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Retention of onion skin quality — a field study

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A report prepared for
New Zealand Onion Exporters Association

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1 Executive summary

We have examined the quality of onions harvested from seven sites around New Zealand in order to provide a benchmark for onion skin quality and to identify possible cultural, harvest and storage-related factors affecting skin development and retention. We collected crop management and climate data for the sites. We devised a number of skin quality assessment methods. We also gathered information on the relationship between leaf and skin development at one site.

We found onion skin quality varied between sites and between pre and post harvest samples. We have not been able to link skin quality to any of the crop management and environmental parameters measured, but some possible relationships have been identified and should be tested in further work. Some of the careful observations made should be communicated to growers and exporters so that they can adopt better methods of skin quality assessment. Industry feedback on the direction of future work that builds on this project should also be sought.

2 Introduction

Good skin quality is a cornerstone of New Zealand's brown onion export trade. As a result of the difficult 2002 onion marketing season, during which poor onion skin quality was noted on many lines, the New Zealand Onion Exporters Association commissioned this study. This project is the first undertaken in New Zealand to gather information on the quality of skins on export grade, commercially grown, early-season brown onions. Research carried out in the 2003 marketing season was to be the first step in seeking practical ways to optimise brown onion skin quality. The overall aim was to build on grower knowledge and experience to identify cultural, harvest and storage related factors that affect the development and retention of onion skins. Improved skin quality will enhance market acceptance in our high value markets in Europe and help to alleviate the risk of thrips infestation.

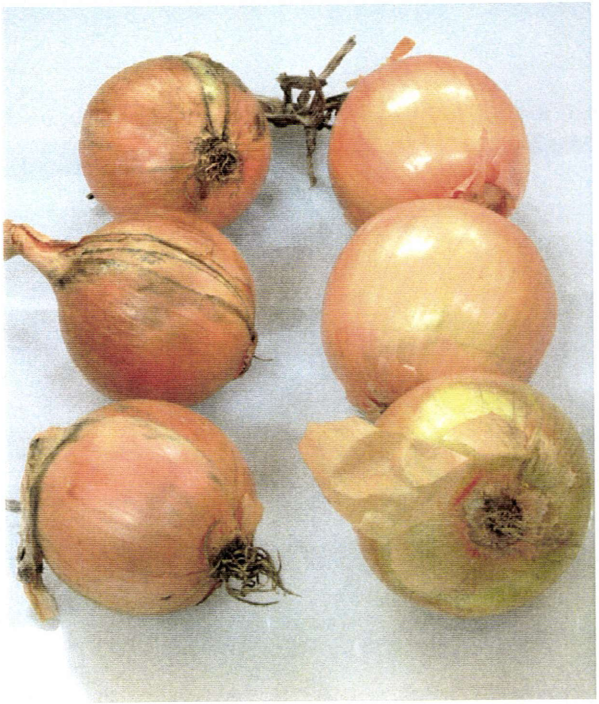


Figure 1: Good quality export onions have 3-4 skin layers that adhere tightly to the onion (LHS). Poor onions have very few loose skins (RHS).

3 Method

3.1 Sites

We worked with onion growers to monitor onion skin development of early-season brown onions up to harvest and changes in skin quality after lifting through to 2 months ambient storage for 7 commercial growing sites. The sites were in 5 growing areas - Karaka (one site, labelled A), Pukekohe (3 sites, labelled B, C and D), Waikato (one site, labelled E), Hawke's Bay (one site, labelled F) and Canterbury (one site, labelled G).

In addition, one of us (Bruce Searle) carried out a very detailed study (weekly or twice-weekly assessments on labelled plants) of leaf and skin development on a brown onion crop at Lawn Road Research Centre in Hawke's Bay in 2002-03.

3.2 Field information

At each grower site we gathered information during the onion development period as follows:

1. soil nutrient levels – from one soil test per site collected in mid-spring,
2. onion plant nutrient levels – from one leaf analysis sample per site collected in mid-spring,

3. crop management details - cultivar, sowing date and plant density; fertiliser programme; soil water-holding capacity and irrigation application; agrichemical application and weed control; and harvest (top-fall stage, lifting date, harvest method, topping method),

4. weather,

5. nutrient status at harvest (from skin samples from each site).

The trial sites were selected with Richard Wood. At each site two or three beds about 25 m long were clearly marked out in consultation with the grower. Within this area, five smaller plots were marked (2 m long, within a bed) for leaf and onion sampling. To minimise costs, samples from each site were collected by local Crop & Food Research staff.

3.3 *Onions for skin quality assessment*

Onions were collected from each site on two occasions – just prior to commercial lifting (the pre harvest sample) and just after commercial harvest into bins (the post harvest sample). The post harvest sample was from a bin of onions collected close to the marked plots. The aim of this sample was to examine the effect of exposure in the field and the effect of lifting/harvesting into bins on onion skin quality. On each occasion at each site 5 bags of 30-40 onions were collected (aiming for 65–80 mm diameter). From 2 sampling times and 7 sites we gathered 70 paper bags of onions for skin quality assessment.

3.4 *Onion skin quality assessment*

Onions were couriered to Food Industry Science Centre, Palmerston North, and held in ambient storage until the necks were dry – 2-3 months. We made the following measurements from a sample of 20 onions in the pre harvest samples and from a sample of 5 onions in the post harvest samples.

1. Bulb weight and diameter (tops trimmed to 50 mm)
2. Dry skin number (see Appendix I)
3. Skin thickness (outermost two skins, using callipers, measurements taken between vascular bundles, close to 'equator')
4. Skin splitting (number of layers, exposure of green flesh)
5. Skin adhesion (subjective scale; see Appendix I)
6. Skin colour (subjective scale; see Appendix I)

Photographs of the procedure are shown in Figures 2 and 3.

