European Innovation Partnership (EIP) Wales

Improving Knowledge and Experience of Micronutrient Management in Cucurbit Production in Wales

Interim Report - March 2021

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Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
European Agricultural Fund for Rural Development: Europe Investing in Rural Areas
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1 Introduction

Pumpkins are becoming an increasingly important crop for growers in Wales, where fruit can be grown for the pick-your-own (PYO) market in the run up to Halloween. Increasing customer interest in PYO pumpkins is a continuation of growth in farm diversification, and enables growers to achieve prices considerably greater than that achievable through conventional field vegetable marketing (e.g. supermarkets). However, pumpkins grown for the PYO market must be left in the field until October, often considerably after reaching harvest maturity. This also means that fruit cannot be cured as is typical with other cucurbits by storage in warm, dry conditions, and places the fruit at increased disease risk due to seasonal weather conditions. This places fruit at increased risk of rots, particularly blossom end rot (BER) caused by infection of the flower scar by a variety of pathogens (e.g. *Fusarium*, *Botrytis*). Not only does this reduce yield, but can also reduce the visual impact of the field which can be a key factor in marketing to customers. Fruit must be of the highest quality so even limited development can render fruit unmarketable, and in bad years up to 20% of the crop can be lost before market.

Conventional broad spectrum fungicides such as Signum (boscalid/pyraclostrobin) may offer some protection, although these are likely to be applied earlier in the season for powdery mildew control and so are likely to be ineffectual in the later season when fruit rots are prone to develop. However, there is an evolving body of evidence that ensuring sufficient calcium supply to the fruit during development can reduce rot incidence and severity. Calcium is used by the plant to strengthen crosslinks between cell wall components, providing mechanical strength and reducing the ability of pathogens to degrade cell walls, preventing rupture. Precise control of calcium in other crops at risk of BER development (e.g. tomato) has been proven to significantly reduce BER incidence. Sufficient control cannot be achieved to this extent in the field. While soil calcium levels are unlikely to be limiting – especially if suitable nutrition and pH management approaches are instigated – restrictions in calcium uptake and use in the plant (e.g. as a result of water stress) can lead to suboptimal calcium supply to the fruit. Even when sufficient calcium is taken up by the plant, higher rates of transpiration in the leaves may lead to a disproportionate supply of calcium to the leaf compared with the fruit, giving localised deficiencies and increasing the risk of BER development. Cultural approaches such as irrigation or the use of mulches can promote calcium uptake and use, although these options may not be available to growers on a large scale and are still subject to environmental impacts.

Foliar application of calcium can provide a method of uncoupling calcium nutrition from root supplies by providing a second, independent source of calcium. The use of foliar sprays containing calcium provides an additional supply to the leaves and fruit that is independent of soil uptake, helping to ensure that calcium demands of the developing fruit are met irrespective of environmental conditions. There is an evolving evidence base that foliar calcium applications can be beneficial in reducing losses due to BER in pumpkin. However, for niche crops little guidance is available as to the optimum application and efficacy of this approach, limiting the ability of growers to make use of foliar application of calcium to reduce BER losses in pumpkin. Calcium applied in this way is available in a variety of formulations, including with additional nutrients (nitrogen, boron or other micronutrients) and/or biostimulants, and how to best use these products (dosage, application methods and timings) is not documented. The application of foliar feeds may also impact crop responses such as increasing growth rates where biostimulants or additional nutrients are included in the feed, or risking changes in foliar disease development that could negatively impact production. Foliar products can be comparatively expensive, and this has impacted on the ability of growers to gain independent experience of using this method to reduce wastage and improve productivity of the pumpkin production. BER is also a concern in allied crops such as courgette and marrow, making the outputs of this project relevant to growers producing vegetable crops for farm shop sales.

This project was set up to explore the potential for foliar feeds of calcium to reduce the impact of BER in PYO pumpkins grown in Wales. Aberbran Fawr (site 1) and Gelynos Farm (site 2) are within 2 miles of each other, and are likely to encounter similar climate conditions and growing schedules to enable valid comparisons between the two sites. Two representative pumpkin crops grown for the PYO market in Wales were used to trial a range of products in commercial settings, followed by targeted assessments of disease development and nutrition status to appraise the impact of this approach.

