Final Report

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Investigation of skin hardening and splitting disorders in sweetpotato

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Summary

The most popular gold sweetpotato variety is prone to splitting in cooler weather. Other varieties are prone to skinning damage. Preliminary USA generated data indicates a link between nutrition and skin hardening. This project initiated a collaborative Australian and USA study to investigate the roles of nutrients in skinning and splitting of sweetpotatoes.

The Australian, industry valued at $87.7M (2016-17) is increasing in significance. A high-quality uniform, tasty product determines customer satisfaction. In recent years, higher performing USA varieties have met these parameters. In the same period, Australian sweetpotato farmers have moved from seasonal to year-round production. Now, farmers are seeing increases in storage root splitting, reducing their marketable yields. 10-30% splitting rates have been observed, often during cooler weather harvests. Bellevue, the only nematode resistant cv which makes up 80% of the current Australian market is particularly susceptible to splitting. A second, issue affecting marketability is skinning damage during harvest and post-harvest operations leading to darkened skin lesions. Several varieties (gold / red / white /purple) are prone to this. Skinning is becoming a greater problem with the American bred single skin varieties entering the market.

Researchers from the Department of Agriculture and Fisheries (DAF) partnered with sweetpotato physiologist Professor Arthur Villordon (Louisiana State University (LSU) AgCenter) to investigate links between key nutrients and skin hardening. Replicated glasshouse studies were undertaken to investigate the individual effects of nutrients. Multiple trials were conducted at the DAF Bundaberg Research Facility (BRF), and LSU Chase, Sweetpotato Research Station in 2019 and 2020. Queensland experiments focused on links between calcium and boron in four varieties. Louisiana studies focused on the roles of nitrogen source (nitrate vs. ammonium) and phosphorus availability on the incidence of early storage root splitting in variety ‘Georgia Jet’.

No splitting was observed in either experiment in Qld. The omission of boron or calcium had no significant effect on root weight, root length, root diameter and total number of roots per plant across all four varieties. However significant differences were identified in individual variety responses. Individual analysis indicated that Bienville root weights were significantly higher and Beauregard roots were significantly longer in the minus boron treatments, experiment. Periderm width values were generally higher in all varieties in experiment two conducted during cooler weather than experiment one conducted during summer. The Louisiana experiments indicated that although ammonium and nitrate forms of nitrogen have roles in sweetpotato splitting, other environmental variables and nutrients are involved.

This successful international collaboration has ensured Australian researchers and industry are at the forefront of international sweetpotato research. The DAF sweetpotato team has been able to successfully conduct technical collaborative research through a period of international upheaval. Researchers have installed a specialised water filtration system at BRF enabling further research in this field. Australian sweetpotato researchers have gained skills in controlled nutrient studies and standardised methodologies now exist between countries. A skinning evaluation tool has been constructed and is now available for use in future projects.

Recommendations for future work include further experiments to investigate calcium and boron effects over the winter months. Detailed investigation of the role of boron and variety in periderm thickness determination and nitrate vs. ammonium studies in storage root spitting. Follow on possible interaction between temperature and splitting associated with nitrate using the ‘Georgia Jet’ as the experimental system.

Keywords

Sweetpotato; skinning, splitting; nutrients, calcium, boron.

Introduction

In Australia, the sweetpotato industry is one of increasing significance, with a fresh market value of $87.7M (2016-17). Consumer satisfaction is directly related to a high-quality consistent product of uniform appearance and taste.

Recent years have seen an increase in the introduction of higher performing USA-developed varieties as well as a change from seasonal to year-round production. At the same time, farmers have identified an increase in storage root splitting, reducing marketable yields. On-farm splitting rates of 10-30% have been observed, during cooler weather harvests. The nematode resistant variety, Bellevue, (Figure 1), now 80% of the current Australian sweetpotato market is particularly susceptible to splitting.

A second, long standing issue affecting sweetpotato marketability is that of skinning damage (Figure 1), during harvest and post-harvest operations. This leads to the development of unsightly, sunken, and later darkened areas on the skin surface. Several varieties (gold / red / white /purple) are prone to this damage. This issue is becoming more important with new American bred single skin varieties entering the market.

Figure 1. Left: Skinning in cv. Murasaki 29. Right: Splitting in cv. Bellevue.

