



# Grower Summary

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## **FV 430**

Reducing wastage in stored  
winter cabbage and swede

Final 2016

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**Project title:** Reducing wastage in stored winter cabbage and swede

**Project number:** FV 430

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**Report:** Final report, November 2016

**Previous report:** Annual report, March 2015

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**Industry Representative:** Andy Richardson and Euan Alexander

**Date project commenced:** 1<sup>st</sup> April, 2014

**Date project completed:** 31<sup>st</sup> November, 2016  
(or expected completion date)

# **GROWER SUMMARY**

## **Headline**

Pre-harvest calcium spray programmes on cabbage increase the weight of harvested heads; increased head size reduces the firmness of internal leaves.

Calcium spray programmes on swede increase calcium content in roots and reduce the rate of tissue browning.

Post-harvest application of the biological control agent Serenade reduced the rate of storage rots caused by Botrytis.

## **Background**

Significant losses in winter cabbage and swedes occur after harvest with up to 30-40% wastage during storage, due to fungal decay and physiological breakdown. A number of post-harvest strategies that combine treatments to improve crop health and lower fungal load were tested to determine their effectiveness in reducing wastage. Pre-harvest nutrient sprays containing calcium and boron have been shown to improve firmness, reduce the rate of senescence and delay the onset of disease of harvested crops.

Additional treatments during storage such as ethylene removal on broccoli and ozone treatments on cucurbits have been reported to reduce water loss in stored products thereby improving the financial return on the saleable crop coming out of store.

The amount of ethylene removal required to provide significant effect on the quality of cabbage is unknown. Previous studies in broccoli stores (FV 395, WRAP) found ethylene accumulating (100-600 ppb) in stores where regular forklift (propane fuelled) activity occurred. Identifying threshold concentrations of ethylene that effect the storage quality of white winter cabbage will determine whether ethylene scrubbing technologies are appropriate for improving the storage quality of stored cabbage. Ozone has been trialled on a range of crops (cucumbers, courgettes, tomatoes) to reduce the incidence of disease and lower moisture loss. Identifying an effective dose of ozone, that lowers disease and water loss of cabbage and swede without discolouring cut surfaces has yet to be determined.

Alternative disease control techniques including advances in the development of bio-control agents such as Serenade (Bayer) afford the possibility to lower disease spread during storage caused by Botrytis. The combination of calcium sprays and post-harvest dipping with biological control agents may provide a viable alternative to current post-harvest fungicide application.

## Summary

A series of trials were initiated to investigate the effect of pre-harvest calcium/nutrients and post-harvest treatments to reduce the onset of disease in white cabbage and swedes.

In year 1, a field site for white winter cabbage cv. Cilion, planted on the 14<sup>th</sup> May 2014 was kindly provided by Naylor Farms, Lincolnshire, and for swede cv. Tweed; A W Mortier, Cedar Farm, Suffolk provided a field site. A randomised plot trial design using four replicate-plots per treatment and was managed by the Allium and Brassica Agronomy Ltd.

The four treatments were as follows: Untreated control, InCa (Plant Impact) – 1L/ha, Brassitrel Pro (Yara) – 4L/ha and Carnival (Headland) – 5L/ha. All sprays applied in 200L/ha water with 02F110 nozzles using a 2m spray boom.

A total of eight sprays were applied at two weekly intervals by the Allium and Brassica Agronomy Ltd starting in July and finishing in mid-October. Cabbages were hand harvested on the 5/6<sup>th</sup> November 2014 and swedes were hand harvested on 23<sup>rd</sup> October 2014. Cabbages and swedes were immediately transported to the Produce Quality Centre at East Malling Research where they were placed in a 1°C air store to remove field heat. Cabbages were stored subsequently under controlled atmosphere conditions of 5% CO<sub>2</sub>, 3% O<sub>2</sub> (1°C). Swedes were air-stored (1°C, 98% RH).

In the second year, a field site provided by Paul Freeman, John Sauls Farm, Boston, for a trial on white winter cabbage cv. Expect planted on the 13<sup>th</sup> June 2015. Two treatments were applied, an untreated control, and InCa (Plant Impact) – 1L/ha. All sprays were applied in 200L/ha water with 02F110 nozzles using a 2m spray boom. Treatments were applied later in the growing season on 1<sup>st</sup>, 15<sup>th</sup> and 28<sup>th</sup> September and the 7<sup>th</sup> October 2015. Cabbages were harvested on the 21<sup>st</sup> November 2015 and transferred to the Produce Quality Centre and stored in wooden bins in air at 1°C. Weather data for the two growing seasons is in the Appendix.