2 Trial Design

A range of products were selected for inclusion in the trial, details of which are given in **Table 1** below. Rates were based on manufacturers' recommendations or extrapolated from comparable crops where these are absent. As a result some variation was seen in the achieved g/Ha of calcium after application, although the reported benefits of some formulations is that calcium availability to the plant increased through enhanced penetration of the product. Product 3 was included as a general organic foliar feed (rather than a specific calcium product) to test for organic-compatible products. Application rates are given below, with each product diluted in 200L of water, and applied at sufficient rates to achieve leaf runoff. All products were applied every 14 days from the onset of flowering, starting from the 16th July until harvest. Samples were taken on the 28 – 30th September in the week preceding the start of marketing in the run up to Halloween.

Table 1. Foliar spray products utilised in the trial.

Product Code	Formulation	Rate (L/Ha)	Calcium Content			Achieved g/Ha
			w/w	w/v	g/l	
N/A	Untreated	0				
2	CaO in a propriety formulation including AXM to promote calcium uptake in periods of low metabolic activity.	2	14.5	21.8	218	436
3	CaO-based organic growth stimulant containing concentrated extract of kelp species *Ecklonia maxima*. Approved as an unrestricted input by the Soil Association.	3			0.8	2.4
4	Calcium formulation including amino acids $(Ca_5H_4N_{12}O_{33})$, plant sugars, lignates and surfactants	3	13.8		138	138
5	Soluble calcium formulation with 30 g/L MgO, 149 g/L N and 300 ppm Zn	5			225	1125
6	Liquid micronutrient fertiliser (calcium chloride solution) for foliar application	5			224	1120

Site 1 had a pH of 5.8 on a sandy silt loam soil with 915 mg/L available calcium, while Site 2 had a pH of 6.6 on a sandy silt loam/sandy loam with 1035 mg/L available calcium before the start of the trial. Pumpkin cultivation was new to site 1 which had been previously used for fodder swedes for sheep grazing, compared with site 2 which had been used for pumpkins in 2019 following longer term grassland cultivation. Following soil analysis, fertiliser applications and lime were applied in line with RB209 to ensure nutrients were not limiting factors – although slightly less N than that recommended by RB209 was applied (a base dressing of 50 kg N/Ha) as is standard for pumpkin.

Plants for both sites were raised by the same propagator (Cae Melwr, Llanrwst) and were planted at the same time. Pumpkins can be established by direct drilling, although this requires a good seed bed and low weed burden. Both growers are relatively inexperienced with the crop and are growing in a cool climate, so propagated plants were considered the easiest route to establishment. Treatments were applied to three replicate plots at each site of 10m lengths of 2 rows width per site. Plots were separated by 1 row gap, or a 1m buffer strip between plots to prevent overspray (**Figure 1**). At the target density of 1 plant/m^2, with typical yields of 1 fruit per plant, this layout will achieve 20 fruit per plot for assessment. Fruit numbers are less than would typically be utilised in trials of this nature, but the large fruit size and low density would make larger-scale trials unfeasible.