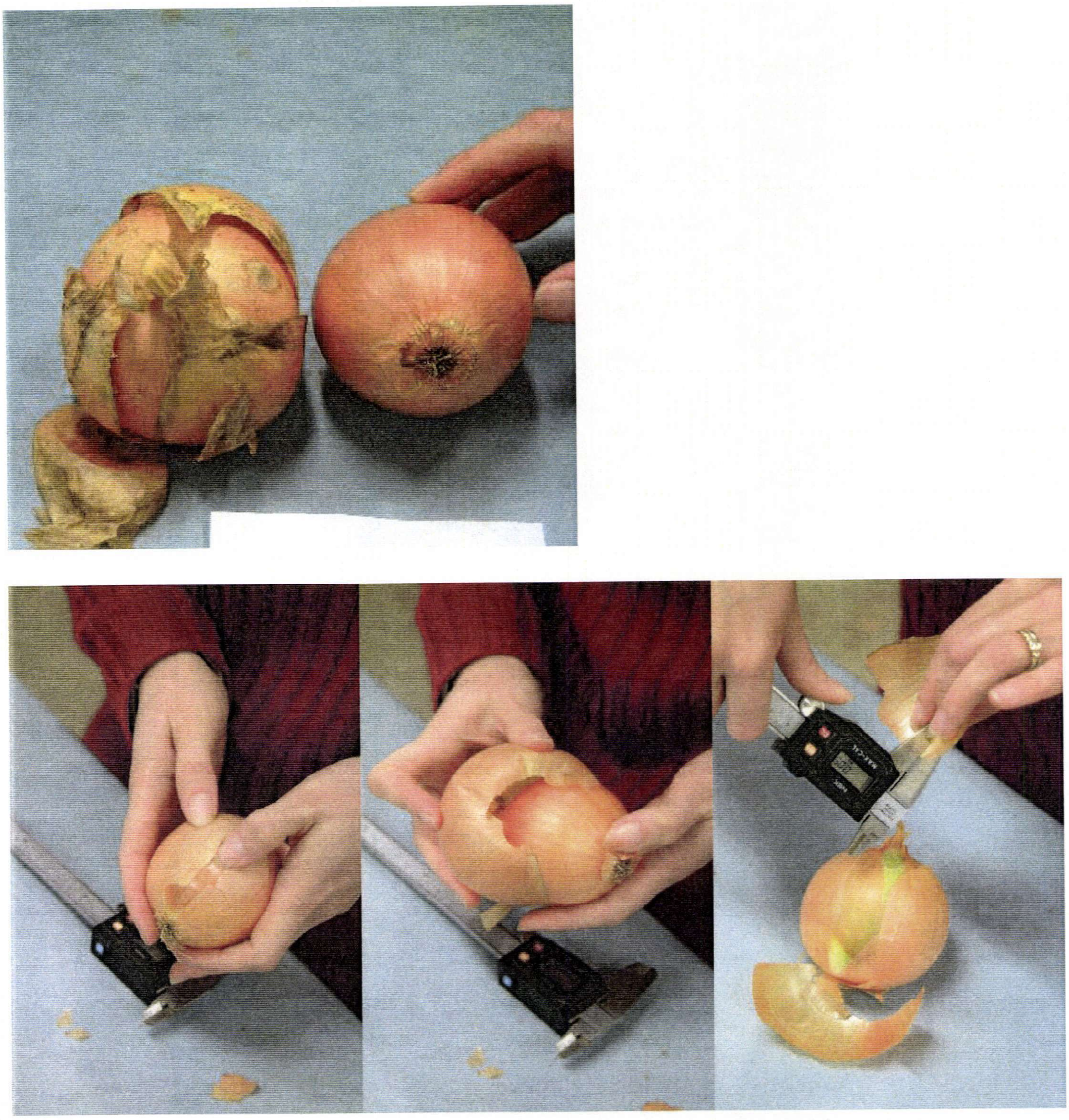
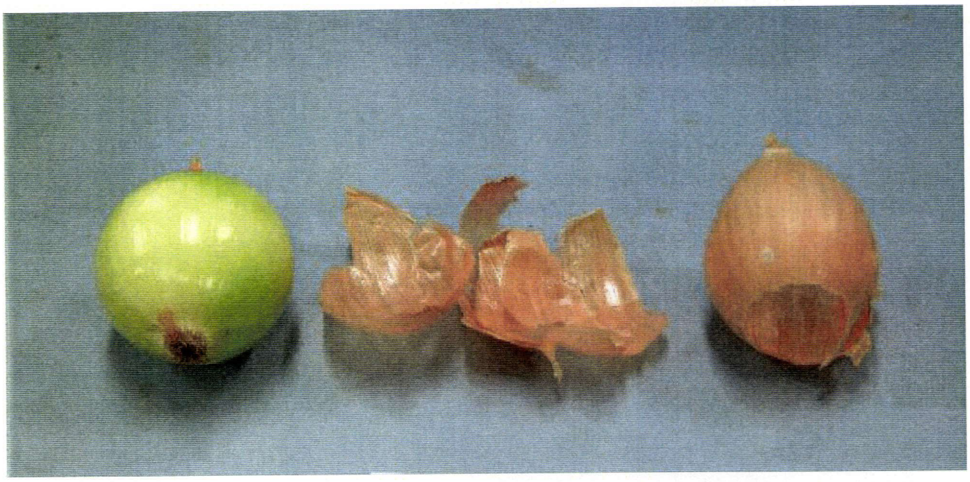


Figure 2: Skin removal and assessment procedure. Loose skins were removed first. These were not assessed. Each skin was removed using a sharp fingernail prior to assessment – by separating the skin from around the basal plate and then splitting it from the bottom to the top of the onion. Skin thickness was measured close to the 'equator' of the onion.

A



B

Figure 3: Skin quality assessment. A two-skin onion (A), and a three-skin onion (B).

4 Results

4.1 Leaf and skin development

Data were obtained from onions (cv. Encore) planted at Crop & Food Research's Hawke's Bay Research Station. Date of leaf appearance and leaf senescence of individual leaves from 30 plants were recorded.

Figure 4 shows the duration of growth for each individual leaf, from the date of first appearance to the date of senescence. The bulbing period and date of 50% top-down are also indicated on the graph. The number of leaves increased linearly with growing degree days (Figure 4). Leaves growing during the bulbing phase were leaves 4-8. Leaves 1-3 had senesced by the time bulbing started, and leaves 9 onwards had not senesced by the time of lifting. This suggests that leaves 4-8 will form the onion skins. In particular, environmental conditions during the growth of leaves 6-8 may be important in influencing skin quality.