## Post-harvest treatments

### Cabbages: Disease control

In Year 1, cabbages were dipped in 200 L of solution in the following treatments;

Water, Serenade (Bayer) 30 mL L<sup>-1</sup>, F233 1 g L<sup>-1</sup>, + Bond sticker (1 mL L<sup>-1</sup>) and Rovral WG (BASF) 0.67g L<sup>-1</sup> /SL567A 0.104 mL L<sup>-1</sup>.

In year 2 cabbages were dipped in 200 L of solution in the following treatments;

Water, InCa (1 mL L<sup>-1</sup>), Serenade (Bayer) 30 mL L<sup>-1</sup>/InCa 1 mL L<sup>-1</sup>, Rovral WG (BASF) 0.67g L<sup>-1</sup> /SL567A 0.104 mL L<sup>-1</sup>.

Bins were transferred to a 1°C air store.

### **Cabbages: Ethylene -trial**

White winter cabbages (4-5 kg/head) were placed in 500 kg storage containers with a constant flow of air ( $1 \text{ L kg}^{-1} \text{ h}^{-1}$ ) amended with 0, 50, 100 or 150 ppb ethylene (BOC, UK).

### **Cabbages/Swede:Ozone-trial**

Cabbages and swedes were exposed to ozone (10 ppm) for 30 or 90 minutes. Treatments were repeated after two and four months of storage.

### **Swedes: Hydrogen peroxide trial**

In year one, Swedes were treated with hydrogen peroxide solution (StoreFresh 7 %  $\text{H}_2\text{O}_2$ ) using a hoselock spray applicator applied at  $100 \text{ mL t}^{-1}$  or  $200 \text{ mL t}^{-1}$ . Treatments were repeated every six weeks. In year two, dry-fogging of hydrogen peroxide was applied using a compressed air ultrasonic nozzle inside storage chambers delivering the equivalent of  $100 \text{ mL t}^{-1}$  or  $200 \text{ mL t}^{-1}$ . Treatments were applied in December, January and March. An additional treatment of dry fogging calcium (InCa  $420 \text{ mL t}^{-1}$ ) was included.

## **Results**

### **Cabbage- Year 1**

Pre-harvest application of InCa significantly increased the amount of calcium present in cabbage (Table 1) while Brassitrel Pro and Carnival increased the weight of cabbage heads (Table 2). The firmness of cabbages measured using a penetrometer showed a reduction in firmness in the tissue around the base of the stalk (heart) where calcium products were applied. Penetrometer testing of cabbages found the outer leaves (Table 2) of InCa and Carnival-treated cabbages were firmer.

All three calcium spray products are formulated with incorporation of nitrogen: Brassitrel Pro (6.9 % N w/w), Carnival (14.9 % N w/w) and InCa (4.5% N w/v). The combination of calcium and nitrogen increased the size of cabbages through encouraging tissue expansion causing a reduction in the density and compactness of central leaves. In general, application of calcium/nutrient sprays reduced weight loss in CA stored cabbage by ~1% over the first 3 months of storage.

On removal from CA storage after nine months cabbages were destructively sampled. The amount of wastage removed from cabbages was between 27.7-33.0% (Table 3), *Botrytis* infections made up the largest proportion of infections (20-22.8%) with a smaller amount of *Phytophthora* infections (7-10%) entering through the stems (Table 3). No treatment effects of pre-harvest application of calcium were observed.

### **Cabbage – Year 2**

The concentration of calcium in untreated cabbage averaged 33.4 mg 100g<sup>-1</sup> and was raised to 39.7 mg 100g<sup>-1</sup> by the InCa spray programme applied between September-October (Table 4). A similar increment in calcium content observed in year 1 (38.1 mg 100g<sup>-1</sup>) where an 8 treatment spray programme was implemented.