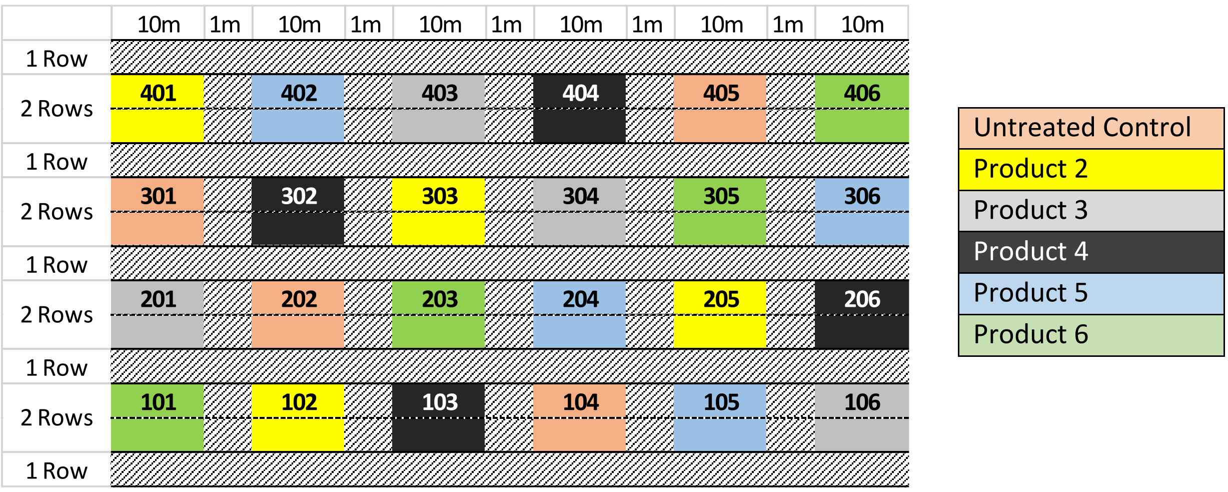

Figure 1. Trial layout replicated at each site. Plot numbers correspond to replicate blocking pattern.

3 Results

3.1 General Crop Responses

Despite difficult weather conditions and problems associated with the covid-19 outbreak (e.g. access to crops to monitor establishment and track progress towards flowering for suitable timing of applications), crops established well and reached maturity within typical thresholds (**Figure 2**). Weather conditions resulted in slightly later crop development than would normally be seen, with the wet autumn increasing the risk of rot development. Weed establishment was comparable between plots and between sites (54% ground cover and 51% at Site 1 and 2 respectively). The same weed management strategy was utilised at each site, although slightly different equipment was used for herbicide application and this may have had a slight impact on the crop. As an indicator of crop performance, flower number was recorded on the first and second site visit to each farm (16th and 30th July respectively) (**Figure 3**) to test for generative potential of the crop. Total flower number, and the proportion of female flowers, was greater at both sites at the second site visit although the number of flowers at Site 1 significantly exceeded that at Site 2 on both occasions. Leaf cover was comparable between treatments at each site, although Site 1 achieved lower leaf cover (32%) compared with Site 2 (52%). The trial area at Site 1 also suffered significant damage from rodent damage – fruit were scored as if marketable and recorded as being damaged separately from disease development.

Figure 2. Pumpkins at harvest at site 1 (left) and site 2 (right). Photographed 28th September 2020.