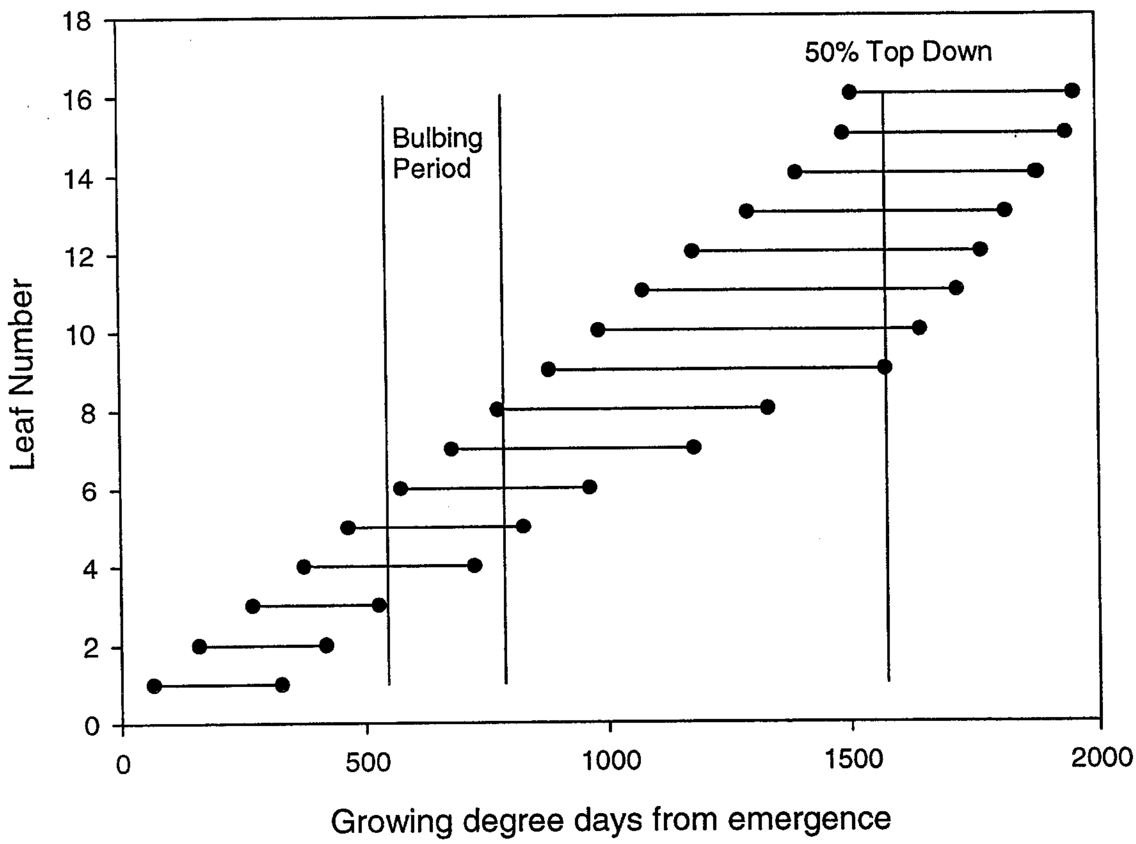


Figure 4: The growing duration of individual leaves of the onion cv. Encore.

4.2 Soil, leaf, and skin nutrient analysis

These data are presented in Tables 1-3.

Table 1: Soil analysis – samples collected in mid-spring.

Site	pH	Olsen-soluble P ug/ml	Calcium MAF	Magnesium MAF	Potassium MAF	Sodium MAF	Min. Nitrogen (kg/ha)	Dry Wgt/Vol (g/ml)	CEC (me/100 g)	Calcium (me/100 g)	Magnesium (me/100 g)	Potassium (me/100 g)	Sodium (me/100 g)
A	6.8	82	17	36	25	11	37	0.73	23	18.1	2.09	1.66	0.27
B	6.6	159	14	23	22	9	22	0.89	16	12.5	1.13	1.19	0.18
C	6.5	217	13	27	30	11	12	0.91	15	10.7	1.26	1.59	0.22
D	6.2	94	8	33	21	21	15	0.80	16	8.2	1.77	1.25	0.46
E	6.1	83	12	33	12	6	118	0.66	22	14.4	2.14	0.85	0.15
F	5.5	51	10	39	18	11	72	0.73	20	10.5	2.28	1.16	0.26
G	6.0	35	10	19	10	9	65	1.00	12.3	7.8	0.82	0.49	0.19

	Base saturation (%)				
Site	Ca	Mg	K	Na	Total
A	80.0	9.3	7.3	1.2	97.8
B	78.1	7.0	7.5	1.1	93.7
C	70.0	8.3	10.4	1.4	90.2
D	52.3	11.3	7.9	3.0	74.5
E	66.9	9.9	3.9	0.7	81.5
F	51.9	11.3	5.7	1.3	70.2
G	63.0	3.7	4.0	1.6	76.0

Table 2: Plant analysis – samples collected in mid-spring.

Site	Total nitrogen (% w/w)	Phosphorus (% w/w)	Potassium (% w/w)	Sulfur (% w/w)	Calcium (% w/w)	Magnesium (% w/w)	Sodium (% w/w)	Px100/N	Sx100/N	Iron mg/kg	Manganese (mg/kg)	Copper mg/kg	Zinc (mg/kg)	Boron (mg/kg)
A	2.23	0.21	1.8	0.37	1.19	0.14	0.046	9.51	16.68	53	263	11	43	16
B	2.06	0.25	2	0.36	1.51	0.1	0.033	12.09	17.57	43	141	14	18	15
C	2	0.19	2	0.37	1.53	0.09	0.03	9.5	18.6	38	131	3	58	14
D	2.12	0.16	2.1	0.36	1.34	0.14	0.034	7.55	16.84	44	90	3	12	14
E	3.52	0`.22	2.4	0.69	1.49	0.2	0.025	6.34	19.6	109	271	104	46	17
F	3.22	0.35	2.4	0.7	0.8	0.16	0.031	10.78	21.58	81	56	7	36	23
G	3.17	0.29	2.5	0.65	1.23	0.14	0.081	9.15	20.63	48	47	3	16	23

Table 3: Skin analysis.

	A		B		C		D		E		F		G	
	pre harvest sample	post harvest sample	pre harvest sample	post harvest sample	pre harvest sample	post harvest sample	pre harvest sample	post harvest sample	pre harvest sample	post harvest sample	pre harvest sample	post harvest sample	pre harvest sample	post harvest sample
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
total nitrogen %w/w	not	0.04	0.19	0.21	0.34	0.25	0.23	0.31	0.22	0.2	0.16	0.3	0.35	0.31
phosphorus % w/w	sufficient	0.02	0.04	0.3	0.04	0.05	0.02	0.04	0.02	0.04	0.02	0.04	0.05	0.03
potassium % w/w	for	0.4	0.6	3.1	0.5	0.5	0.3	0.5	0.6	0.6	0.7	0.7	0.7	0.3
sulfur % w/w	analysis	0.06	0.06	0.36	0.14	0.1	0.06	0.11	0.09	0.05	0.07	0.17	0.24	0.1
calcium % w/w		1.63	1.86	0.36	1.68	1.89	2.48	1.69	1.91	2.02	1.79	1.67	1.71	2.01
magnesium % w/w		0.07	0.09	0.21	0.13	0.17	0.16	0.14	0.13	0.1	0.17	0.15	0.17	0.12
sodium % w/w		0.039	0.035	0.121	0.026	0.053	0.097	0.068	0.045	0.038	0.05	0.025	0.042	0.072
Px100/N		57.5	21.58	140.48	10.29	18	7.39	13.23	10.91	18	11.88	12.33	13.14	8.06
Sx100/N		142.5	31.05	169.52	41.18	40.8	27.39	35.16	41.36	27	41.25	55	68.29	32.58
iron mg/kg		91	408	144	132	465	119	100	154	385	101	74	122	70
manganese mg/kg		30	53	203	77	89	50	43	68	80	63	46	57	29
copper mg/kg		2	2	12	6	3	2	5	3	3	2	4	3	2
zinc mg/kg		8	11	40	28	25	19	17	12	9	11	35	31	18
boron mg/kg		15	20	5	24	26	26	24	21	23	23	26	28	23
cobalt mg/kg		0.04	0.19	0.03	0.03	0.27	0.04	0.03	0.07	0.31	0.08	-0.02	0.15	0.04
molybdenum mg/kg		0.42	0.13	0.21	0.19	0.24	0.08	0.6	0.22	0.26	0.09	0.19	0.13	0.11

It is clear from these analyses that the dry skins have lost most of the mobile nutrients (e.g. N, P, K), but retained less mobile nutrients such as Ca and B.

