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Effects of calcium fertiliser and copper bactericide applications on incidence of bacterial soft rot of onion plants in the field and bulbs in store: 12-month progress report for the period to June 2006

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Contents

1 Executive summary

"Developing an Integrated Pest and Disease Production System for Onions and other *Allium* Crops" is a MAF SSF project instigated by the New Zealand Onion Exporters Association. Project 10 of the MAF SFF project is titled "Bacterial soft rot in onions". This report is the second annual report for project 10, and reports investigations on the effects of calcium (Ca) fertiliser and copper (Cu) bactericide applications on incidence of bacterial soft rot of onion plants in the field and of bulbs in store.

In the 2005-06 growing season, two field experiments were undertaken at the Crop & Food Research Centre at Pukekohe. Experiment 1 tested eight calcium treatments (combinations of two pre-plant Ca treatments, two Ca side-dress treatments, and two Ca foliar fertiliser treatments). Experiment 2 tested eight Cu treatments, comprising different Cu foliar application times. For both experiments, five methods were used to wound the plant foliage: weed eater; sand blaster; water blaster; motor blower; no wounding. A suspension of soft-rotting bacteria was sprayed onto all plants within 5 minutes of wounding.

Increasing levels of wounding lead to increased levels of foliage rot and increasing levels of rot in stored onion bulbs. The wounding treatments were the major factor affecting the prevalence of rot in both experiments. The calcium treatments did not affect the foliage calcium content (content range 2.1–2.5%), or the incidence of foliage rot (disease score range 1.06–1.19), or the percentage of stored bulbs with rot (range 0.8–1.5%). The copper treatments had a small effect on foliage rot, with the same-day copper application having slightly lower disease incidence (disease score 0.96) than the other copper applications (disease score range 1.05–1.10). There were no effects of copper on the prevalence of stored onion bulbs with rot (percentage range 0.3–0.7%).

2 Project background

In 2004, the New Zealand Onion Exporters Association initiated a project titled: "To develop an Integrated Pest and Disease Production System for Onions and other *Allium* Crops". Over a 3-year period, a "best practice" manual is going to be developed for New Zealand *Allium* growers. The manual will document integrated pest and disease management (IPM) strategies from current knowledge and from contracted research over this period.

The project team includes growers and exporters from the New Zealand onion industry. A science team, comprising agronomists, consultants and scientists from Crop & Food Research and HortResearch, is working on 12 individual projects identified as areas where there are gaps in IPM knowledge. Bacterial soft rot in onions is Project 10 of the Integrated Pest and Disease Management Programme for onions and other *Allium* crops in New Zealand.

This report is the second annual report for project 10 - Effects of calcium fertiliser and copper bactericide applications on incidence of bacterial soft rot of onion plants in the field and bulbs in store.

3 Introduction

Bacterial soft rot can cause significant losses of onions in the field, in storage, and during transit to export destinations. Soft rot infection in the field is favoured by cool, wet conditions and damage to the foliage (e.g. hail, severe rainstorms, wind, etc.). At present there are few chemicals available to control bacterial diseases on horticultural crops. Copper is the most widely used chemical. However, some negative aspects of copper applications include phytotoxicity, reduced sensitivity to copper of some bacterial strains, and environmental effects. These aspects have been improved through attention to time of applications, tank mixes, use-rate reductions, and formulation used.

The value of plant nutrition in reducing the incidence and severity of plant pathogens has been recognised for many years. Although most metabolic or physiological mechanisms involved in host-pathogen interactions are not clearly understood, specific nutrients are known to reduce disease severity by affecting virulence of the pathogen, enhancing resistance of the plant, and activating plant defences against infection. Several scientific papers report the role that calcium (Ca) has in plant nutrition relative to lessening the impact of several fungal and bacterial plant diseases. It is generally believed that Ca increases the resistance of plant tissue by enhancing the structural integrity of cell walls and membranes, making them more resistant to degradation by pectolytic enzymes produced by pathogens.

Aims of Project 10:

1. To determine the effects of Ca and N on bacterial soft rot of onion.
2. To determine whether copper sprays control onion soft rot in the field and in storage.
3. To transfer results of the research on copper to control bacterial soft rot to growers via the IPM/best practice manual.
4. To transfer results of research on effects of Ca and N nutrition on onion soft rot to growers via the IPM/best practice manual.