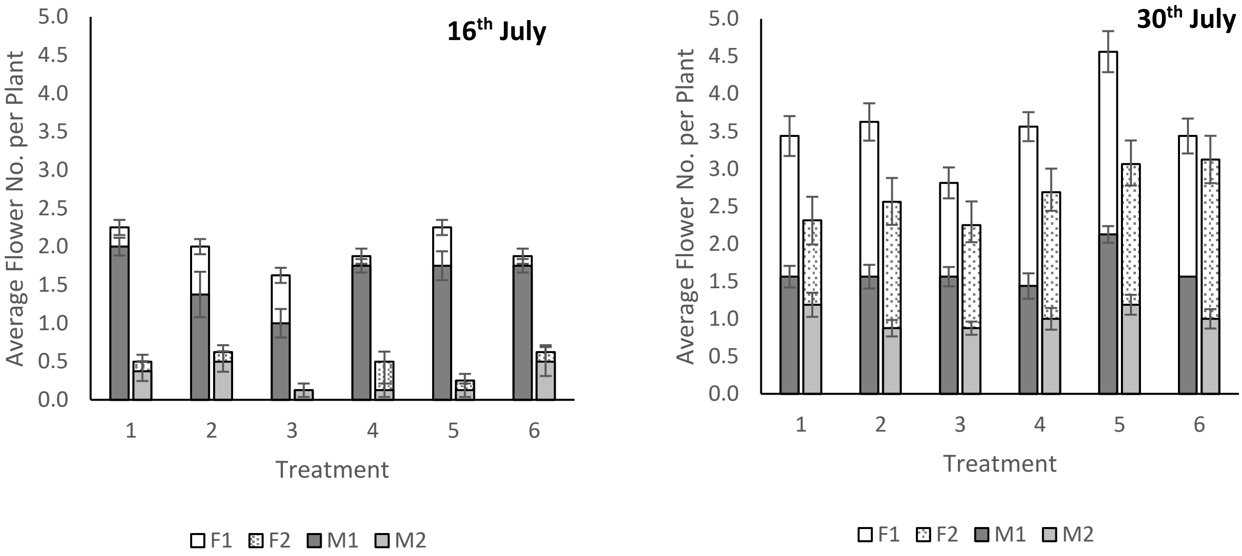

Figure 3. Male and female flower number recorded at Site 1 (F1/M1) and Site 2 (F2/M2) on the 16th and 30th July.

At harvest there were no significant differences in pumpkin number between site, or between treatment. However, significant differences were seen between treatment (p = 0.04) and site (p = 0.03), so these are presented separately in below (**Figure 4**). Overall, fruit at Site 2 were marginally smaller in diameter, although there were minor but significant differences between treatments with the treated fruit showing greater diameter than the untreated controls. At Site 1 treatment fruit were marginally larger, particularly treatments 5 and 6 compared with the control. At Site 2 the control fruit were smaller than those seen in the treatments, although no significant differences were seen between the treatments.

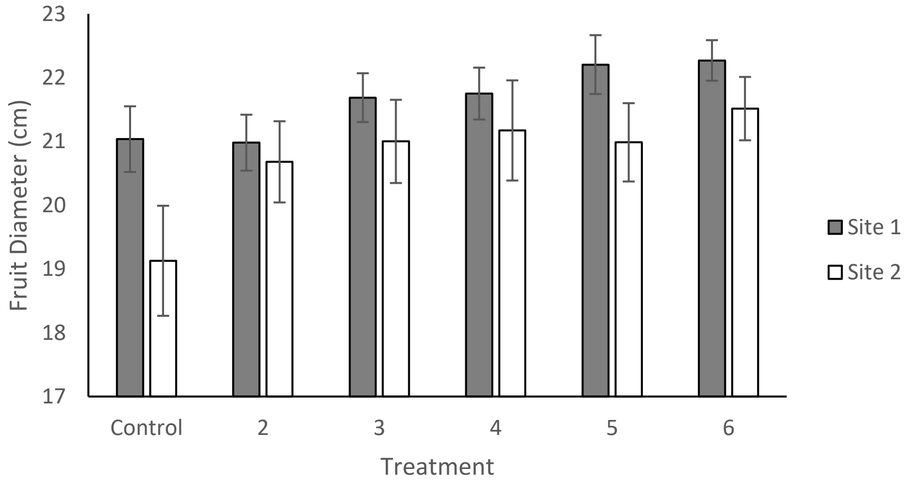

Figure 4. Average fruit diameter of pumpkins at harvest.

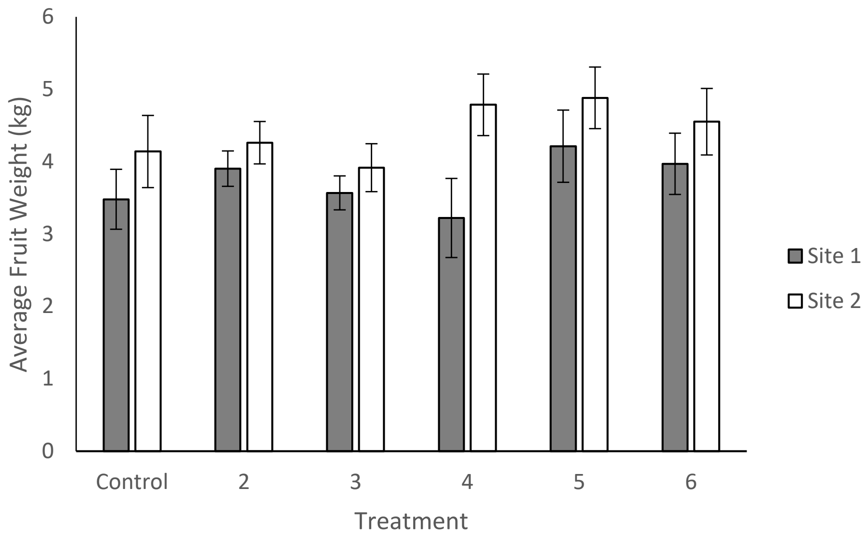

Figure 5. Average fruit weight of pumpkins at harvest.