4.3 *Agrichemical use*

These data have been summarised and are shown in Appendix II.

4.4 *Environmental conditions during growth*

Sites B, C and D had slightly warmer temperatures during growth than the other sites. Rainfall was lower during growth at site G than at other sites, site A had the highest rainfall during growth and curing. Warmest temperature during bulbing was at site E, followed by Site G; these sites also had the lowest amount of rainfall during bulbing.

Table 4: Average daily temperatures and total rainfalls from planting to lifting, from lifting to curing and during bulbing at each site. Dates of bulbing were estimated using photothermal time.

	From planting to lifting		From lifting to harvesting		During bulbing	
Site	Average temp. (°C)	Rainfall (mm)	Average temp. (°C)	Rainfall (mm)	Average temp. (°C)	Rainfall (mm)
A	12.9	514.7	17.9	178.5	12.9	81.8
B	13.4	444.1	18.2	112.5	13.6	74.2
C	13.4	460.7	18.0	28.2	13.2	54.4
D	13.7	459.7	18.1	101.3	13.6	75.6
E	12.8	387.2	17.3	1.2	16.4	35.2
F	12.9	350.4	18.2	9.0	13.8	52.4
G	12.4	273.0	17.4	12.0	15.6	32.2

4.5 *Lifting, curing, harvest and assessment dates*

Grower practices on lifting and curing are outlined in Table 5. We did not standardise storage times duration prior to assessment. Onion skin quality assessments were generally made after 70-90 days in ambient storage. When we examined skin quality data we did not find evidence of a link between skin quality parameter and storage duration.

Table 5: Lifting, curing, harvest and assessment dates for the growing sites.

Site	Lift date (pre harvest)	Harvest date (post harvest)	Curing time (days)	Skin assessment date		Storage time (days)	
				Pre harvest	Post harvest	Pre harvest	Post harvest
A	31/12	24/2	55	20/3	13/5	79	78
B	7/1	20/2	44	26/3	14/5	78	83
C	7/1	24/1	17	30/3	15/5	82	111
D	20/1	24/2	35	4/4	15/5	74	80
E	17/1	31/1	14	11/4	18/5	84	107
F	4/1	31/1	27	2/5	20/5	118	109
G	29/1	20/1	22	9/4	22/5	70	91

4.6 Skin quality

We collected skin quality data from the outer two entire adhering skins. We found that we needed to identify how far out from the fleshy bulb skins these outermost skins were in order to standardise our data. We used the 'number of dry skins' data for each onion to determine which skins we had measured in detail; for example, if there were 3 dry skins, the skins we measured were skins 2 and 3, counting outwards from the fleshy bulb.

See Appendix I for the assessment technique. Split skins (where green flesh was exposed) occurred very rarely – in no more than 10 onions - and results of this assessment have not been included in this report.

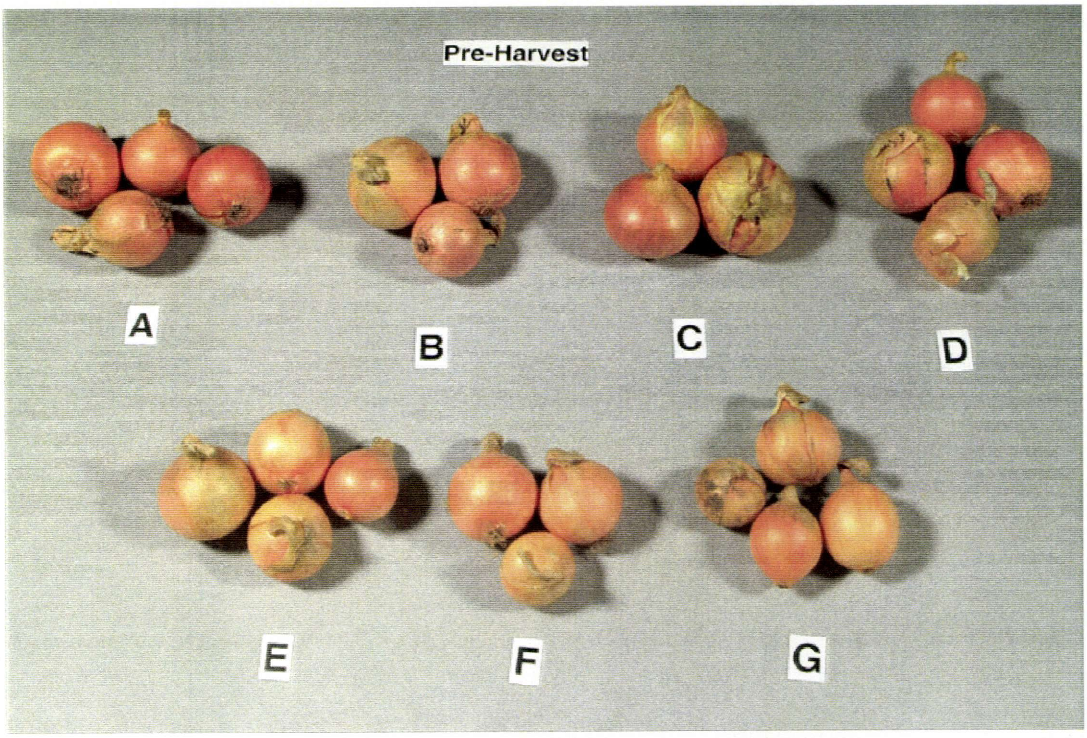


Figure 5: Onions collected from pre harvest sampling from all sites, after storage and just prior to skin quality assessment.