Goals of Project 10:

Years 1 and 2

- To determine the effects of Ca and N on incidence and severity of bacterial soft rot in wounded and non-wounded onions that were artificially inoculated in the field.
- To determine the effects of Ca and N on bulb yield, bulb skin quality characteristics, and rots in storage.
- To investigate the effects of different copper formulations for control of bacterial soft rot of onion.
- To investigate the effects of timing of different copper formulations for control of onion soft rot.
- To develop a method to artificially wound and inoculate onions with soft-rotting bacteria to be able to fully test the copper treatments.
- To determine any phytotoxicity of different copper formulations.

Year 3

- To develop a Ca and N application strategy and evaluate it in grower fields.
- To transfer results of the research on effects of Ca and N on bacterial soft rot to growers via the IPM/best practice manual.
- To develop a copper application strategy and evaluate it in grower fields.
- To transfer results of the research on copper to control bacterial soft rot to growers via the IPM/best practice manual.

4 *Materials and methods*

The field experiments were done at the Crop & Food Research Centre at Pukekohe on a soil type described as a Patumahoe mottled clay loam (pH 5.5; cation exchange capacity 18; Ca 9 MAF QT units; 43.1% base saturation). Seed of the onion cultivar Kiwigold was direct-seeded on 5 August 2005 using a Stanhay precision seed planter in 18 six-row beds, each 102 m long and 1.5 m wide. Plant density 1 month after sowing was 55-65 plants/m of bed. Base fertiliser application of 15% potassic superphosphate (1 t/ha) was applied to the experimental site 6 weeks prior to sowing. Irrigation and the control of weeds, insect pests, and fungal diseases during the growing seasons were managed as is local commercial practice. In the copper experiment, nitrogen (at a rate of 135 kg N/ha), as urea, was applied in three equal side-dressings on 5 September, 5 October, and 5 November 2005.

Both experiments were laid out in exactly the same way, in randomised blocks with four treatment replications (plots) along four beds (Figure 1). Each experiment comprised nine beds: four datum beds, flanked on each side by a guard bed. Plot size was 12 m long x 1.5 m wide and treatments were randomly allocated to plots so that each treatment was present once in each block and in each bed. There were eight plots in each datum bed, with a 1 m buffer zone between plots. Each plot was divided into five sub-plots. The sub-plots were 2.2 m long, and were separated from each other by a 0.25 m buffer zone.

1	3	4	5	6	8	7	2
6	8	3	7	1	2	5	4
2	5	1	6	4	7	3	8
7	4	8	2	3	5	6	1
Block 1		Block 2		Block 3		Block 4	

Figure 1: Plot layout.

4.1 *Experiment 1: calcium treatments*

The eight calcium treatments consisted of combinations of two pre-plant Ca treatments, two Ca side-dress treatments, and two Ca foliar fertiliser treatments (Table 1). For plots requiring pre-plant Ca treatments, gypsum ($CaSO_4$) at a rate of 5 tonnes/ha was applied to seed beds and cultivated-in to a depth of c. 50 mm, 1 month before seed was sown. For plots requiring Ca side-dressings, calcium nitrate (15% N; 21% Ca) at a rate of 45 kg N/ha (91 kg Ca/ha) was applied on three occasions (5 September, 5 October, 5 November 2005). For plots not receiving Ca side-dressing, urea (45 kg N/ha) was applied to supply the same amount of N as the $CaNO_3$. Plants receiving foliar applications of Ca were sprayed every 7 days (9 November until 7 December 2005) with Wuxal Aminocal (15% calcium as calcium chloride) at a rate of 4 L in 500 L water/ha. On 12 December 2005, 10 fully-expanded, mature leaves were randomly taken from 10 plants (one leaf per plant) for each plot and sent to Gribbles Analytical Laboratories for analyses of Ca content.

Table 1: Calcium treatments.

Treatment number	Pre-plant Ca	Ca side-dressings	Ca foliar applications
1	–	–	–
2	–	–	+
3	–	+	–
4	–	+	+
5	+	–	–
6	+	–	+
7	+	+	–
8	+	+	+

4.2 *Experiment 2: copper treatments*

Eight copper treatments consisted of eight application times (Table 2). A three-nozzle knapsack was used to spray copper as copper hydroxide (Kocide 2000 DF) at a rate of 500 g product in 1000 L water/ha.

