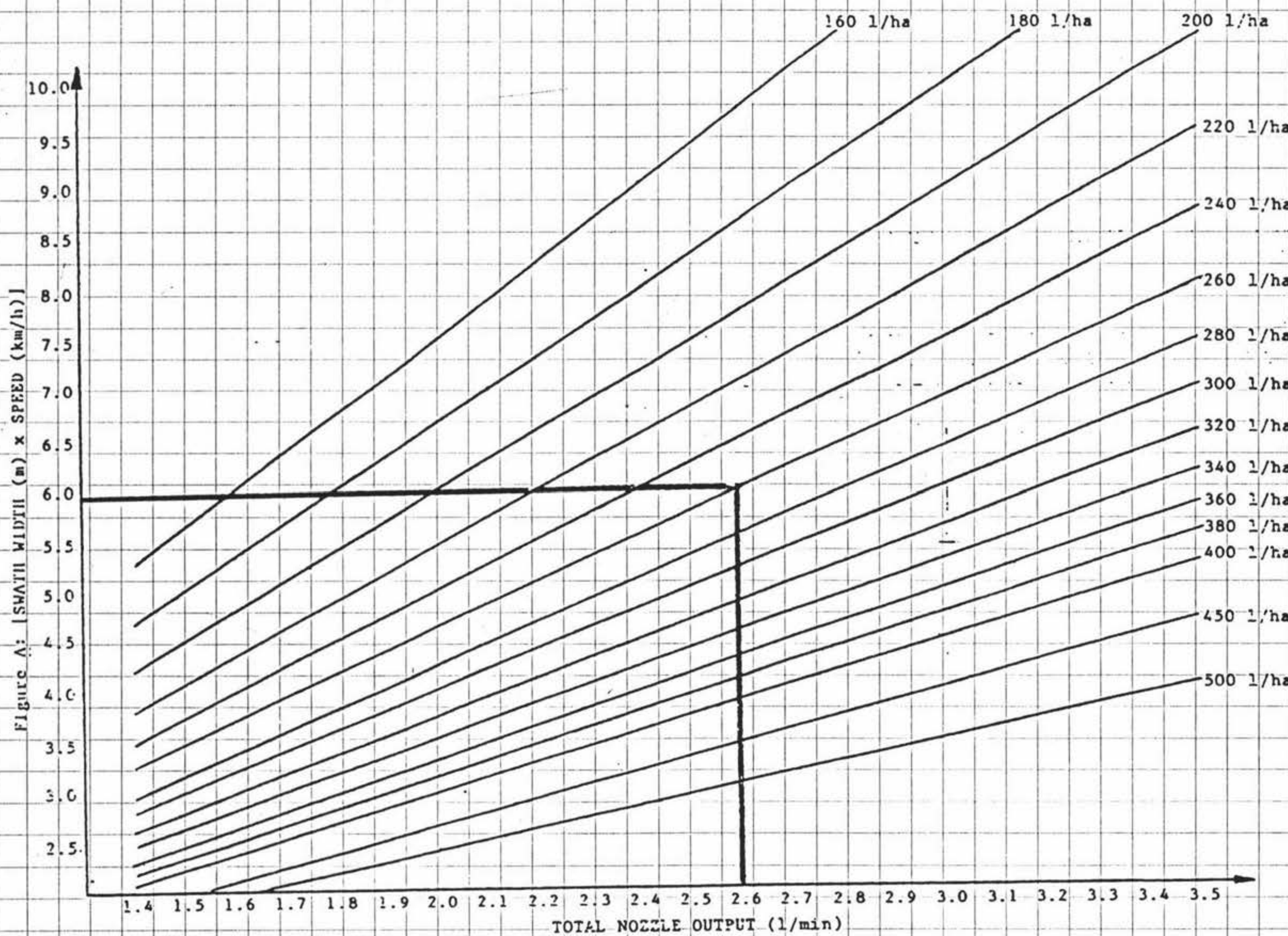


Chart A1.2: Graphical derivation of application rates using calculations from work sheet in survey. (Now needing modification based on study results).