In general, very little is known about non-pathogenic causes of storage root splitting or why some varieties are more prone to skinning. Other than prior evidence linking boron deficiency with skin blister, there is no current data available on specific causes of sweetpotato splitting or skinning. Researchers at the Louisiana State University AgCenter, Sweet Potato Research Station (LSU AgCentre) have generated preliminary data supporting the hypothesis that there may be linkages among variety, nutrition, and skin hardening (thickening of the periderm and cortex). This preliminary greenhouse work was conducted using a mericlone of the sweetpotato variety “Georgia Jet” that is prone to splitting in field conditions.

Recent evidence from ongoing studies at the LSU Ag Centre also supports the evidence that variety effects may in part be attributed to periderm thickness. In other root crops, it has been determined that thicker periderms are associated with the tendency of longitudinal splitting (Lockley, 2016).

Preliminary data support the hypothesis that nitrogen plays a role in storage root splitting in susceptible varieties. There is also some evidence that calcium, boron, and potassium may play indirect or contributing roles in skinning or splitting. In this research, priority was given to nitrogen (N), potassium (K), calcium (Ca), and boron (B).
Under controlled environments, this project undertook exploratory pot trials to identify possible interactions and/or links between calcium, boron, nitrogen and phosphorus and their relationship to splitting and skinning of sweetpotato roots. These trials were conducted as a collaborative venture

between the Department of Agriculture and Fisheries (DAF) sweetpotato researchers and LSU AgCenter sweetpotato physiologist, Professor Arthur Villordon.

Methodology

Queensland experiments
Preliminary glasshouse studies were undertaken in Australia at the DAF Bundaberg Research Facility, Queensland and in Louisiana at the LSU Sweetpotato Research Station, Chase in 2019 and 2020. Aligned with the Louisiana studies, Queensland pot experiments were designed to investigate any individual effects of boron and calcium on splitting and skinning. Randomised complete block design experiments incorporated three nutrition treatments and four susceptible varieties with six replicates of 1 plant/plot.

Experiment 1 was planted on December 3, 2019 and experiment 2 was planted on February 18, 2020. The varieties selected for the experiments were Beauregard (known control), Bienville and Bellevue, (highly susceptible to splitting at harvest) and Murasaki (susceptible to skinning). Virus (pathogen) tested standardised vine tip cuttings (25 to 35cm long) were vertically planted into pots containing sand and placed onto mesh benches with wheels, 24 pots were allocated to each bench and benches were rotated weekly to ensure even lighting.

Nutrient application
For the first 5 Days after planting (DAP) all plants received 225 ml of the quarter-strength complete nutrient solution morning and afternoon. This approach was designed to avoid wilting and nutrient runoff while initial root set was occurring. From days one to 50 all plants received 450 ml of complete Hoagland nutrient solution, three times per week. Excess solution was initially captured in a pot tray in experiment one. After foliage toxicity was noticed at 30 DAP, excess nutrient was then allowed to drain from the pots for the remainder of the experiments.

From day 51 to day 140 (time of the final harvest). Plants received 600 ml of their one of the three designated nutrient treatments.

- Hoagland's nutrient solution (complete)
- Hoagland's nutrient solution minus Boron (-B)
- Hoagland's nutrient solution minus Calcium (-Ca)

Reverse Osmosis (RO) water was used in all nutrient solutions to remove minerals such as calcium and eliminate effects of any volatile chemicals such as chlorine in the local water supply. When required it was also used for direct watering of plants. Pests and diseases were controlled in the screen house by regular monitoring, the use of yellow sticky traps to attract whiteflies, aphids and other insects and a scheduled preventative spray program.

Two destructive samplings at 50 and 140 days after planting (DAP), were conducted. The 50-day harvest was to establish a baseline prior to nutrient treatment application while the second harvest at 140 DAP was to replicate a commercial harvest. Storage roots were evaluated for splitting. Other measurements included aboveground biomass, total number of roots per plant, number of roots per node, individual root weight, length and diameter. Due to the balanced nature of the design, analysis of variance (ANOVA) was used to analyse all variables.

To simulate susceptibility to skinning, two average-size storage roots randomly chosen from each plant were subjected to hydraulic periderm removal at each harvest. The hydraulic periderm removal technique, designed by Prof. Villordon, (in publication) uses water pressure to measure skin adhesion or time to periderm removal. Roots were clamped to a retort stand and exposed to a jet of water at 50 psi, at a fixed distance of 70cm. The time taken to remove periderm tissue (peel the root) was recorded using a stopwatch. Data captured at the 50 DAP harvest provided a baseline to evaluate any nutrient effects on periderm thickness at 140 DAP.