The proportion of infected tissue in air-stored cabbage (untreated) averaged 17.7% after 7 months storage in air (1°C); predominately caused by *Botrytis cinerea* (Table 13). Cabbages treated pre-harvest with InCa averaged 13.6% infected tissue. Post-harvest drenching with Serenade/InCa (9% rots) was as effective as Rovral/SL567A (6.5% rots) in reducing rotting caused by *Botrytis* (Table 13). Post-harvest application of InCa (14.6 %) failed to reduce the incidence of rotting compared to dipping in water (13.6%).

### **Swede – year 1**

All calcium spray programmes tested increased the calcium content of roots. Whether the resultant increase in calcium was the movement of calcium from leaves to roots is unknown. In addition to calcium, Brassitrel Pro increased iron, phosphate and manganese; InCa application increased potassium and phosphate and Carnival led to raised iron content in the roots. Interestingly, no increase in boron was observed in swedes even though Brassitrel Pro and Carnival are formulated with boron as a minor element.

No effect on yield or size distributions were observed between treatments and no increase in nitrogen or dry matter content in roots was recorded. Application of Carnival increased the resistance to splitting/crack formation after harvest when tested using a wedge fracture test. All calcium treatments reduced the rate of tissue browning in swedes cut after harvest.

*Botrytis* rots developed on the leaves and petioles with a large amount of visible sporulation, disease spread to the stem and in severe cases infection progressed to the main root. Initial experiments with hydrogen peroxide and ozone treatments to reduce inoculum load showed no reduction in stem or root rotting. There was no effect of calcium sprays controlling disease spread on leaves and no significant treatment effects were observed.

**Table 1.** Mineral content of cabbages sprayed with InCa, Brassitrel Pro and Carnival

Minerals	Control	InCa	Brassitrel Pro	Carnival	LSD <sub>0.05</sub>
<b>mg 100g<sup>-1</sup></b>					
<b>N</b>	161.5	180.2	150.2	175.8	30.2
<b>Ca</b>	32.62	<b>38.12</b>	31.6	36.85	4.5
<b>K</b>	210.5	218.5	202.8	<b>234.8</b>	19.6
<b>mg kg<sup>-1</sup></b>					
<b>B</b>	1.22	<b>1.53</b>	1.22	<b>1.44</b>	0.15
<b>% Dry Mat.</b>	8.9	8.6	8.5	8.9	0.31
<b>Ca/DM</b>	3.7	<b>4.3</b>	3.6	<b>4.2</b>	0.41

**Table 2.** Weight and firmness of cabbages sprayed with calcium products InCa, Brassitrel-Pro and Carnival

Treatment	Position	Control	InCa	Brassitrel Pro	Carnival	LSD <sub>0.05</sub>
<b>Weight (kg)</b>		3.6	3.8	<b>4.4</b>	<b>4.3</b>	0.21
<b>Firmness (N)</b>	Heart	101.1	<b>86.4</b>	<b>92.1</b>	<b>88.1</b>	3.72
<b>Firmness (N)</b>	Outer Cortex	94.8	<b>105.0</b>	<b>83.7</b>	<b>104.6</b>	3.72

*N.B.* Results in bold are significantly different ( $P < 0.05$ ) from the control within the same row

**Table 3.** The incidence of disease and weight loss in cabbage after nine months CA storage (5% CO<sub>2</sub>, 3% O<sub>2</sub> at 1°C) treated pre-harvest with calcium/nutrient sprays.

Storage time	Control	InCa	Brassitrel Pro	Carnival	LSD <sub>0.05</sub>
<b>% Total wastage (wt)</b>	29.1	33.0	27.7	30.8	10.84
<b>% Botrytis (wt)</b>	21.1	20.0	20.6	22.8	6.81

*N.B.* Results in bold are significantly different ( $P < 0.05$ ) from the control within the same row

**Table 4.** Mineral content of swedes sprayed with InCa, Brassitrel Pro and Carnival

Minerals	Control	InCa	Brassitrel-Pro	Carnival	LSD <sub>0.05</sub>
<b>mg 100g<sup>-1</sup></b>					
<b>N</b>	88.8	111.2	104.5	102.8	31.57
<b>Ca</b>	36.25	<b>40.15</b>	<b>42</b>	<b>41.52</b>	3.65
<b>K</b>	261	<b>297.5</b>	287.5	272.8	31.28
<b>mg kg<sup>-1</sup></b>					
<b>B</b>	1.97	1.94	2.01	2.01	0.2
<b>%Dry Mat.</b>	11.3	11.0	11.2	11.3	0.92
<b>Ca/DM</b>	4.1	4.5	<b>4.8</b>	<b>4.7</b>	0.41