CHART A1.3 Times for patternator test based on measured forward speed

SPEED km/h	SPEED m/s	time for 67.27m (seconds)	SPEED km/h	SPEED m/s	time for 67.27m (seconds)
2.50	0.694	96.9	4.85	1.347	49.9
2.55	0.708	95.0	4.90	1.361	49.4
2.60	0.722	93.1	4.95	1.375	48.9
2.65	0.736	91.4	5.00	1.389	48.4
2.70	0.750	89.7	5.05	1.403	48.0
2.17	0.756	88.1	5.10	1.417	47.5
2.80	0.778	86.5	5.15	1.431	47.0
2.85	0.792	85.0	5.20	1.444	46.6
2.90	0.806	83.5	5.25	1.458	46.1
2.95	0.819	82.1	5.30	1.472	45.7
3.00	0.833	80.7	5.35	1.486	45.3
3.05	0.847	79.4	5.40	1.500	44.8
3.10	0.861	78.1	5.45	1.514	44.4
3.15	0.875	76.9	5.50	1.528	44.0
3.20	0.889	75.7	5.55	1.542	43.6
3.25	0.903	74.5	5.60	1.556	43.2
3.30	0.917	73.4	5.65	1.569	42.9
3.35	0.931	72.3	5.70	1.583	42.5
3.40	0.944	71.2	5.75	1.597	42.1
3.45	0.958	70.2	5.80	1.611	41.8
3.50	0.972	69.2	5.85	1.625	41.4
3.55	0.986	68.2	5.90	1.639	41.0
3.60	1.000	67.3	5.95	1.653	40.7
3.65	1.014	66.3	6.00	1.667	40.4
3.70	1.028	65.5	6.05	1.681	40.0
3.75	1.042	64.6	6.10	1.694	39.7
3.80	1.056	63.7	6.15	1.708	39.4
3.85	1.069	62.9	6.20	1.722	39.1
3.90	1.083	62.1	6.25	1.736	38.7
3.95	1.097	61.3	6.30	1.750	38.4
4.00	1.111	60.5	6.35	1.764	38.1
4.05	1.125	59.8	6.40	1.778	37.8
4.10	1.139	59.1	6.45	1.792	37.5
4.15	1.153	58.4	6.50	1.806	37.3
4.20	1.167	57.7	6.55	1.819	37.0
4.25	1.181	57.0	6.60	1.833	36.7
4.30	1.194	56.3	6.65	1.847	36.4
4.35	1.208	55.7	6.70	1.861	36.1
4.40	1.222	55.0	6.75	1.875	35.9
4.45	1.236	54.4	6.80	1.889	35.6
4.50	1.250	53.8	6.85	1.903	35.4
4.55	1.264	53.2	6.90	1.917	35.1
4.60	1.278	52.6	6.95	1.931	34.8
4.65	1.292	52.1	7.00	1.944	34.6
4.70	1.306	51.5	7.05	1.958	34.4
4.75	1.319	51.0	7.10	1.972	34.1
4.80	1.333	50.5	7.15	1.986	33.9

APPENDIX 2: LIST OF GROWERS SURVEYED

Tony Murdoch
Haurau Orchard
Napier Road
PALMERSTON NORTH
Sprayer not calibrated

Paul Wycherley
Riverside Orchard
Ashhurst
PALMERSTON NORTH
Sprayer calibrated.
Patternator used.

David Ludbrook
Waititi Orchard
RD 1
Richmond
NELSON
Sprayer calibrated.
Patternator used.

Bruce Fraser
Bronte Orchard
Bronte Road Estate
RD 1
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

Mark Rutledge
Carmel Orchard
Redwoods Valley
RD 1
RICHMOND
Sprayer calibrated.
Patternator used.

Don Lindsay
Gainhill Orchard
RD
Brightwater
NELSON
Sprayer calibrated.
Patternator used.

Miles Middlington
Newmount Orchards
RD 1
Richmond
NELSON
Sprayer calibrated
Patternator used.

D J Sutton & Co Ltd
170 Salisbury Road
Richmond
NELSON
Sprayer not calibrated.

R and S Thompson
Eves Valley Road
RD 1
Brightwater
NELSON
Sprayer not calibrated.