Conversely, average fruit weight was greater at Site 1 than Site 2 (**Figure 5**). Treatments 4, 5 and 6 gave greater fruit weight at Site 1, although this was only significantly different than the untreated control for treatment 4. Likewise, fruit weight from treatments 5 and 6 were greater than the control at Site 1, but not at significant levels. These data suggest that some of the foliar treatments, particularly 5 and 6, may promote larger and heavier fruit – these treatments include other nutrients and so may have a wider benefit. However, these assessments were based on a limited fruit number and so it is difficult to draw conclusions at this stage.

The general climate at Site 1 was warmer and more sheltered than Site 2 – average day temperatures were 17.5°C and 16.8°C respectively, and night temperatures of 13.5°C and 14.5°C. Day time relative humidity was comparable at both sites (86%) but was higher at night at Site 1 (91% vs. 87%).

3.2 Fruit Calcium Content

Healthy fruit were sampled from each site to test for the impact of treatment on fruit calcium content. Two representative fruit per plot were sampled, and sections from the top, middle and bottom portion of the fruit were sampled for Ca content. Equal weights of fruit sections were combined into a single sample for analysis. Dry matter content (as mg/g dry matter) were converted to fresh matter content (as mg/g fresh matter) using water content figures determined for each sample. Average fruit Ca content varied significantly both within and between treatments, but was proportionately lower at Site 1 compared with Site 2 (**Figure 6**). As a general trend a decrease in Ca was seen between the upper and lower sections of the fruit at both sites, demonstrating a calcium gradient across the fruit. There is significant variation in the results, most likely as a result of the limited sample size used for analysis. However, Site 2 indicates that fruit Ca content may be boosted by foliar applications, as treatments 2, 4, 5 and 6 exceeded that seen in the untreated control fruit.