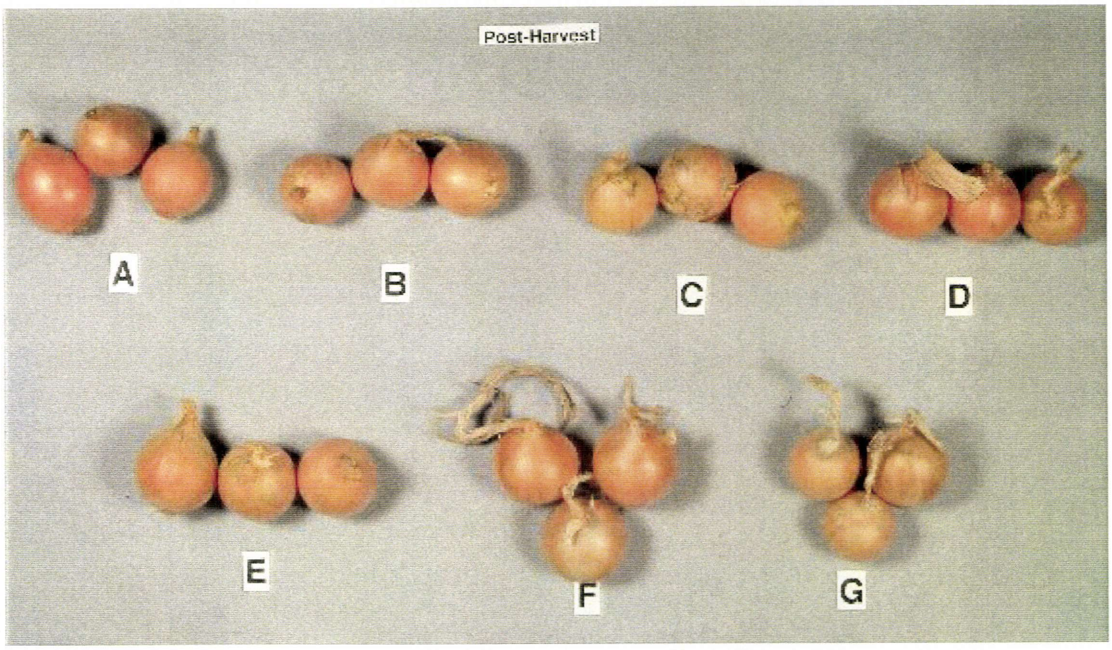


Figure 6: Onions collected from post harvest sampling from all sites, after storage and just prior to skin quality assessment.

4.6.1 *Pre harvest skin quality*

A summary of all data, including onions outside the standard diameter range, is given in Tables 6 and 7. Data for skin colour, adhesion and thickness were separated out into skins 1-4, where skin 1 is the first dry skin adjacent to the inner fleshy bulb tissue.

When data from all the sites were grouped we compared skin colour, adhesion and thickness between the different layers (Table 6). It was clear that the inner layers were more tightly adhering, and thicker, than the outer layers. Although there was a statistically significant difference between the colours of the skin layers, it would be indistinguishable to the eye.

Table 6: Summary of pre harvest skin quality for all sites, grouped by skin layer.

Layer	Skin colour	Skin adhesion	Skin thickness[¶] (μm)
1	2.9	2.7	-2.8 (60)
2	2.7	1.8	-2.9 (56)
3	2.6	1.3	-3.0 (50)
4	2.7	0.9	-3.2 (40)
l.s.d. (5%)[†,‡]	0.2**	0.2***	0.2***

[†]Probability rating: * < 5%, ** <1% and *** < 0.1% that the observed differences between layers are due to chance.

[‡]l.s.d. = least significant difference; smallest difference between two means that are significantly different at the 5% significance level.

[¶]Log-transformed data were required for statistical analysis; the back-transformed values are shown in parentheses.

We found a number of significant differences between onions from the different sites (Table 7).

The main points to note from Table 7 are that Sites E and G produced much smaller onions than the other sites. Site A produced onions with darker skins. Onions from Site E had looser skins while onions from sites A and D often had tighter skins.

Onions from Sites E and F had thin skins; onions from site A had thicker skins; and onions from site C had thicker outer skins. Onions from Site A had more skins than onions from other sites.

We resorted and reanalysed the data using only onions in the 65-80 mm diameter range to take out possible effects of site-to-site variation in the size of onions collected/available. Our analysis produced only slight changes in the data, which indicates that the presence of smaller and larger onions did not significantly skew the data.

Table 7: Pre harvest skin quality for all onions, sites A-G.

Site	Weight‡ (g)	Diameter (mm)	Sphericity†	Skin colour				Skin adhesion				Skin thickness‡ (μm)				No. dry skins
				4	3	2	1	4	3	2	1	4	3	2	1	
A	5.17 (175)	70	1.00	*3.2*¶	3.3	3.3		*1.2*	1.7	2.3	2.5	*-2.8 (58)*	-2.8 (64)	-2.5 (81)	-2.5 (81)	2.9
B	5.16 (175)	70	0.97		*2.4*	2.6	2.8		*1.3*	1.6	2.6		*-3.0 (51)*	-2.9 (57)	-2.7 (64)	1.8
C	5.16 (174)	71	0.94	*2.2*	*2.7*	2.8	3.0	*0.9*	*1.2*	1.6	2.6	*-3.8 (23)*	*-2.7 (65)*	-2.6 (73)	-2.7 (67)	1.9
D	5.11 (166)	69	0.96	*3.6*	2.5	2.7	*3.0*	*1.2*	1.4	2.2	2.9	*-3.2 (42)*	-3.0 (49)	-2.9 (56)	-2.6 (71)	2.4
E	5.10 (164)	69	0.97		*2.4*	2.6	2.7		*1*	1.4	2.4		*-3.2 (40)*	-3.2 (40)	-3.1 (43)	2.0
F	5.19 (180)	70	1.01		2.3	2.5	*2.5*		1.1	1.7	2.6		-3.2 (42)	-3.2 (42)	-3.2 (40)	2.3
G	5.06 (158)	69	0.94		*2.4*	2.3	2.6		*1.2*	1.7	2.8		*-3.0 (48)*	-2.9 (56)	-2.7 (66)	1.7
l.s.d. (5%)§	0.09*	2	0.04***	N/A	0.4***	0.4***	0.4**	N/A	0.3***	0.3***	0.3***	N/A	0.2**	0.2***	0.2***	0.5***

† Sphericity = weight divided by calculated volume (based on diameter).

‡ Log-transformed data were required for statistical analysis; the back-transformed values are shown in parentheses.

¶ Numbers shown in italics were excluded from statistical analysis because of the low number of observations.

§ See Table 6 for explanation of l.s.d. and asterisks. N/A means 'not analysed' because of the low number of observations.

4.6.2 *Post-harvest skin quality*

Comparing pre and post harvest data for the 'layers' (Tables 6 and 8) shows skin colours are not different between layers and do not change over time. Adhesion of skin 1 remained tight, but skins 2 and 3 adhered less strongly than in the pre harvest samples ($P<0.001$). There was a huge loss of skin thickness - all skins were thinner than the outermost skin of pre harvest onions.

Table 8: Summary of post harvest skin quality for all sites.