Michael Hoddy
Aniseed Valley Road
RD
Richmond
NELSON
Sprayer calibrated.
Patternator used.

Colin Markwell/
Phil Holland
Seaton Valley Estate
RD 1
Upper Moutere
NELSON
Sprayer not calibrated.

Rob and S T McKee
Pomona Road
RD 1
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

Hilbrend den Boon
Boons Gardens
PO Box 7
Brightwater
NELSON
Sprayer calibrated.

Phillip Kempthorne
Eves Valley Road
RD 1
Brightwater
NELSON
Sprayer calibrated.
Patternator used.

John Richards
RD 1
Upper Moutere
NELSON
Sprayer calibrated.

Martin Strong
Marriages Road
RD 1
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

Peter Morris
Pineview Orchards
PO Box 5084
NELSON
Sprayer not calibrated.

John Kilmarton
Kilmarton Orchards Ltd
RD 1
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

Trevor Ivory
Nelson Horticultural
Advisory
126 Salisbury Road
Richmond
NELSON
Sprayer calibrated.
Patternator used.

R L Taylor
RD 2
Upper Moutere
NELSON
Unconventional.
No herbicide strips.

Les Fahey
Golden Hills Orchard
PO Box 10
NELSON
Sprayer not calibrated.

John Martin
RD 2
Upper Moutere
NELSON
Sprayer not calibrated.

Brian Limmer
Fletts Road
RD 2
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

Dave Collins
RD 2
Upper Moutere
NELSON
Sprayer not calibrated.

Steve Rowling
RD 2
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

Leo van Workum
RD 2
Upper Moutere
NELSON
Sprayer calibrated.

Geoff Paynter
RD 1
Upper Moutere
NELSON
Sprayer calibrated.

Don Urquhart
RD 2
Upper Moutere
NELSON
Sprayer not calibrated.

Phil Barnaby
Barnaby Orchards Ltd
RD 2
Upper Moutere
NELSON
Sprayer calibrated.
Patternator used.

John Johnston
RD 2
Upper Moutere
NELSON
Sprayer not calibrated.

Ashton Johnston
Pakowhai Road
RD 3
NAPIER
Sprayer not calibrated.

David Easton
RD 2
Upper Moutere
NELSON
Sprayer not calibrated.

Paul Heywood
Heywoods Orchards
Dehra Doon Road
RD 3
MOTUEKA
Sprayer not calibrated.

Graeme Emerre
Riwaka
RD 3
MOTUEKA
Sprayer not calibrated.

Noel R Goodall
Dehra Doon Road
RD 3
Riwaka
NELSON
Sprayer not calibrated.

Kerry Martin
Whakerewa Street
Motueka
NELSON
Sprayer not calibrated.

Derek Williams
Braeburn Orchard
19 Woodlands Avenue
Motueka
NELSON
Sprayer not calibrated.

Doug Lines
Silvan Orchard
York Road
HASTINGS
Sprayer not calibrated.

Robert Sykes
Sykes Partnership
Pakowhai Road
RD 3
NAPIER
Sprayer calibrated.
Patternator used.

Alan Bridgeman
Percival Road
HASTINGS
Sprayer not calibrated.

Tony Harrington
Kelston Orchard
RD 5
HASTINGS
Sprayer calibrated.
Patternator used.

Mike Donnelly
Flaxmere Orchard
PO Box 353
HASTINGS
Sprayer calibrated.
Patternator used.

Peter McGowan
Raupere
RD 5
HASTINGS
Sprayer calibrated.
Patternator used.

Tim Harding
Ford Road
WAIPUKURAU
Sprayer not calibrated.

Robin Mudgeway
Waipawa Orchard
40 Church Street
WAIPAWA
Sprayer calibrated.
Patternator used.

Stu Covell
Lorien Orchard
Pakowhai Road
RD 3
NAPIER
Sprayer not calibrated.

Grape Grower/Salesman
"Did not wish to be identified"
Sprayer calibrated.
Patternator used.

Don Steedman
Oak Glen
RD 5
HASTINGS
Sprayer not calibrated.

Clive Beattie
Ascott Orchard
PO Box 317
WAIPUKURAU
Sprayer calibrated.
Patternator used.