Table 2: Copper treatments.

Treatment number	Time of copper applications
1	No copper applications
2	15 days + 8 days + 1 day before wounding and inoculation
3	8 days + 1 day before wounding and inoculation
4	1 day (24-28 h) before wounding and inoculation
5	Same day (within 4 hours) as wounding and inoculation
6	1 day (24-28 h) after wounding and inoculation
7	3 days after wounding and inoculation
8	7 days after wounding and inoculation

4.3 *Wounding and bacterial treatments*

For both the Ca and copper experiments, the onions in each of the five sub-plots within the main plots were then wounded in a different manner (Figure *4: Using motor blower to blow onion leaves.* Table 3), with sub-plots randomly arranged within each plot. On 14 December 2005, onion foliage was wounded in four different ways to simulate different types of damage. (1) A weed eater was used to cut the tops of onion plants off, to simulate severe mechanical damage to the foliage (Figure 2); (2) A sand blaster was used to blow sand onto the foliage in an attempt to simulate hail damage (Figure 3); (3) A water blaster was used to spray water on to the onion plants, to simulate heavy rain (Figure 4); (4) A motor blower was used to simulate strong wind (Figure 5). The nozzles of the sand blaster, water blaster, and leaf blower were moved in a gentle sweeping motion 0.5–1 m above foliage for approximately 60 seconds per plot. The cuticle of the leaves was penetrated by the impacting sand from the sand blaster, and sap droplets formed at the wound site (Figure 6). Visible signs of damage caused by the water blaster and motor blower included flattened plants and cracks and tears in foliage, particularly at leaf bases.

Figure 2: Using a weed eater to cut off tops of onion leaves.

Figure 3: Sand blown onto onion leaves using motor blower.

Figure 4: Using water blaster on onion leaves.

Figure 5: Using motor blower to blow onion leaves.

*Figure 6**:** Sand from the sandblaster, upon striking onion leaves, left small puncture wounds <1 mm in diameter. A few seconds after being damaged, small droplets of moisture exuded from most wounds.*

Table 3: Wounding treatments.

Treatment number	Wounding method
1	None
2	Motor blower
3	Water blaster
4	Sand blaster
5	Weed eater

Within 5 minutes of completion of wounding, a three-nozzle knapsack was used to spray bacterial suspension (at rate of 300 mL suspension/m^2) onto the plants to the point of run-off. The bacterial suspension used for inoculation consisted of 24-hour-old cultures (grown on nutrient agar) of *Pseudomonas viridiflava* (ICMP 8132), *P. marginalis* (ICMP 8129), and *Erwinia carotovora* subsp. *carotovora* (ICMP 3915) in sterile water adjusted to a concentration of c. 10^8 colony-forming units per mL (cfu/mL) for each bacterium strain.

On 21 December 2005, 9 days after bacterial inoculation, 30 plants per plot (15 consecutive plants from the two middle rows of onions) from the centre of each sub-plot, were assessed for incidence and severity of soft rot, using a scale where 0 = no rot symptoms on mature leaves; 1 = one or two mature leaves infected; 2 = three or more mature leaves soft-rotted (Figure 7). A random sample of 100 plants in the trial on December 21 showed that the average onion had six mature (fully expanded) leaves and two immature leaves.

Figure 7: Foliar soft rot severity scale: 0 = no rot symptoms on mature leaves (onion at bottom); 1 = one or two mature leaves infected (middle onion); 2 = three or more mature leaves were soft-rotted (top onion). Photo taken 9 days after wounding and inoculation with soft rotting bacteria.

Onions were lifted by hand on 14 February 2006 when the foliage had collapsed (top-down) in more than 90% of the plants. Bulbs were left on the ground to field-cure for 10 days, then mechanically topped. Bulbs were graded according to bulb size, placed in nylon string bags, and a sample of 50 medium-sized bulbs from each sub-plot was stored in a ventilated shed at ambient temperatures (range 12–27°C) and humidity (range 70–85% RH). On 1 June 2006, all bulbs were cut in half longitudinally and examined for soft rot. Incidence of bulb rotting was determined; no attempt was made to measure the degree of rotting.