To investigate the hypothesis that periderm thickness influences individual variety's susceptibility to splitting and skinning, periderm measurements were obtained. A microscope-mounted camera and NIS software were used to measure periderm thickness on representative storage roots from each

plant. Again, data from the 50 DAP harvests provided baseline data to compare to future harvests.

Louisiana experiments

Exposure to simulated and natural low temperature and splitting.

The varieties used were 'Evangeline', 'Bellevue' and 'Beauregard'. Low substrate temperatures were simulated by wrapping pots in coils attached to a water chiller (Fig. 1A). Pots in the control treatment were also wrapped in coil and insulation but not chilled. All plants were initially grown with the standard temperature regime. After 60 days, low night substrate temperature treatments (substrate temperature = 15C) were imposed on designated pots. Storage root samplings were made 10 and 20 days after the imposition of the low temperature treatments (Fig. 1B). Some pots were also taken outside and exposed to near freezing (below 5C; Fig. 2) temperatures during the early to middle part of October 2019.

Ammonium vs. nitrate effects on storage root splitting

The varieties used were 'Georgia Jet', 'Beauregard', and 'Evangeline'. Plants were provided with half strength Hoagland's nutrient solution with either nitrate or ammonium as the nitrogen source. Storage roots were sampled at 50 days and assessed for splitting.

Phosphorus and storage root splitting follow-up work

In the prior study, it was observed the splitting was more prevalent in plants grown with nitrate as the nitrogen source vs ammonium. This follow-up work investigated the possible role of phosphorus (P) availability in Ga Jet plants provided with nitrate as the N source. P was given priority due to its well-documented role in root architecture development and root system adaptations to variation in P availability.

Three experimental treatments were used in this study: Hoagland's nutrient solution without P (0P), 16 ppm P (1X), and 32 ppm P (2X).

Early in the project a Project Reference Group (PRG) made up of sweetpotato growers from the Australian Sweetpotato Growers Association Inc, research and development committee was formed to provide tactical direction, oversight and support to ensure that the project meets its objectives.

An initial planning meeting was held in Bundaberg on the 7 November 2019, coinciding with Professor Villordons Australian visit from the 1-13 November 2019. A project update was held in both Bundaberg and Cudgen for growers and stakeholders in November 2019 also aligned to Prof Villordons visit. A PRG meeting to discuss experimental results was delivered on line on the 4th of November 2020 and a grower update was delivered by zoom on 12 November 2020.

Although control measures related to Covid-19 have affected aspects of the communication extension activities the project team continued to communicate with Professor Villordon and the PRG via phone and zoom meetings. The planned Australian visit of Prof. Villordon (28 March – 8 April 2020) has now been rescheduled for 2021.

Outputs

Project Planning and implementation

- A program logic with linkage to Hort Innovation and industry/fund objectives.
- A monitoring and evaluation plan.
- A stakeholder engagement plan.
- Six monthly milestone reports (two).
- Final report to inform industry of direction for future research and development to address skinning and splitting issues.
- Protocols, safe operating procedures, and risk assessments developed for project activities and added to DAF register.
- Developed hydraulic periderm removal tool for quantification of skinning susceptibility in sweetpotato.

Communication and Extension activities

- Trial results documented and communicated to industry both as reports and presentations at grower/industry meetings, in Bundaberg and Cudgen. In 2020, farmer group workshops, the preferred communication format were unable to be conducted so webinars were used as an alternative delivery method.
- Report produced on initial results in Queensland.
- Report produced on initial results in Louisiana.
- Report produced on Prof. Villordon Australian visit, November 2019.
- Although control measures related to Covid-19 have affected aspects of the communication extension activities. The planned Australian visit of Prof. Villordon (March 2020) had to be cancelled and is now rescheduled for November 2021.
- Results were presented to the PRG November 2020.

Table 1. List of grower engagement events.