Warren Temperton
Thornton Orchard
Grocorp Pacific Ltd
PO Box 47
ONGA ONGA
Sprayer not calibrated.

Mr Pearse
Clareview Orchard
RD 2
HASTINGS
Sprayer calibrated.
Patternator used.

Ray Cartwright
Cartwright Orchards
Havelock North
HASTINGS
Sprayer not calibrated.

Ian Whiffen
Grocorp Pacific Ltd
PO Box 58
TIKIKINO
Sprayer not calibrated.

Richard Scott
PO Box 1083
HASTINGS
Sprayer not calibrated.

R G Masters
Crosses Road
RD 2
HASTINGS
Sprayer not calibrated.

Anthony Bewley
Roselea Orchards Ltd
Crosses Road
RD 2
HASTINGS
Sprayer calibrated.
Patternator used.

Ashley Pattullo
Sandy Loam Orchard
C/- Richmond Pacific Ltd
PO Box 940
HASTINGS
Sprayer not calibrated.

Ross Duncan
Adelong Orchard
RD 3
NAPIER
Sprayer not calibrated.

Don Jeffery
Evenden Road
HASTINGS
Sprayer not calibrated.

Brian Isles
Grassmere Road
Meeanee
Taradale
NAPIER
Sprayer calibrated.
Patternator used.

Alan Ladbrook
Cedar Orchard
RD 5
HASTINGS
Sprayer not calibrated.

Yos Dames
C A Dames Ltd
Havelock North
HASTINGS
Sprayer calibrated.
Patternator used.

Brian Blackberry
Grassmere
RD 2
HASTINGS
Sprayer calibrated.
Patternator used.

Brian Dillon
Melrose Orchard
C/- Post Office
Pakowhai
NAPIER
Sprayer calibrated.
Patternator used.

Peter Berry
Maketu Kiwifruit
Partnership
PO Box 19
TE PUKE
Sprayer calibrated.

Reg Whyte
Grassmere Orchards Ltd
Grassmere
RD 2
HASTINGS
Sprayer not calibrated.

Bernie Caccioppoli
Popular Orchard
Poukawa
RD 11
HASTINGS
Sprayer calibrated.
Patternator used.

Garry Coker
Pukuhau Orchard
St. Georges Road (Sth)
RD 2
HASTINGS
Sprayer not calibrated.

Peter Weskitt
Windermere Orchard
57 Georges Road
RD 2
HASTINGS
Sprayer calibrated.
Patternator used.

J R Trevor Mills
Te Timatanga
Te Aute Road
RD 2
HASTINGS
Sprayer calibrated.
Patternator used.

K A Kale
Boysenbrook Orchard
Temata-Mangateretere Roard
RD 2
HASTINGS
Sprayer calibrated.
Patternator used.

Orchard Manager
Fruit Crops Unit
Massey University
PALMERSTON NORTH
Sprayer calibrated.
Patternator used.

Tony Masters
Appledore Orchard
Havelock Road
HASTINGS
Sprayer calibrated.
Patternator used.

Ross Beaton
McDonalds Orchard
PO Box 18
Taradale
NAPIER
Sprayer calibrated.
Patternator used.

Stuart Horn
Berrilea Orchard
Miller Road
HASTINGS
Sprayer calibrated.
Patternator used.

Paul Goldfinch
Stirling Orchards Ltd
Main Road
RD 2
NAPIER
Sprayer calibrated.
Patternator used.

Alan De Vries
Fairways Orchard
Partnership
RD 5
HASTINGS
Sprayer not calibrated.

Mr McGrath
Gaemur Orchard
PO Box 8212
HAVELOCK NORTH
Sprayer not calibrated.

Mike Aveling
Raupare Road
RD 5
HASTINGS
Sprayer calibrated.
Patternator used.

APPENDIX 3: GLOSSARY OF HERBICIDES

In the text herbicides have been named by their common name. This section provides the reader with additional information that may be required.

Information on herbicides has been divided into three groups:

1. Broad spectrum knockdown herbicides
2. Residual herbicides
3. Special purpose knockdown herbicides

Table 3A.1 lists those herbicides that are used to kill a wide range of existing weeds. Of these amitrole and glyphosate are translocated, (the herbicide moves within the plant once it is absorbed) whilst the rest are contact (the herbicide only works on green plant parts it has a direct contact with).