*N.B.* Results in bold are significantly different ( $P < 0.05$ ) from the control within the same row



**Table 5.** Mineral analysis of cabbages (Year 2) treated pre-harvest with InCa

mg 100g <sup>-1</sup>	InCa	Control	LSD <sub>0.05</sub>	F prob
<b>N</b>	<b>209.9</b>	181.0	14.28	0.002
<b>Ca</b>	39.7	34.3	7.88	0.152
<b>K</b>	288.6	284.4	6.84	0.556
mg kg <sup>-1</sup>				
<b>Cu</b>	<b>0.23</b>	0.19	0.01	0.002
<b>Zn</b>	<b>1.38</b>	1.18	0.06	<.001
<b>B</b>	1.57	1.57	0.13	0.966

N.B. Results in bold are significantly different (P<0.05) from the control within the same row

**Table 6.** Harvest quality of cabbages (Year 2) subject to four late season applications of InCa

Cabbage	InCa	Control	LSD <sub>0.05</sub>	F prob
<b>Firmness (N)</b>				
Inner cortex	90.4	<b>94.5</b>	3.86	0.003
Outer cortex	59.9	<b>72.3</b>		
<b>Yield per head</b>				
Weight (kg)	<b>4.5</b>	4.2	0.14	<.001
<b>Leaf Colour</b>				
Colour L	71.1	72.6	1.38	0.032
Colour a	<b>-16.7</b>	-15.2	0.43	<.001
Colour b	<b>31.4</b>	29.5	1.41	0.009

N.B. Results in bold are significantly different (P<0.05) from the control within the same row

**Table 7.** The incidence of wastage caused by Botrytis infection in cabbages treated with pre- or post-harvest calcium (InCa) application or post-harvest application of Rovral/SL567A and combination of InCa/Serenade

Post-harvest Dipping trial				Pre-harvest Spray trial		Combined analysis	
InCa/Serenade	Rov/SL567A	Water	InCa	Control	InCa-Spray	LSD <sub>0.05</sub> on 18 df	F pr.
<b>9.0</b>	<b>6.5</b>	13.6	14.6	17.7	13.6	4.20	<.001
LSD (4.31 on 12 df)				LSD (4.99 on 6df)			

N.B. Results in bold are significantly different (P<0.05) from the control within the same row

**Table 8.** The incidence of Botrytis (*B. cinerea*) infection on Swedes treated with a dry fog of hydrogen peroxide (StoreFresh 7% v/v H<sub>2</sub>O<sub>2</sub>) or InCa, air-stored for six months (1°C)

Treatment	% Stem Infection		Stem severity (Max 60)		% Side rots	
	Stalks		Stalks			
	Trimmed	Untrimmed	Trimmed	Untrimmed	Trimmed	Untrimmed
<b>Water</b>	0.6	67.0	0.4	29.5	2.0	4.6
<b>Calcium</b>	0.7	75.6	0.1	32.8	5.5	10.2
<b>100 ml/t H<sub>2</sub>O<sub>2</sub></b>	2.6	76.8	1.4	34.9	8.1	5.0

<b>200 ml/t H<sub>2</sub>O<sub>2</sub></b>	2.0	72.5	0.7	31.8	4.6	5.9
<b>LSD</b>	2.89	20.14	1.46	9.84	5.08	6.09

### **Financial Benefits**

The potential financial benefits of this project are that growers may be able in future to use biological control agents such as Serenade to help combat *Botrytis* infections developing in winter cabbage during storage.

### **Action Points**

- Pre-harvest sprays of calcium formulated with nitrogen increased the weight of cabbages
- Larger cabbages tended to have softer centres - managing head development will be important in determining the crispness of leaves
- Application of InCa and Carnival increased the sucrose content of cabbages
- Post-harvest application of Serenade reduced post-harvest application of Botrytis
- Calcium sprays increased calcium content of swedes, reduced the onset of tissue browning and increased the sucrose content.
- Removing leaf and petiole material from the stalks of swedes reduced significantly the rate of disease development during storage
- Neither ozone or hydrogen peroxide applied at harvest nor a repeat application during storage reduced the rate of Botrytis infection of swedes.