Event	Where	Date	Type	Who	Businesses	Project team
On farm visit – LSU tour of AUS	Bundaberg, QLD	05/11/2019	Face to Face	LSU, DAF and grower	3	4
On farm visit – LSU tour of AUS	Bundaberg, QLD	05/11/2019	Face to face	LSU, DAF and grower	3	4
On farm visit – LSU tour of AUS	Bundaberg, QLD	07/11/2019	Face to face	LSU, DAF and grower	1	4
Initial PRG Meeting	Bundaberg, QLD	07/11/2019	Face to face	PRG and Project Team (LSU and DAF)	4	4
Project Update	Bundaberg, QLD	07/11/2019	Face to face	Growers and project team	11	4
On farm visit – LSU tour of AUS	central, QLD	09/11/2019	Face to face	LSU and grower	2	1
On farm visit – LSU tour of AUS	central, QLD	09/11/2019	Face to face	LSU and grower	5	1
On farm visit – LSU tour of AUS	Cudgen NSW	11/11/2019	Face to face	LSU, DAF and grower	2	4
Project Update	Cudgen, NSW	11/11/2019	Face to face	Growers and project team	7	4
Quick response to PRG - toxicity incidence	Online	02/01/2020 to 12/01/2020	Email	PRG member, LSU and DAF	2	5
PRG Meeting	Online	04/11/2020	Zoom	PRG and Project team	5	5
Team Meeting	Online	27/04/2020	Microsoft Teams	Project Team	0	5
Team meeting	Online	27/05/2020	Microsoft Teams	DAF project team	0	5
Team Meeting	Online	12/10/2020	Microsoft Teams	Project Team	0	5
Team Meeting	Online	27/10/2020	Microsoft Teams	Project Team	6	5
Team Meeting	Online	05/11/2020	Zoom	Project Team	0	5
Team Meeting	Online	12/11/2020	Zoom	Project Team	0	5
Project update	Online	12/11/2020	Zoom	Growers and Project Team	14	5

Outcomes

- It is not expected that project findings will lead to immediate on farm adoption. Rather, this pilot study has provided an insight into the complexities of nutritional and variety relationships between skin hardening, that influences splitting and skinning in Australia's main sweetpotato varieties.

- The Australian industry has new understanding of the interactions and physiological attributes between individual varieties and nutrients, both those bred in the USA and of Australian origin and their adaptability to the expanded year-round Australian production system.

- Improved understanding of nutritional and climatic interactions in sweetpotato root development in pot trials. This has identified pathways for future research to reduce yield losses.

- Mutually beneficial international collaborative partnerships established to overcome sweetpotato production issues (skinning and splitting).

- Positive collaboration and communication between Australian and USA project staff led to successful trial implementation.

- Australian researchers have gained increased knowledge, skills and experience through collaboration with overseas sweetpotato experts.

- Overseas experts have increased knowledge and experience on specific variety performance under year-round Australian growing conditions. This has enhanced research capability to benefit Australian growers.

Monitoring and evaluation

Effectiveness

This pilot study has provided data on interactions between key nutrients and individual sweetpotato varieties. The studies in Australia and the US have provided an insight into the complexities of the interactions between individual varieties and their growing environments, providing background for future research.

The project was extremely relevant to the sweetpotato industry with the PRG providing strategic oversight of the project activities such as experimental design, final decision on varieties studied and project progress reviews. This process ensured grower focused outcomes to meet the needs of levy payers and made sure that it was tracking according to plan.

The intended beneficiaries are sweetpotato growers (levy payers). Face to face updates were presented to growers in Bundaberg and Cudgen in November 2019. Zoom updates were presented to growers in November 2020.

A face to face PRG meeting was conducted in Bundaberg in November 2019. A PRG meeting was conducted via zoom in November 2020. Phone discussions were conducted throughout the life of the project in relation to issues such as the burning off that occurred in late 2019 and early 2020.
A Project update newsletter was sent out to all growers in December 2019.
Growers were updated on the projects progress during numerous on farm visits as part of the project and others throughout the life of the project.

Control measures related to Covid-19 have affected aspects of the communication extension activities. The planned Australian visit of Prof. Villordon (28 March – 8 April 2020) had to be

cancelled. This was initially rescheduled for November 2020 but has now been booked for 2021. A project update and glasshouse walk were planned to coincide with Prof Villordons visit which was also cancelled. As the preferred communication format of farmer group workshops were unable to be conducted in 2020, webinars were used as an alternative delivery method. Detailed instructions were developed by the project team on joining zoom meetings for computer, mobile devices both iOS and android. The project team also set up a help / "hot" line to assist participants in real time with technical issues in logging in to the webinar.

An online survey tool was designed to capture grower feedback on project update presentations Results indicated that 100% of participants rated the quality of the presentation as good or better. When asked how relevant the event was to them 44% of respondents said the presentation was highly relevant, 44% said it was mostly relevant 44% and 12 % stated that it was moderately relevant.