Amitrole is available in two forms. Activated Amitrole, IWD Amitrole 4L and Weedazol 4L contain amitrole plus ammonium thiocyanate. All other formulations contain amitrole only. Ammonium thiocyanate is added as a synergist (the joint action of amitrole and ammonium thiocyanate is greater than the sum of their activity when used alone). For the purposes of this survey all herbicides listed above are classed as amitrole.

Paraquat is available in products by itself (trade name Gramoxone) or with diquat (trade names Preeglone and Spraygrow). Spraygrow or Preeglone is the formulation normally used by orchardists, and for the purposes of this survey all applications of "paraquat" are classed as paraquat/diquat.

Table 3A.2 lists all residual herbicides used or mentioned by growers. Of these simazine is available in many products formulated as a wettable powder, a flowable liquid and disperable granule.

TABLE 3A.1: Nomenclature of broad-spectrum knockdown herbicides and their chemical group.

Herbicide common name	Herbicide trade name	Chemical group
amitrole	Amitrole 40 AC, Weedazol 4L	amino-triazole
glyphosate	Roundup, Nufarm Glyphosate 360	substituted N-glycine
glufosinate	Buster	ammonium phosphate
paraquat and or diquat	Preeglone, Spraygrow, (Gramoxone, Paraquat)	bipyridyl

TABLE 3A.2: Nomenclature of residual herbicides and their chemical group.

Herbicide common name	Herbicide trade name	Chemical group
linuron/diuron	Cohort	urea
methabenzthiazuron/ diuron	Amatin	ureas
metolachlor/ terbuthylazine	Primextra II 500 FW	amide and triazine
norflurazon	Solicam	phenylpyridazinone
oryzalin	Surflan	dinitroaniline
oxadiazon	Foresite	oxadiazole
oxyfluorfen	Goal	nitrophenyl ether
pendimethalin	Stomp 330EC	dinitroaniline
simazine	Simazine 50FL Gesatop 500FW Simatox 90G Simazol 5A	triazine
terbacil	Sinbar	uracil
terbuthylazine/ terbumeton	Caragard 500FW	triazine
terbuthylazine	Gardoprim 500FW	triazine

Herbicides in Table 3A.3 are special purpose herbicides used in orchards only on specific weeds.

TABLE 3A.3: Nomenclature of special purpose herbicides and their chemical group.

Herbicide common name	Herbicide trade name	Main targets	Chemical group
asulam	Asulox	docks	carbamate
clopyralid	Versatill	yarrow, thistles	picolinic
dicamba	Banvel, Dicambone	convolvulus, clover	benzoic
fluazifop-P-butyl	Fusilade	grasses	phenoxyphenoxy
haloxyfop	Gallant	grasses	phenoxyphenoxy
metsulfuron	Escort		sulphonyl urea
picloram/2,4-D	Tordon 50-D		picolinic and phenoxy
2,4,5-T	2,4,5-T Butyl Ester	fennel and mallow	phenoxy
2,4-D/dicamba	Banvine	convolvulus	phenoxy and benzoic
2,4-D	2,4-D Amine	docks	phenoxy

APPENDIX 4: SUMMARY OF HERBICIDE PROGRAMMES

In an attempt to rationalise all the growers programmes into one table, Tables A4.1 to A4.3 were produced. The growers programmes were more different than expected. Note number of growers in each category on extreme right of Tables is carried through to totals.

The letter "K" represents a knockdown herbicide, and the letter "R" a residual herbicide. K/R indicates that they are applied together whilst a comma "," indicates separate applications. Use of specific herbicides is indicated by a "Y" (yes) or "N" (no).

TABLE 4A.1: Summary of herbicide programmes of 33 Nelson growers.