4.4 Statistical analysis

The mean foliage soft rot scores and the mean percentage of stored bulbs with soft rot were compared using analysis of variance (ANOVA). The calcium experiment was analysed as a randomised block, factorial, split-plot design with the eight Ca treatment combinations (2 × 2 × 2 factorial) applied to main plots, and the five wounding methods applied to sub-plots. The copper experiment was analysed as a randomised block, split-plot design with the eight copper treatments applied to main plots and the five wounding methods applied to sub-plots. Following a significant treatment effect, means were compared using Fisher's Least Significant Difference (LSD).

5 Results

5.1 Experiment 1

Foliage Ca content: Calcium applications, either individually or in combinations with each other, did not affect the Ca concentration in onion leaf tissues (Table 4). The lowest foliar calcium level (2.08%) was in onions that received base and side Ca applications, whereas the highest foliar Ca level (2.47%) was in onions that received base and foliar applications of Ca.

Foliage rot: Wounding of leaves prior to inoculation with soft-rotting bacteria had a big effect on severity of foliar rotting (Figure 8) and accounted for almost all of the variation in the foliage rot scores (ANOVA R^2 = 95%). Foliage rot scores were related to severity of damage: onions wounded using a weed eater had the highest mean foliar rot score (2.00), followed by sand blaster (1.76), water blaster (1.17) (Table 5, Figure 9), motor blower (0.73), and no wounding (0.00). These mean foliage rot scores were all significantly different from each other (P<0.001, 5% LSD = 0.08).

There was no difference in mean foliage rot score between the treatment with no calcium applied (Base–, Side–, Foliar–; mean 1.16) compared with the treatment with most calcium applied (Base+, Side+, Foliar+; mean 1.13) (Table 5, 5% LSD = 0.15). There was no interaction between the three kinds of calcium applications and the wounding method (Base×Wounding P=0.25, Side×Wounding P=0.92, Foliar×Wounding P=0.61, Table 6). This means that applying calcium had no effect on the amount of disease caused by the wounding treatments.

Table 4: Effects of calcium (Ca) applications and wounding methods on Ca content of foliage.

Calcium applications			
Base Ca	Side Ca	Foliar Ca	Foliage Ca content (%)
–	–	–	2.21
–	–	+	2.18
–	+	–	2.28
–	+	+	2.25
+	–	–	2.32
+	–	+	2.47
+	+	–	2.08
+	+	+	2.22
		Mean	2.25

Figure 8: Onions on right of pink tag were sand blasted, onions on the left were not wounded. Photo taken 9 days after wound-inoculation treatments.

Table 5: Effects of calcium (Ca) applications and wounding methods on incidence of bacterial soft rot in onion plants. Mean foliage rot score on 21 December 2005 (0 = no rot; 1 = 1–2 mature leaves infected; 2 = >2 mature leaves soft-rotted).

Calcium applications			Foliage wound method					
Base Ca	Side Ca	Foliar Ca	Weed eater	Sand blaster	Water blaster	Motor blower	No wounding	Mean
–	–	–	2.00	1.86	1.15	0.81	0.00	1.16
–	–	+	2.00	1.55	1.12	0.63	0.00	1.06
–	+	–	2.00	1.64	1.20	0.53	0.00	1.07
–	+	+	2.00	1.72	0.96	0.76	0.00	1.09
+	–	–	2.00	1.83	1.33	0.79	0.00	1.19
+	–	+	2.00	1.83	1.17	0.73	0.00	1.16
+	+	–	2.00	1.79	1.22	0.93	0.00	1.19
+	+	+	2.00	1.83	1.17	0.67	0.00	1.13
		Mean	2.00	1.76	1.17	0.73	0.00	1.13

Figure 9: Onion plants showing symptoms of foliar soft rot 9 days after water

Table 6: Effects of calcium applications and wounding methods on incidence of bacterial soft rot in onion plants. Mean foliage rot score on 21 December 2005 (0 = rot; 1 = 1–2 mature leaves infected; 2 = >2 mature leaves soft-rotted).