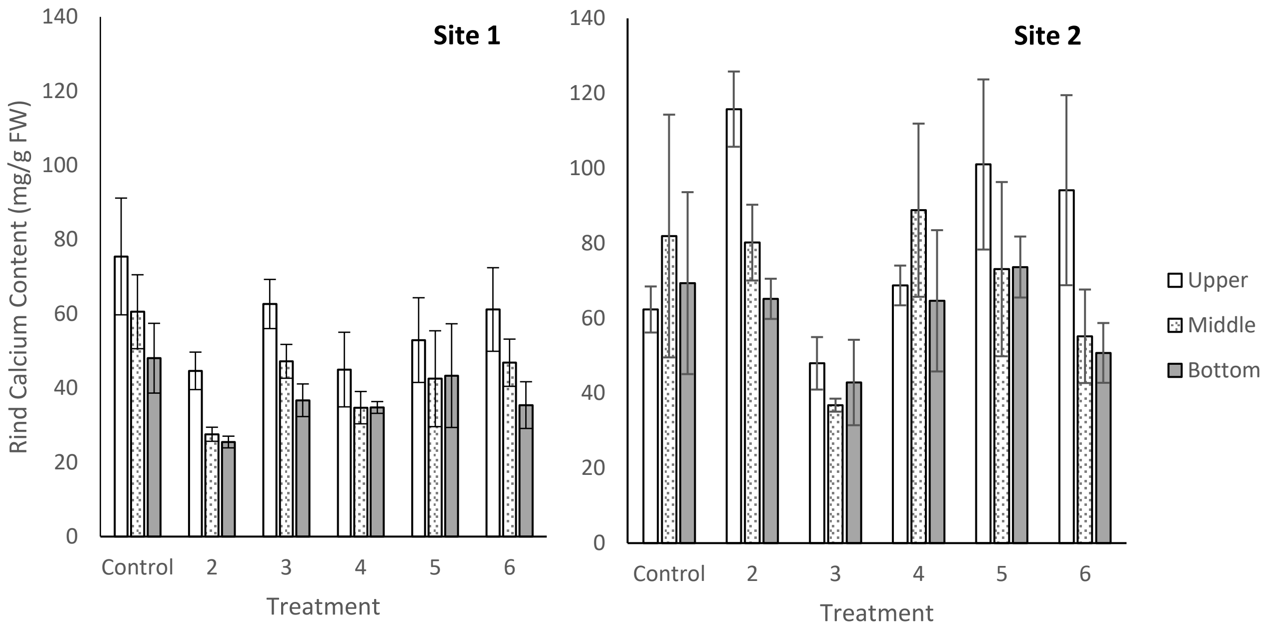

Figure 6. Average fruit calcium content of fruit sampled at harvest, expressed as mg Ca/g FW of rind.

3.3 Disease Development

Fruit were assessed in the field for rot development, including number and size of rot. The percentage of fruits exhibiting rots (as a proportion of total fruit of marketable size) was significantly greater at Site 2 across all treatments compared with Site 1 (**Figure 7**). As pumpkins were grown the previous year at site 2 there may be slightly higher levels of inoculum in the soil leading to the differences seen here, although the range of organisms that can caused BER are likely to be already present in the environment, and other factors (e.g. climate) may have had a more significant impact. At Site 1 treatments 2 and 5 gave significantly lower incidence of rot compared with the control, whilst treatments 3, 4 and 6 were relatively comparable to the untreated control. At Site 2 average fruit rots showed no significant differences between treatments and the control due to variation in numbers between plots, although rot numbers were slightly reduced in treatments 2, 3 and 4.

For fruits showing rot, the proportion of the fruit rotted at harvest was also determined (**Figure 8**). Treatments 2, 3 and 4 showed reduced rot severity compared with the control, although this was not significant between treatments.

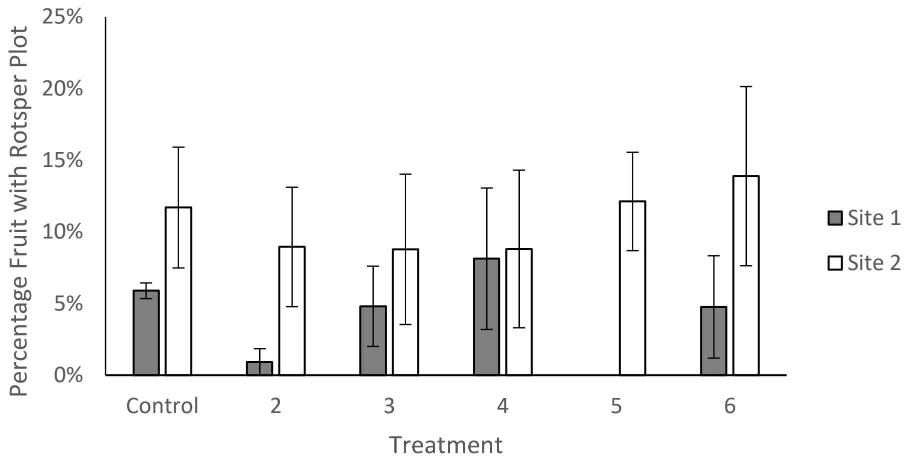

Figure 7. Percentage of rotted fruits per treatment at both sites.