Autumn	Aug-Sept	Oct-Nov	Summer	Specifics	No.Growers
K	K/R	R	R,R	N	1
K	K/R	K	K/R	Y	1
K	K/R	-	K/R/R	N	1
K	K/R	-	K	N	3
K	K/R	-	K,K	N	1
K	R	-	K	N	1
K	-	K	K,K	N	1
K	-	R	K	N	1
K	-	K/R	K	N	1
K	-	-	K	N	1
-	R or K/R	-	K/R	N	1
-	K,K/R	-	K,K	N	1
-	K/R	K/R	R	N	1
-	K/R	K	K	N	1
-	K/R	K	K/R	N	1
-	K/R	R	-	-	1
-	K/R	-	K	N	4
-	K/R	-	K	Y	3

-	K/R	-	K,K	Y	1
-	K	K	K	N	1
-	-	K/R	K	N	2
-	-	K/R	K	Y	1
-	-	K/K	-	N	1
-	-	K	K	N	1
-	-	-	K,K	N	1
TOTAL					33
12K	23K, 20R	13K, 8R	33K, 8R	26N, 6Y	

TABLE 4A.2: Summary of herbicide programmes of 40 Hawkes Bay growers.

Autumn	Aug-Sept	Oct-Nov	Summer	Specifics	No. growers
K	K/R/R	-	K	Y	1
K	K/R/R	-	K	N	1
K	K/R	K/R	K	N	2
K	K/R	K	K	N	1
K	K/R	K	K,K/R	N	1
K	K/R	-	K/R	Y	1
K	K/R	-	K,K	N	1
K	K/R	-	K	N	4
K	K,R	-	K	N	1
K	R/R	-	K,K	Y	1
K	R/R	-	K	N	1
K	K/K	K/R/R	-	N	1
K	R	-	K	Y	2
K	K	K,K	K/R	N	1
K	K	-	K	N	1
K	-	R/R	-	Y	1
K	-	K	K	Y	1
-	K/R/R	-	K or 4xK	N	1
-	K/R	K/R	-	Y	1
-	K/R	R	K	N	1
-	K/R	-	K	Y	2
-	K/R	-	K	N	3
-	K/K	R	-	Y	1
-	R	K/K	K	N	1
-	R	-	K	Y	1
-	K	R/R	K,K	N	1
-	K	K/R	-	N	1
-	K	K/R	K	N	1
-	K	K/R	K	Y	1
-	-	K/K	R/K	N	1
-	-	K/R	K,K	N	1
-	-	K	-	N	1
TOTAL					40
22K	31K, 32R	17K, 15R	38K, 4R	27N, 13Y	

TABLE 4A.3: Summary of herbicide programmes of all growers.

Autumn	Aug-Sept	Oct-Nov	Summer	No. growers
K,R	R	K/K	K	1
K	K/R/R	-	K	2
K	K/K	K/R/R	-	1
K	R/R	-	K	1
K	R/R	-	K,K	1
K	K/R	K/R	K	2
K	K/R	K/R	-	1
K	K/R	K	K/R	1
K	K/R	K	K,K/R	1
K	K/R	K	K	1
K	K/R	R	R/R	1
K	K/R	-	K/R/R	1
K	K/R	-	K,K/R	1
K	K/R	-	K,K	1
K	K/R	-	K	7
K	K/R	-	K/R	1
K	K/R	-	K	1
K	R	-	K	3
K	K	K,K	K/R	1
K	K	-	K	1
K	-	R/R	-	1
K	-	K/R	K	1
K	-	R	K	1
K	-	K	K,K	1
K	-	K	K	1
K	-	-	K	1
-	K,K/R	-	K,K	1
-	K OR K/R	-	K/R	1
-	K/K/R	-	K or 4xK	1
-	K/R	K/R	-	1

TABLE 4A.3 Continued

Autumn	Aug/Sept	Oct/Nov	Summer	No Growers
-	K/R	K/R	R	1
-	K/R	K	K	2
-	K/R	K	K/R	1
-	K/R	R	K	1
-	K/R	R	-	1
-	K/R	-	K	13
-	K/R	-	K,K	1
-	K/K	R	-	1
-	R	-	K	1
-	R	K/K	K	1
-	K	K	K	1
-	K	R/R	K,K	1
-	K	K/R	-	1
-	K	K/R	K	3
-	-	K/K	R/K	1
-	-	K/K	-	1
-	-	K/R	K	3
-	-	K/R	K,K	1
-	-	K	K	2
-	-	K	-	1
-	-	-	K/K	1
TOTAL				77
36K, 1R	58K, 55R	34K, 23R	76K, 13R	