		Foliage wound method					
Calcium applications		Weed eater	Sand blaster	Water blaster	Motor blower	No wounding	Mean
Base	–	2.00	1.69	1.11	0.68	0.00	1.10
	+	2.00	1.82	1.23	0.78	0.00	1.17
Side	–	2.00	1.77	1.20	0.74	0.00	1.14
	+	2.00	1.75	1.14	0.72	0.00	1.12
Foliar	–	2.00	1.78	1.22	0.76	0.00	1.15
	+	2.00	1.73	1.11	0.70	0.00	1.11

Stored onion rot: In the calcium experiment, 1% (80 bulbs) of 8000 stored onion bulbs had bacterial soft rot present (Table 7). The effect of wounding was highly significant (P<0.001) and had the biggest effect on the presence of soft rot in the stored onions, accounting for half of the variation in the results (ANOVA, R^2 = 50%), whereas the calcium treatments accounted for much less of the variation (R^2 = 4.3%). The mean percentage of stored onion bulbs with rot present in the no wounding treatment (0.06%) was significantly lower than that in all of the other wounding treatments, and the weed eater treatment (2.9%) gave a significantly higher mean than the others (5% LSD = 0.44%). The motor blower, water blaster, and sand blaster treatments (0.6–0.8% bulbs with rot) were not significantly different from each other and were intermediate in percentage of rot to the other two wounding treatments. The calcium treatments on their own did not have a significant effect on the presence of rot in the stored onions (Foliar P=1.0, Side P=0.17, Base P=0.17), but there was an interaction between the side-dressing of calcium and the wounding treatments (P=0.001). The interaction was caused by the plants that were wounded with the weed eater and given calcium as a side dressing (Side+) having fewer bulbs with rot in storage (2.3%) than the Side-treatment (3.6%) (Table 8, 5% LSD = 0.62%). For all other wounding methods, there was no effect of a side-dressing of calcium on the amount of rot in stored onions (Table 8).

Table 7: Effects of calcium (Ca) applications and wounding methods on incidence of bacterial soft rot in onion bulbs in storage. Figures are the percentage of rotted bulbs on 1 June 2006.

Calcium applications			Foliage wound methods					
Base Ca	Side Ca	Foliar Ca	Weed eater	Sand blaster	Water blaster	Motor blower	No wounding	Mean
–	–	–	5	1	0	0.5	0	1.3
–	–	+	3.5	1	0	0.5	0	1.0
–	+	–	1.5	0.5	2	0	0	0.8
–	+	+	2	0.5	0	0	0	0.5
+	–	–	3	0.5	0.5	1.5	0	1.1
+	–	+	3	1	1	0	0	1.0
+	+	–	2.5	0.5	0.5	0.5	0	0.8
+	+	+	3	1.5	1	1.5	0.5	1.5
		Mean	2.94	0.81	0.63	0.56	0.06	1.00

Table 8: Effects of calcium applications and wounding methods on incidence of bacterial soft rot in onion bulbs in storage. Figures are the percentage of rotted bulbs on 1 June 2006.

		Foliage wound method					
Calcium applications		Weed eater	Sand blaster	Water blaster	Motor blower	No wounding	Mean
Base	–	3.0	0.8	0.5	0.3	0	0.90
	+	2.9	0.9	0.8	0.9	0.1	1.10
Side	–	3.6	0.9	0.4	0.6	0	1.10
	+	2.3	0.8	0.9	0.5	0.1	0.90
Foliar	–	3.0	0.6	0.8	0.6	0	1.00
	+	2.9	1.0	0.5	0.5	0.1	1.00

5.2 Experiment 2

Foliage rot: As with the calcium experiment, most of the variation in the foliage rot scores was caused by the wounding treatments (R^2 = 97%) with only very little of the variation caused by the copper treatments (R^2 = 0.4%). The wounding treatments were each significantly different from each other (*P*<0.001, 5% LSD = 0.05, Table 9). The order of the mean disease scores was the same as the order of the damage caused by the wounding: weed eater > sand blaster > water blaster > motor blower > no wounding.

The copper treatments had a small effect on the mean foliage rot scores (*P*=0.013). This was caused by the same-day copper application having a slightly lower mean foliage rot score than the other copper treatments (5% LSD = 0.07, Table 9). The difference is probably not agronomically important and seems to be because, compared with the other copper treatments, the same-day treatment had a slightly higher percentage of plants with no rot (score of 0) and a slightly lower percentage with a rot score of 2 (Table 10). There was no significant interaction between the copper treatments and the wounding treatments (*P*=0.70).

Table 9: Effects of copper applications and wounding methods on incidence of bacterial soft rot in onion plants. Mean foliage rot score on 21 December 2005 (0 = no rot; 1 = 1–2 mature leaves infected; 2 = >2 mature leaves soft-rotted).