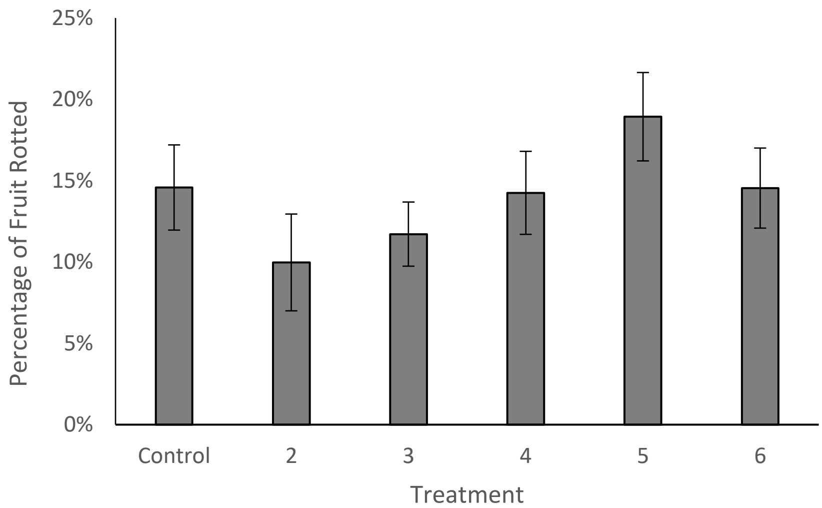

Figure 8. Rot severity per treatment as determined by percentage of fruit rotted.

3.4 Post Harvest Rot Development

At harvest two representative pumpkins from three plots at each site were sampled and stored in mock commercial conditions (20°C with a 12 hour light cycle). Fruit were surface sterilised before wounding and inoculation with *Fusarium* cultures previously isolated from pumpkin as a source material. The inoculations did not take, although sufficient disease pressure from natural sources was present to ensure sufficient levels of rot development occurred in storage. Fruit were assessed for rot incidence and severity up to four weeks after harvest. Pumpkins sampled from Site 1 showed lower rot incidence in treatments 2, 3, 5 and 6 (most significantly in treatments 5 and 6. Pumpkins sampled from Site 2 showed high level of rot development except for treatment 5 (**Figure 9**).

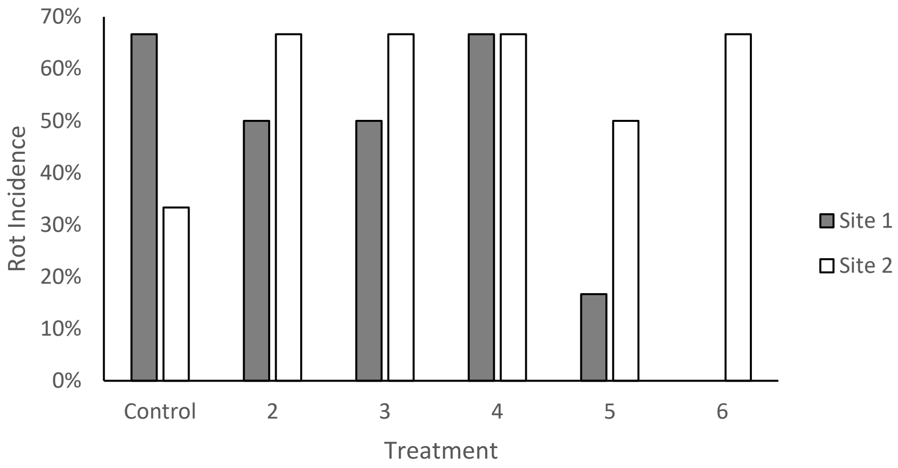

Figure 9. Incidence of postharvest rot development in pumpkin, pooled per treatment.

4 Summary of Year 1

Broad variation was seen within and between both sites. However, as the pumpkin cultivars used were of F1 hybrid origin, significant variation due to various agronomic factors is to be expected (including climatic and soil-related features which are likely to be highly heterogenous in Wales). In addition, large fruit size and low density limits the number of individual fruit that can be assessed, further impacting the ability to identify statistically significant differences unless very large differences are seen between treatments. Despite the variation, there are some strong indications in the data produced that foliar calcium applications can have a positive effect on rot development in pumpkin.