APPENDIX 5: SPRAYER SETTING ERRORS

Tables 5A.1, 5A.2, 5A.3, 5A.4, 5A.5, list the information recorded in Sections 5 and 8 of the survey (Appendix 1), enabling errors to be calculated. The formula used to calculate the error is:

$$\% \text{ Application Error} = \frac{(\text{Actual Rate} - \text{Intended Rate}) \times 100}{\text{Intended Rate}}$$

Where, Intended Rate equals that given at question 5.1 of the survey, and the Actual Rate equals that calibrated. Where an error can not be calculated because the intended rate is not known "NC" denoting not calculated is given in the column.

TABLE 5A.1: Intended and actual application rates and errors of 41 herbicide sprayers.

Intended application rate ℓ/ha	Actual application rate ℓ/ha	Error %
500	625	+ 25
350	205	- 41
450	280	- 38
360	255	- 29
400	310	- 22
370	355	- 4
500	540	+ 8
490	530	+ 8
160	180	+ 12
720	400 (uphill) 310 (downhill)	- 44 - 57
440 or 215	313 or 159	- 29 - 26
270	360	+ 33
560	360	- 36
450	265	- 41
450	320	- 29
416	398 (right) 433 (left)	- 4 + 4
500	250 (left) 300 (right)	- 50 - 40

550	594 (left) 622 (right)	+ 8 + 13
500	470	- 6
500	786 (left) 762 (right)	+ 57 + 52
500	312	- 38
600	590 (left) 543 (right)	- 2 - 9
300	245	- 18
800	320 (left) 315 (right)	- 60 - 60
515 *	262	- 50
660	641 (right) 671 (left)	- 3 + 2
600	195	- 208
≈ 200	206	+ 3
300	270	- 10
500	427	- 15
500 **	607	+ 21
400	340	- 15
380	296	- 22
600	630	+ 5
Don't know	425	NC
Don't know	750	NC
Don't know	450	NC
Don't know	687	NC
Don't know	485	NC
Don't know	450	NC

* $\frac{900\ell}{3.5ha} = 515\ell/ha$

** $\frac{450\ell}{2ha} = 500\ell/ha$

Tractors going varying speeds according to contour have had these errors averaged before statistical analysis on advice from Brook (1991).

TABLE 5A.2: Intended and actual forward speed and errors of 41 herbicide sprayers.

Intended forward speed km/h	Actual forward speed km/h	Error %
don't know	5.4	NC
3.5	3.7	5.7
4.0	4.05	1.3
6.0	6.6	10
3.8	3.8	0
4.12	4.2	1.9
3.5	4.767	36.2
5.3	4.65	-12.3
don't know	2.45	NC
5.3	5.27	0.5
4.4	6.2 (uphill) 8.0 (downhill)	41 82
3.9	3.9	0
4.6	3.6	-21.7
4.83	5.41	12
4	4.15	3.8
3.2	3.2	0
don't know	6.91	NC
5	5.36	7.2
4	4.25	6.3
4.8	5.3	10.4
3.0	5.2	73
3.6	3.52	-2.2
6.0	4.0	-33.3
3.3	2.62	-20.6
6.8	6.3	-7.4
don't know	6.67	NC
2.4	4.05	68.8
5.76	5.5	-4.7
don't know	4.15	NC

don't know	3.1	NC
3.6	3.6	0
don't know	6.17	NC
5.75	6.0	4.3
5.0	3.65	-37
don't know	3.56	NC
3	3.17	5.7
don't know	3.85	NC
3.0	3.10	3.3
4.8	4.5	-6.3
don't know	4.45	NC

$n = 40$

$\mu = 4.53$km/h

$\sigma = 1.21$

Left and right spraying booms have had the nozzle output errors averaged before statistical analysis on advice from Brook (1991).