Layer	Skin colour	Skin adhesion	Skin thickness‡
1	2.7	2.6	-3.3 (35)
2	2.7	1.3	-3.4 (35)
3	2.6	1.1	-3.4 (34)
l.s.d. (5%)	0.3	0.2***	0.2

‡ Log-transformed data were required for statistical analysis; the back-transformed values are shown in parentheses. See Table 6 for explanation of l.s.d. and asterisks.

When post harvest samples of onions from different sites were compared, some of the differences evident in the pre-harvest onions had been lost (Table 9). The average number of dry skins was generally a little lower in post harvest onions than pre harvest, but on average less than one whole skin had been lost. This loss could have been due to mechanical damage during harvest. Site A skins were not much darker than others and skin adhesion (which was generally lower than in pre harvest onions, cf. Tables 7 and 9) was no longer variable between sites.

Skin thickness patterns had changed a little in the post harvest samples - now Site D, A and G onions sometimes had thicker skins in a layer. Onions from sites E and F still had the thinnest outer skins.

Table 9: Post harvest skin quality for all onions, sites A-G.

Site	Weight‡ (g)	Diameter (mm)	Sphericity†	Colour			Adhesion			Thickness‡ (µm)			No. dry skins
				3	2	1	3	2	1	3	2	1	
A	5.02 (151)	68	0.94	*3.1*	2.9	*3.1*	*1.1*	1.5	2.6	*44*¶	-3.0 (48)	-3.0 (50)	2.2
B	5.20 (180)	71	0.96	*2.3*	2.8	*2.9*	*1*	1.2	2.5	*35*	-3.5 (31)	-3.7 (25)	1.9
C	5.13 (169)	70	0.93	*2.9*	2.8	*3.5*	*1*	1.4	2.7	*48*	-2.9 (54)	-3.1 (44)	1.9
D	5.16 (174)	70	0.96	*3.1*	2.8	*3*	*1*	1.2	2.6	*55*	-3.5 (31)	-3.5 (30)	1.9
E	5.17 (175)	71	0.94	*2*	2.2	*2.5*	*1*	1.5	2.5	*21*	-4.1 (17)	-3.7 (24)	1.8
F	5.26 (193)	73	0.95	*2.5*	2.8	*2*	*1*	1.2	2.7	*23*	-3.4 (34)	-3.4 (34)	1.9
G	5.19 (179)	71	0.95	*2.4*	2.3	*2.1*	*1.3*	1.3	2.5	*40*	-3.2 (42)	-3.0 (51)	1.9
l.s.d. (5%)	0.07***	2***	0.06	N/A	*§	N/A	N/A	§	§	N/A	0.3***	0.3***	0.3

† Sphericity = weight divided by calculated volume (based on diameter).

‡ Log-transformed data were required for statistical analysis; the back-transformed values are shown in parentheses.

¶ Numbers shown in italics were excluded from statistical analysis because of the low number of observations; where this affects a whole column, N/A is shown at the bottom.

§ Non-parametric Kruskal-Wallis one-way ANOVA was used to compare sites; therefore no l.s.d. figure is available, but asterisks are used where there are significant differences.

4.6.3 *Observations*

One of us (T. Pinkney) carried out all the assessments of onion skin quality and made the following observations.

- If the neck is ~3 cm or more in length and intact and the base of the skins around the roots is intact, it would appear the skin is more likely to stay attached to the onion, even if it seems thin. The skins can be quite thin but if they're still intact can adhere strongly to the onion.
- The technique used to remove the skins was to twist around the neck of the onion, slide a fingernail down the length of the onion, The fingernail is then run under the top skin around the root base of the onion often resulting in the skin sloughing off almost intact (see Figure 2).
- For some onions there is an additional observation of either L = Leathery or C = Cardboard-like, this indicates a skin that is especially tough and difficult to remove and is also quite thick. The 'C' type skins often need to be 'chipped' from the onion in small pieces while the 'L' type skins often needed to be peeled from the onion and had a definite 'leathery' texture.

4.6.4 *Correlations*

Onion diameter and weight were strongly correlated, as expected. There was no connection between diameter and any of the following: no. of dry skins, skin adhesion, skin thickness, skin colour (for any layer). This explains why leaving out the smaller and larger onions (outside the 65-80 mm window) made very little difference to the data.

4.6.5 *A skin quality index?*

We added up the total skin thickness as a measure of skin quality (averaged across all onions at a site and having to insert an average skin thickness for inner skins where they were not measured). Sites E and F had the thinnest skin and, therefore, the lower quality, but B and G were almost as low. B and G had fewer skins while E and F had the normal number but thinner skins. An alternate approach was to calculate a 'total quality score', by multiplying four scores together: skin colour, skin adhesion, average skin thickness and number of dry skins. These concepts could be explored further in discussion with industry.

4.6.6 *Environment conditions and skin quality*

There appeared to be no significant correlations between individual skin quality characteristics and temperature or rainfall conditions during the growth of the crops. However, when the total quality score was considered there was a correlation between temperature and rainfall during the bulbing phase (data not shown). Simply put, a higher quality score was obtained at sites where the average temperature during bulbing was lower and where rainfall was higher. More work is required to identify the best combination of quality scores for obtaining a total quality score.

4.6.7 *Fertility and plant nutrient level*

No consistent correlation between soil nutrients and the total quality score was found. No consistent correlation between nutrient levels in skins at lifting or at harvest with total quality score could be found. However, there was some correlation between total quality score and percentage K in leaves and the S/N ratio at first sampling (early bulbing) (data not shown). We noted that the three sites that produced onions with the thinnest skins (E and F) or with fewer, thicker skins (G) and therefore had the lowest 'total quality score', also had soils with the lowest pH, and highest mineral N; and the plants from these sites had the highest N, S and Mg levels in their leaves (Tables 1 and 2). Further testing is needed to determine whether there is a connection between these observations.

4.6.8 *Field curing effects*

The effects of environmental conditions and the duration of curing on changes in skin quality between pre and post harvest samples were examined. While on average there was no difference in skin colour between pre harvest and post harvest samples, warmer sites during curing (>18°C) had least change in colour. Cooler temperatures tended to result in some colour loss.

Adhesion became worse the longer onions were left in the field to cure, and the warmer the temperature was. Temperature and time were integrated into growing degree days for the curing period, and analysis of the relationship shows that for every 100 GDD there is a loss of 0.1 adhesion units.

The longer the curing period, the greater the loss of skins, though this did not hold at Site B. Temperature alone was not important in determining skin loss during curing. While there was a loss of skin thickness with curing, there was no consistent correlation with temperature or duration of the curing period.

5 *Conclusions and recommendations*

Careful observations have been made on the more readily measurable aspects of skin quality – a first attempt at a poorly understood subject. We welcome the opportunity to discuss the measurement techniques developed and the observations we have made with growers and exporters with the purpose of deciding how best to develop management guidelines that can enhance onion skin quality.