Foliar applications of Ca did lead to increased fruit Ca concentration, particularly at site 2 (**Figure 6**). It is noteworthy that treatment 3 is the only foliar feed that did not lead to increased fruit Ca concentrations – in comparison with the other treatments the achieved calcium content is several orders of magnitude less than that achieved by the other treatments (**Table 1**). Likewise, the greatest fruit concentrations were achieved in treatments 2, 5 and 6, corresponding with the greater concentrations of applied Ca to the fruit.

While overall rot development was limited, differences were seen between treatments, with treatments 2 and 5 in particular showing reduced proportions of rotted fruit in the field (**Figure 7**). Treatment 5 (along with treatment 6) in particular reduced postharvest rot development, giving further indications that foliar Ca applications can help to mitigate rot development.

The provision of additional nutrients may also enhance fruit size (**Figure 4**), particularly with treatments 5 and 6. Many pick your own growers will grade fruit on size as opposed to weight (e.g. dropping fruit through holes of varying diameter to determine price at the point of sale) so increasing fruit size may enhance profitability of the fruit produced.

Improved calcium nutrition may enhance the ability of the fruit to mitigate rot risk, but if conditions and disease pressure are great then rot onset will still be seen. An additional aspect is that the development of rots is linked to a number of site-specific factors, and that the low incidence of rots in a low calcium-background (or vice versa) may not be directly related to total calcium content if significant differences in disease pressure were present between sites (e.g. surface wetness, temperature and disease pressure). Therefore, the high incidence of rots despite the high level of fruit calcium content at Site 2 may be due to elevated disease pressures.

It is noteworthy that treatment 2 seems to have had the smallest effect on fruit condition, whilst treatments 5 and 6 have had the largest impact. Treatments 5 and 6 provided the greatest level of applied Ca per ha (**Table 1**), which is potentially indicative of a dosage response. This effect is not translated through to the achieved Ca concentration of the fruit, although the highly variable and limited sample size here limits the extent to which this data can be examined.

Overall, this project has so far demonstrated that foliar treatments may improve fruit calcium status, and this may translate through to improved resistance to rot development. However, the variability of the results produced this season precludes any firm conclusions, although this will be addressed through repetition of this work in the 2021 season to further explore the impact of foliar feeding on rot development.

5 Plans for the Next Season

The trials carried out in the 2020 season will repeated at the same sites in 2021. This will allow a second set of data, collected under different conditions, to be accumulated to further explore the impact of foliar calcium feeding in pumpkin to reduce rots. Given that weather conditions approaching harvest are the predominant factor in developing rots this will allow further testing of these products in a different season. Other aspects (e.g. rodent damage) will also be subject to additional controls to mitigate crop losses to other causes. It is likely that the crops will be grown on the same sites, so that both sites will have a history of pumpkin cultivation to provide even disease risk exposure should any differences have impacted results this year. While other aspects (e.g. spraying frequency, rates) could be adjusted it is recommended that treatments are applied in the same way as the 2020 season as replication will help support any clear messages coming from this work as opposed to introducing further levels of variation. It will also be necessary to undertake a financial appraisal of this approach, including the cost of products and from application requirements to develop an understanding of the likely cost/benefit implications of foliar feeding in a typical PYO pumpkin crop.

While this project will be replicated at the same sites, there are a range of other variables that could be explored to expand on the themes developed in the 2020 season. For example, grower feedback suggested that applications every two weeks may incur labour costs at a level that would make it difficult to achieve comparable economic returns from the crop. Less frequent applications may improve the economic basis of using these materials, but there is a risk that their effects will be diluted to less frequent applications reducing the availability of calcium to the fruit. This is reflected in the lack of pumpkin-specific guidance from the manufacturers, and could be further explored through optimisation of dose/application frequency in later trials. In addition, there could be a potential to tank mix these products with other sprays being applied to the crop such as fungicides for foliar disease control. This could reduce application costs whilst potentially enhancing the impact of the materials, although this would require further testing for a combined impact. Lastly, as weather conditions are the primary driver of BER risk in pumpkin, replication in conditions where disease risk is likely to be enhanced may inform the cost:benefit analysis that will be performed for these products. These aspects will be explored during the planning stages for the 2021 season, including feedback from the operational group, to identify the most positive project plan for the second year of this EIP project.