TABLE 5A.3: Actual and intended nozzle output and errors of 41 herbicide sprayers

Intended output ℓ/min	Actual output ℓ/min	Error %
don't know	6.2	NC
2.125	1.65	-22
don't know	2.45	NC
5.4	4.2	-22
2.8	2.55	-9
3.3	3.10	-6
don't know	6.0	NC
5.2	5.8	11
don't know	2.3	NC
1.6	1.9	19
don't know	7.85	NC
don't know	2.65	NC
4.25	2.9	-32
don't know	8.95	NC
2	2.3	15
don't know	3.0	NC
don't know	4.8	NC
2.8	2.85 (right) 3.10 (left)	2 11
don't know	2.4 (right) 2.3 (left)	NC
5.0	5.5 (left) 5.25 (right)	10 5
don't know	4.9	NC
don't know	4.85 (left) 4.70 (right)	NC
don't know	2.5	NC
2.25	2.90 (right) 3.15 (left)	29 40
don't know	3.35	NC
don't know	4.25	NC

don't know	2.3	NC
9.5	7.7 (left) 7.2 (right)	-19 -24
don't know	3.9	NC
don't know	2.35	NC
don't know	1.05	NC
don't know	2.65	NC
don't know	2.15	NC
2.77	2.60	-6
don't know	5.1	NC
don't know	3.2	NC
don't know	3.9	NC
3.60	3.75	4
don't know	3.3	NC
don't know	2.85	NC

$n = 39$ (8.95ℓ/min excluded as full width)

$\mu = 3.58\ell$/min

$\sigma = 1.57\ell$/min

TABLE 5A.4: Actual and intended herbicide strip widths and errors of 41 herbicide sprayers.

Intended spray width (m)	Actual spray width (m)	Error %
1.0	1.1	10
1.4	1.3	-7
1.3	1.3	0
1.25	1.5	20
1.5	1.3	-13
1.3	1.25	-3.8
1.4	1.4	0
1.2	1.4	17
1.5	1.3	-13
1.0	1.2	20
1.6	1.9	19
1.2	1.3	8
1.0	1.35	35
don't know	2.75	NC
1.0	1.25	25
don't know	0.75	NC
1.25	1.3	4
0.8	0.95	19
0.9	1.1	22
1.0	1.0	0
1.0	1.2	20
1.0	1.05	5
1.0	1.2	20
1.0	1.25	25
1.0	1.3	30
1.0	1.2	20
1.2	1.3	30
1.5	1.25	-17
1.0	1.25	25
0.75	1.0	33
0.8	0.9	12

1.0	1.25	25
0.8	0.8	0
1.2	1.0	-17
1.0	1.25	25
1.0	1.25	25
1.2	1.0	-7
1.2	1.15	4
1.0	1.3	30
1.0	1.3	30

$n = 39$ (2.75m excluded as not usual practice.)

$\mu = 1.21$m

$\sigma = 0.20$m

TABLE 5A.5: Percentage errors of sprayer forward speed, spray width, nozzle output and total application error of 41 herbicide sprayers.

Forward speed error %	Spray width error %	Nozzle output error %	Total application error %
NC	10	NC	+25
5.7	-7	-27	-41
1.3	0	NC	-38
10	20	-22	-29
0	-13	-9	-22
1.9	0	-6	-4
36.2	0	NC	8
-12.3	17	11	8
NC	-13	NC	NC
0	20	19	12
60	19	NC	-51
0	8	NC	-28
-21.7	35	-32	33
12	NC	NC	-36
3.8	25	15	-41
0	NC	NC	NC
NC	0	NC	-29
7.2	0	7	0
6.3	22	NC	-45
10.4	0	10,5	11
73	20	NC	-6
-2.2	0	NC	55
-33.3	20	NC	-38
-20.6	25	35	-6
-7.4	30	NC	-18
NC	20	NC	-60
68.8	30	NC	-50
-4.7	-17	-22	0
NC	25	NC	NC
NC	33	NC	NC

0	12	NC	-208
NC	25	NC	3
4.3	0	NC	-10
-37	-17	-6	-15
NC	25	NC	NC
5.7	25	NC	NC
NC	-7	NC	21
3.3	0	34	5
-6.3	30	NC	-15
NC	30	NC	-22

Under errors	Over errors
n = 23	n = 10
μ = 37.0	μ = 18.1
σ = 41.38	σ = 16.93

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