	Foliage wound methods					
Copper applications	Weed eater	Sand blaster	Water blaster	Motor blower	No wounding	Mean
None	2.00	1.43	1.37	0.71	0.00	1.10
15, 8 & 1 days pre-	2.00	1.46	1.35	0.68	0.00	1.10
8 & 1 days pre-	2.00	1.41	1.26	0.64	0.00	1.06
1 day pre-	2.00	1.41	1.21	0.63	0.00	1.05
Same day	2.00	1.21	1.15	0.43	0.01	0.96
1 day post-	2.00	1.33	1.28	0.65	0.00	1.05
3 days post-	2.00	1.45	1.28	0.63	0.00	1.07
7 days post-	2.00	1.45	1.30	0.66	0.00	1.08
Mean	2.00	1.39	1.27	0.63	0.00	1.06

Table 10: Percentage of copper-treated onion plants with foliage rot score 2005 (0 = rot; 1 = 1–2 mature leaves infected; 2 = >2 mature leaves soft-rotted) in each of eight copper applications (rows: sum = 100%, n = 600).

	Bulb rot score		
Copper applications	0	1	2
None	33.7	22.5	43.8
15, 8 & 1 days pre-	34.2	21.8	44.0
8 & 1 days pre-	34.5	24.8	40.7
1 day pre-	37.3	20.5	42.2
Same day	39.7	24.8	35.5
1 day post-	35.2	24.5	40.3
3 days post-	35.8	21.2	43.0
7 days post-	34.5	22.8	42.7
Mean	35.6	22.9	41.5

Stored onion rot: Only a few (0.45%, 36 of 8000) onion bulbs in storage had bacterial soft rot evident. Because of this, any small effects of the treatments may not be discernable. There were no significant differences in the incidence of soft rot in stored onions among the copper treatments (P=0.66, 5% LSD = 0.5%), but there were differences caused by the wounding treatments (P<0.001) (5% LSD = 0.35%, Table 11). The weed eater method had greater incidence of rot than all of the other methods. The motor blowing and water blasting methods had a rot level no different to that of the no-wounding treatment. There was no significant interaction between the copper and wounding treatments (P=0.96).

Table 11: Effects of copper applications and wounding methods on incidence of bacterial soft rot in onion bulbs in storage. Figures are the percentage of rotted bulbs on 1 June 2006.

	Foliage wound methods					
Copper applications	Weed eater	Sand blaster	Water blaster	Motor blower	No wounding	Mean
None	2.0	1.0	0	0	0	0.60
15, 8 & 1 days pre-	1.5	0.5	0	0.5	0	0.50
8 & 1 days pre-	1.5	0.5	0	0	0	0.40
1 day pre-	1.5	0.5	0	0	0	0.40
Same day	1.0	0	0	0.5	0.5	0.40
1 day post-	1.5	0	0	0	0	0.30
3 days post-	1.5	0	0	0	0	0.30
7 days post-	2.0	1.0	0	0.5	0	0.70
Mean	1.56	0.44	0	0.19	0.06	0.45

6 Discussion

The field experiments clearly demonstrated that wounding of plant leaves is necessary for severe bacterial soft rot of onion foliage to occur. With a range of wounding treatments that increased in severity, there was a corresponding increase in both severity of foliage rot and incidence of rot in stored onion bulbs. The experiments also showed that application of calcium or copper did little to prevent or alleviate the presence of foliage soft rot or the presence of bacterial soft rot in onion bulbs in storage.

Increasing the level of wounding increased both the incidence of foliage rot and the percentage of stored onion bulbs with rot. All 1920 onions wounded with the weed eater (in both experiments) showed the highest level of foliage rot (> 2 mature leaves soft-rotted), whereas only one of 1920 un-wounded onions showed any foliage rot. In contrast to the high incidence of foliage rot, overall, only 1% or less of the stored onion bulbs showed rot in the two experiments. The effects of wounding were still apparent with between

26 and 49 times more rot in onions wounded by the weed eater than in the un-wounded onions.

The calcium and copper treatments seemed to have little or no effect on the levels of rot. However, there was evidence that adding a side-dressing of calcium reduced rot in stored bulbs, but this effect was noticed only for the most heavily wounded onions (weed eater treatment). Given the extent of rot and the small reduction (from 3.6% to 2.3% of bulbs with rot) the usefulness of calcium applications to growers is probably minimal.