6 *Acknowledgements*

We appreciate the assistance of Peter Wright and Tabitha Armour who collected soil, leaf, bulb nutrient samples and onions for skin quality assessment from the Pukekohe/Waikato and Canterbury sites, respectively. John Koolaard provided invaluable assistance with statistical analysis.

Appendices

Appendix I - Skin quality assessment methods

1. **Diameter**

   Diam – to nearest 5 mm, measured with plastic calipers

2. **Skin colour**

   1 = yellow/green

   2 = straw

   3 = light brown

   4 = brown

   5 = dark brown

3. **Skin adhesion**

   L = 1 = Loose, cracks/shatters and comes away in large pieces when rubbed

   M = 2 = Medium, stays adhered to the onion, feels wrinkly and comes away in bigger pieces than Strong

   S = 3 = Strong, have to peel the skin away from the onion.

4. **Skin thickness**

   Using digital calipers. Measured between vascular bundles close to the 'equator'. See Figure 6.

5. **Dry skin number**

   At least 85% of the skin was brown and/or dry (translucent and papery). The skin must be whole, covering at least 80% of the onion. If a skin had any flesh it was not counted as a dry skin. Outer skin 'remnants' were not counted. If the skin came away easily in the hands or when lightly rolled from one hand to the other it was not counted. See Figures 2 and 6.

6. **Skin splits**

   These are not splits in the very outer skins, but the deep splits that may happen at the neck or base and expose the fleshy scales.

7. **Observations**

   We made notes on the occurrence of 'leathery', 'cardboard' and 'papery' (normal) dry skins.

Appendix IIA – Agrichemical usage – fertiliser applications

Site Code	date	type and rate	date	type and rate	date	type and rate	date	type and rate
A	not provided							
B	12-Jun	DAP 100 kg/ha	28-Aug	80kg/ha CalNitro	30-Oct	160kg/ha HydroGreen	13-Nov	75kg/ha HydroGreen
C	15-May	15%PotMag 250 kg/ha	20-Aug	NitroBlue 250 kg/ha	27-Oct	NitroBlue 250 kg/ha		
D		Nil	20-Aug	NitroBlue 210 kg/ha	12 Sep & 13 Oct	NitroBlue 240 kg/ha	18-Nov	NitroBlue 300 kg/ha
E	30-Mar	3.5t/ha Lime	17-May	10%Magphos 4 t/ha	10 Aug & 23 Sep & 2 Nov	DAP 280 kg/ha		
F	21-May	30% Potash Super 750 kg, DAP 100 kg	25-Jul	DAP 350 kg	24-Oct-02	12-10-10, 200 kg	10-Nov	12-5-14, 200 kg
G	July	Potassic Super 350 kg	August	Cropmaster 350 kg				

Appendix IIB - Agrichemical usage – weed, pest and disease control

Site A. No data provided.

Site B.

Date	Product	Rate L or Kg/ha
28-Jun-02	Roundup Extra	2.2
28-Jun-02	Stomp	0.375
24-Jul-02	Stomp	0.375
3-Aug-02	Cereous	1.66
5-Aug-02	Flag	1.5
5-Aug-02	CIPC	1.5
5-Aug-02	Peptoil	1
23-Aug-02	Stomp	0.375
23-Aug-02	Cereous	1.66
8-Sep-02	Totril	0.3
14-Sep-02	Totril	0.5
14-Sep-02	Tribunil	0.5
18-Sep-02	Stomp	0.375
18-Sep-02	Cereous	1.66
5-Oct-02	Totril	0.4
5-Oct-02	Basagran	0.6
9-Oct-02	Ridomil	2.5
9-Oct-02	Dithane	1
11-Oct-02	Frontier	1.25
11-Oct-02	Cereous	1.66
15-Oct-02	Galant	1.5
15-Oct-02	Peptoil	1
15-Oct-02	Dithane	3
21-Oct-02	Dithane	3
29-Oct-02	Dithane	3
5-Nov-02	Totril	0.5
5-Nov-02	Basagran	1
8-Nov-02	Frontier	1.25
8-Nov-02	Ridomil	2.5
8-Nov-02	Dithane	1
8-Nov-02	Lorsban	1
8-Nov-02	Copper	0.5
14-Nov-02	Basagran	1.5
18-Nov-02	Dithane	3
18-Nov-02	Lorsban	1
25-Nov-02	Dithane	3
3-Dec-02	Dithane	3
3-Dec-02	Monitor	1
3-Dec-02	Copper	0.5
9-Dec-02	Dithane	3
9-Dec-02	Monitor	1
16-Dec-02	Dithane	3

16-Dec-02	Monitor	1
16-Dec-02	Copper	0.5
23-Dec-02	Dithane	3
23-Dec-02	Prolific	0.5
23-Dec-02	Decis	0.4
30-Dec-02	Dithane	3
30-Dec-02	Prolific	0.5
30-Dec-02	Decis	0.4
7-Jan-03	Dithane	3
7-Jan-03	Prolific	0.5
7-Jan-03	Decis	0.4
13-Jan-03	Dithane	3
13-Jan-03	Karate	0.04

Site C. No data received.

Site D.

Date	Product	Rate L or Kg/ha
28-Feb-02	Stomp	1
28-Feb-02	Ramrod	5
28-Feb-02	Preeglone	2.5
5-Aug-02	Cereous	1.5
28-Aug-02	Maneb	2
28-Aug-02	Carbendazim	0.75
28-Aug-02	Stomp	0.25
1-Sep-02	Cereous	1.5
12-Sep-02	Totril	0.3
16-Sep-02	Tribunil	0.4
16-Sep-02	Totril	0.2
16-Sep-02	Tribunil	0.5
16-Sep-02	Totril	0.2
4-Oct-02	Tribunil	0.5
4-Oct-02	Cypro	0.2
8-Oct-02	Basagran	1
10-Oct-02	Cereous	1.5
10-Oct-02	Frontier	1.2
18-Oct-02	Totril	0.5
18-Oct-02	Tribunil	0.5
29-Oct-02	Totril	0.5
9-Nov-02	Maneb	2
9-Nov-02	Ridomil	2.5
9-Nov-02	Lorsban	0.5
9-Nov-02	Bond	0.4
10-Nov-02	Cereous	1.5
15-Nov-02	Maneb	3
15-Nov-02	Fusilade	1.5
15-Nov-02	Oil	1
23-Nov-02	Maneb	2