- To ensure efficiency of resources and a uniform approach, experimental design and planting of the Bundaberg trials were organised to coincide with Prof. Villordons 2019 visit, a grower update and a PRG meeting. The proposed March visit was originally planned to coincide with a trial harvest in Bundaberg, a grower update and a PRG meeting.
- Project updates were where possible aligned with industry events to minimise growers time off farm.
- During Covid travel restrictions, electronic communication formats were utilized as an alternative. Microsoft Teams, the preferred departmental standard did not prove to be 'farmer friendly' so the zoom platform was adapted. Growers found this a more acceptable format.
- The time differences between Louisiana, Queensland and NSW (daylight savings) meant that the project team had to carefully consider meeting schedules so that times were suitable for all parties.
- Covid work and intrastate travel restrictions meant that workflows had to be restructured and alternative methods developed for trial maintenance, harvests and assessments.

Recommendations

This research generated a lot of new information in relation to nutrients and variety interactions. To further understand these complex relationships, we propose controlled pot studies be undertaken in Queensland and Louisiana.

Experimental results from the Bundaberg trials support the hypothesis of a possible boron mediated genotype effects in periderm thickness. Evidence from Louisiana supports the hypothesis that form of nitrogen (nitrate vs ammonium) plays a role in genotype-specific splitting in sweetpotato. Preliminary data does not currently support the role of phosphorus in reducing splitting in 'Georgia Jet'. Identify studies. The lack of splitting in Queensland and Louisiana experiments conducted during the summer phase (higher greenhouse temperatures) suggest that interrelated factors, e.g. varying environmental conditions, affect the role of key nutrients in genotype-specific splitting.

We propose a follow-on project should consider the following:

- Further investigation of the role of boron and variety in periderm thickness determination across differing planting dates.

- Follow-up studies on the role of nitrate vs. ammonium in storage root spitting as well as other possible effects on storage root sizing and yield.
- Follow on possible interaction between temperature and splitting associated with nitrate using the 'Georgia Jet' as the experimental system.
- Investigation of the effects of other key nutrients
- We propose field studies to inform a decision-making tool to reduce skinning. These could include variety, hardening period and environmental conditions.
- Collect baseline knowledge of periderm thickness over time in Australian grown varieties.

Intellectual property, commercialisation and confidentiality

There are no project IP, project outputs, commercialisation or confidentiality issues to report.

References

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Appendices

Appendix 1. Queensland DAF experiments Nov 2020
Appendix 2. Louisiana LSU experiments Nov 2020
Appendix 3. Summary trip report Nov 2019 Arthur Villordon
Appendix 4. Sweetpotato grower research update December 2019

Appendix 1: Queensland DAF experiments Nov 2020

Australian experiments as part of PW18001 'Investigation of skin hardening and splitting disorders in sweetpotato November 2019 to November 2020'.

Prepared by the DAF project team:
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To address the question posed by the Sweetpotato Industry, "Do Calcium and Boron influence splitting and skinning in sweetpotato?" we conducted two exploratory glasshouse experiments at the Bundaberg Research Facility (BRF).

Experiment location
Experiments were established under controlled screen house conditions in 2019 and 2020 at the Bundaberg Research Facility in Queensland; Australia located 24°50'54''S, 152°24'14''E and 14 m above sea level.

Experimental design
Aligned with the Louisiana studies, these pot experiments were designed in collaboration with the Project Reference Group (PRG) to investigate any individual effects of boron and calcium on splitting and skinning. Randomised complete block design experiments incorporated three nutrition treatments and four susceptible varieties with six replicates of 1 plant/plot. The first experiment was planted on December 3, 2019 and the second experiment was established on February 18, 2020. Each experiment contained 144 plants. Two destructive sampling dates were determined at the initial PRG planning meeting; 50 days after planting (DAP), to gather baseline data, prior to the commencement of the differing nutrient treatments and at 140 DAP to replicate commercial harvest.

The varieties selected for the experiments were Beauregard (known control), Bienville and Bellevue, (highly susceptible to splitting at harvest) and Murasaki (susceptible to skinning (Table 1). Two nodes of virus (pathogen) tested, standardised vine tip cuttings (25 to 35cm long) were vertically planted into PVC pots containing washed sand. Pots were placed onto moveable mesh benches. Each bench was allocated 24 pots (one replicate) and benches were rotated weekly within the glasshouse to ensure even lighting.