23-Nov-02	Lorsban	1
23-Nov-02	Bond Xtra	0.35
29-Nov-02	Maneb	2
29-Nov-02	Antracol	2
29-Nov-02	Mavrik	1
29-Nov-02	Bond Xtra	0.6
6-Dec-02	Alto	1.5
9-Dec-02	Maneb	3
9-Dec-02	Mavrik	1
9-Dec-02	W/A	5
9-Dec-02	Duwett	0.4
16-Dec-02	Maneb	3
16-Dec-02	Condifor	0.7
16-Dec-02	Bond Xtra	0.7
21-Dec-02	Maneb	3
21-Dec-02	Karate	0.04
21-Dec-02	W/A	5
21-Dec-02	Duwett	0.04
27-Dec-02	Maneb	3
27-Dec-02	Karate	0.04
27-Dec-02	Guard	5
27-Dec-02	Duwett	0.04
3-Dec-02	Maneb	3
3-Dec-02	Decis	0.36
3-Dec-02	Bond Xtra	0.8
12-Dec-02	Maneb	3
12-Dec-02	Decis	0.36
12-Dec-02	Duwett	0.4
20-Dec-02	Maneb	3
20-Dec-02	Dominex	0.25
20-Dec-02	Bond Xtra	0.6
27-Dec-02	Maneb	2
27-Dec-02	Antracol	2
27-Dec-02	Carbendazim	0.75
27-Dec-02	Duwett	0.4
6-Jan-03	Maneb	2.5
6-Jan-03	Dominex	0.25
6-Jan-03	Duwett	0.4
15-Jan-03	Maneb	3
15-Jan-03	Karate	0.04
15-Jan-03	Bond Xtra	0.6

Site E.

Date	Product	Rate L or Kg
16-Jul-02	Stomp Xtra	0.25
28-Aug-02	Chloro IPC	1.5
28-Aug-02	Chloronion	1.5
28-Aug-02	Goldazim	0.5
4-Sep-02	Chloronion	1.5
4-Sep-02	Chloro IPC	1.5
23-Sep-02	Cy-Pro 90 DF	0.1
23-Sep-02	Twin-Star	0.2
2-Oct-02	Cy-Pro 90 DF	0.15
2-Oct-02	Twin-Star	0.3
10-Oct-02	Frontier	1.5
10-Oct-02	Gallant NF	1.5
10-Oct-02	Stomp Xtra	0.35
25-Oct-02	Dithane M 45	2
6-Nov-02	Manzate WP	1
6-Nov-02	Ridomil Gold MZ	2
14-Nov-02	Condifor Supra	1
14-Nov-02	Kocide 2000 DF	0.35
14-Nov-02	Manzate WP	2
18-Nov-02	Cy-Pro 90 DF	0.2
18-Nov-02	Twin-Star	0.6
21-Nov-02	Kocide 2000 DF	0.35
21-Nov-02	Manzate WP	2
25-Nov-02	Totril	0.5
25-Nov-02	Trump	0.5
28-Nov-02	Confidor Supra	1
28-Nov-02	Frontier	1.5
28-Nov-02	Kocide 2000 DF	0.25
28-Nov-02	Manzate WP	2
2-Dec-02	Basagran	0.6
2-Dec-02	Totril	0.5
5-Dec-02	Confitor Supra	1
5-Dec-02	Manzate WP	1
5-Dec-02	Ridomil Gold MZ	2
11-Dec-02	Kocide 2000 DF	0.5
11-Dec-02	Lorsban 40 EC	1.5
11-Dec-02	Manzate WP	2.5
19-Dec-02	Kocide 2000 DF	0.5
19-Dec-02	Lorsban 40 EC	1.5
19-Dec-02	Manzate WP	2.5
23-Dec-02	Kocide 2000 DF	0.5
23-Dec-02	Lorsban 40 EC	0.5
23-Dec-02	Manzate WP	2.5
30-Dec-02	Kocide 2000 DF	0.5
30-Dec-02	Lannate	2
30-Dec-02	Manzate WP	2.5
7-Jan-03	Goldazim	0.5

7-Jan-03	Lannate	2
7-Jan-03	Manzate WP	2
7-Jan-03	Super Sprout Stop	9

Site F.

Date	Product	Rate L or Kg
15-Jun-02	Ramrod	7.00
15-Jun-02	Stomp Xtra	0.43
17-Aug-02	Totril	0.30
22-Aug-02	Totril	0.35
28-Aug-02	Totril	0.40
3-Sep-02	Totril	0.40
7-Sep-02	Stomp Xtra	0.25
7-Sep-02	Prolific	0.50
23-Sep-02	Totril	0.60
23-Sep-02	Tribunil	0.50
29-Sep-02	Dithane	2.50
29-Sep-02	Gallant	1.50
8-Oct-02	Dithane	2.50
8-Oct-02	Stomp Xtra	0.43
8-Oct-02	Frontier	1.25
23-Oct-02	Dithane	1.00
23-Oct-02	Boron	1.00
23-Oct-02	Ridomil Gold	2.50
1-Nov-02	Antrocol	2.00
1-Nov-02	Boron	1.00
1-Nov-02	Zinc	0.80
1-Nov-02	Confidor	0.23
9-Nov-02	Dithane	1.00
9-Nov-02	Tamaron	1.00
9-Nov-02	Ridomil Gold	2.50
9-Nov-02	Frontier	1.00
22-Nov-02	Dithane	2.50
22-Nov-02	Kocide	0.50
22-Nov-02	Tamaron	1.00
29-Nov-02	Antrocol	2.00
29-Nov-02	Tamaron	1.00
29-Nov-02	Frontier	0.50
13-Dec-02	Dithane	2.50
13-Dec-02	Kocide	0.50
13-Dec-02	Carbendazim	0.50
13-Dec-02	Deltaphar	0.40
21-Dec-02	Antrocol	2.50
21-Dec-02	Deltaphar	0.40
21-Dec-02	Carbendazim	0.50
28-Dec-02	Carbendazim	0.50
28-Dec-02	Deltaphar	0.40
28-Dec-02	Dithane	2.50

Site G.

Date	Product	Rate L or Kg/ha
3-Aug-02	Stomp 330	0.7
23-Aug-02	Preclone	2.5
15-Sep-02	Chloronion	1.5
15-Sep-02	CIPC	1.5
26-Sep-02	Carbendazim	0.5
7-Oct-02	Totril	0.45
21-Oct-02	Totril	0.4
21-Oct-02	Tribunil	0.4
28-Oct-02	Totril	0.4
28-Oct-02	Tribunil	0.4
11-Nov-02	Totril	0.4
11-Nov-02	Tribunil	0.4
10-Dec-02	Carbendazim	Label Rates
10-Dec-02	Manzate	Label Rates
10-Dec-02	Decis	Label Rates
29-Dec-02	Acto	Label Rates
2-Jan-03	Manzate	Label Rates
2-Jan-03	Copper	Label Rates
2-Jan-03	Decis	Label Rates
17-Jan-03	Manzate	1.5
17-Jan-03	Carbendazim	0.5
25-Jan-03	Manzate	1.5
25-Jan-03	Carbendazim	0.5