Nutrient application
For the first five Days after planting (DAP) all plants received 225 ml of the quarter-strength complete nutrient solution morning and afternoon. This approach was designed to avoid wilting and nutrient runoff while initial root set was occurring. From six to 50 DAP), the time of the first harvest all plants received 450 ml of complete Hoagland nutrient solution, three times per week (Table 1). At 25 DAP in experiment 1, the nutrient concentration was doubled to half-strength to prevent nutritional deficiencies. Excess solution was initially captured in a pot tray and when nutritional toxicities were observed, plants were flushed with water for one week and the concentration was again reduced to quarter-strength and excess nutrient was allowed to freely drain from the pots.

From day 51 to day 140 (time of the final harvest), the amount of nutrient solution (quarter strength) administered to each plant was increased to 600 ml, three times per week. Each plant received one of the three designated nutrient treatments.

- Hoagland's nutrient solution (complete)
- Hoagland's nutrient solution minus Boron (-B)
- Hoagland's nutrient solution minus Calcium (-Ca)

Table 1: Experimental design, varieties and nutrient treatments.

Variety	Reason for inclusion	Treatments *Day 1 to day 50*	Sampling time	Treatments *Day 51 to day 140*	Sampling time
Beauregard	Control	Complete	Day 50	Complete minus Calcium minus Boron	Day 140
Bellevue	Prone to Splitting	Complete	Day 50	Complete minus Calcium minus Boron	Day 140
Bienville	Prone to Splitting	Complete	Day 50	Complete minus Calcium minus Boron	Day 140
Murasaki	Prone to Skinning	Complete	Day 50	Complete minus Calcium minus Boron	Day 140

Reverse Osmosis (RO) water was used in all nutrient solutions to remove minerals such as calcium and eliminate effects of any volatile chemicals such as chlorine in the local water supply. When required RO water was also used for direct watering of plants.

The sand and nutrient solutions were sent for nutrient analysis. The temperature and relative humidity in the screen house were monitored with a Lascar USB Relative Humidity and Temperature Data Logger. Standard practices were followed to control pests and diseases, with a scheduled preventative insecticide spray program and yellow sticky traps used to attract flying insects especially, whiteflies and aphids.

Harvest and assessment

Two destructive sampling dates 50 and 140 days after planting (DAP), were conducted. The primary interest of the first harvest and analysis was to obtain baseline data and understand variety effect prior to changing nutrient treatment applications. The second harvest at 140 DAP was to replicate a commercial harvest. Storage roots were evaluated for splitting. Other measurements included aboveground biomass, total number of roots per plant, number of roots per node, individual root weight, length and diameter. Due to the balanced nature of the design, analysis of variance (ANOVA) was used to analyse all variables.

To simulate susceptibility to skinning, two average-size storage roots from each plant were subjected to hydraulic periderm removal at each harvest. Designed by Prof. Villordon, this method (in publication) used water pressure to measure skin adhesion or time to periderm removal. Two roots randomly chosen from each plant were clamped to a retort stand and exposed to a jet of water at 50 psi, at a fixed distance of 70cm. The time time taken to remove the periderm tissue (peeling) was recorded using a stopwatch. Data captured at the 50 DAP harvest provided a baseline to evaluate any nutrient effects on periderm thickness at 140 DAP.

Figure 1: Hydraulic periderm removal apparatus, experiment 1, 50 DAP.

To investigate the hypothesis that periderm thickness influences individual variety's susceptibility to splitting and skinning, periderm measurements were obtained for each plant. Representative storage roots were transported to Gatton Research Facility where 1 mm thick sections (about 1 cm square sections) were removed from the widest portion of the root and stained with toluidine blue. A Nikon microscope-mounted camera and NIS software was used to obtain periderm thickness measurements under magnification.

Figure 2: PVC pipes were filled with sand and planted with Pathogen tested planting material.

Figure 3: Experiment 1 prior to harvest.

Harvest and assessment

At 50 and 140 DAP, the plants were harvested to determine canopy weights and root morphology traits. The vines were cut at soil level and weighed to determine the plant canopy weight. The root system of each plant was washed to remove sand and left to air-dry to enable the root assessment process. Storage roots were assessed for splitting, and the whole root system including stem photographed and weighed. Plants were visually assessed, and data captured included individual root weight, root length, root diameter, fibrous root weight per plant, total number of roots per plant and number of roots per node. Two average-size storage roots from each replicate were randomly selected for skin adhesiveness or time to peeling assessment. All storage roots were later sent to the sweetpotato research team at the Gatton Research Facility for periderm thickness assessment and image analysis to quantify skinning.

Data analysis

Due to the balanced nature of the trial design, the data was analysed using analysis of variance (ANOVA) in Genstat 19th edition. Treatment means and differences between varieties were deemed significant at the 0.05 level. Pairwise comparisons were performed using the 95% least significant difference (LSD) on significant effects. Means with a letter in common are not significantly different. The variables analysed were; total number of roots per plant, total number of nodes per plant, mean root weight, mean root length, mean root diameter, time to peeling and periderm thickness. Any nodes, which produce no roots, were considered missing values for root weight, length and diameter.

Figure 4: Beauregard, Murasaki, Bellevue and Bienville roots after water pressure testing at 50 DAP.

Experiment 1

Root morphological attributes

There were no significant differences between nutrient treatments for root weight, root length, root diameter and roots per plant across all four varieties (Table 2). Though not significant, the minus boron treatment had the highest root weight and root length compared with the minus calcium and control treatments for Beauregard and Bienville. Whilst the minus calcium treatment had the largest root diameter for Beauregard, the minus boron treatment had the largest root diameter for Bienville and Murasaki. The control treatment had the highest number of roots per plant for Beauregard, Bellevue and Murasaki compared with the minus boron and calcium treatments. Individual variety analysis showed significant differences in nutrient treatments for Beauregard's root length ($P < 0.047$) and Bienville's root weight ($P < 0.004$). The minus boron treatment had significantly higher root length and root weight for both varieties, respectively.

Time to skinning/peeling

At 50 DAP: All plants received the same nutritional treatment and there were no significant differences between varieties. At 140 DAP, there were significant variations in nutrient treatments for Beauregard, Bellevue and Bienville for time to skinning (Table 2, Figure 1). The Beauregard and Bienville control treatment took a significantly longer time to peel compared with the minus calcium and minus boron treatments. In Bellevue and Murasaki, the minus boron treatment took

longer time to peel compared with the control and minus calcium treatments, though this was not significant. Individual variety analysis showed no significant differences in nutrient treatments for Bienville ($P > 0.05$).

Periderm thickness

At 50 DAP: All plants received the same nutritional treatment and there were no significant differences between varieties. At 140 DAP, significant variations between nutrient treatments were noted for periderm thickness in Beauregard and Bellevue ($P < 0.05$) (Table 2, Figure 2). The Beauregard minus calcium treatment had significantly thicker periderms compared with the minus boron treatments, though neither were significantly different to the control. Bellevue roots were significantly thicker in the minus calcium and minus boron treatments than the control. Murasaki mean periderm thickness was significantly higher in roots receiving the control treatment. No significant differences between treatments were observed for Bienville ($P > 0.05$).

Table 2: Summary of nutrient treatment effects on various sweetpotato variety's root morphological attributes in experiment 1 at 140 DAP. Treatments within a column followed by the same letter(s) are not significantly different.

Experiment 1		**Root morphological attributes – mean values**					
Variety	Treatment	Root weight (g)	Root length (cm)	Root diameter (mm)	No of Roots per plant	Time to peeling (Sec)	Periderm width (µm)
Beauregard	Complete	41	7	30	5	3.14c	345bc
	-Ca	51	7	34	5	1.55a	385c
	-B	55	8	32	5	1.70ab	328b
Bellevue	Complete	40	8	29	8	1.69ab	234a
	-Ca	43	7	28	7	1.47a	316b
	-B	41	7	28	7	1.75ab	234a
Bienville	Complete	28	4	21	3	5.08d	246a
	-Ca	31	5	21	3	2.32abc	236a
	-B	56	5	28	2	2.97bc	258a
Murasaki	Complete	38	6	21	5	1.88abc	327a
	-Ca	31	5	22	3	1.91abc	251a
	-B	31	6	24	4	2.82abc	217a
P-value		0.129 (ns)	0.447 (ns)	0.582 (ns)	0.156 (ns)	0.007	0.008
Interaction		0.145 (ns)	0.895 (ns)	0.924 (ns)	0.590 (ns)	0.027	<0.001

ns = not significant ($P > 0.05$); complete = complete Hoagland solution; -Ca = minus calcium; -B = minus boron

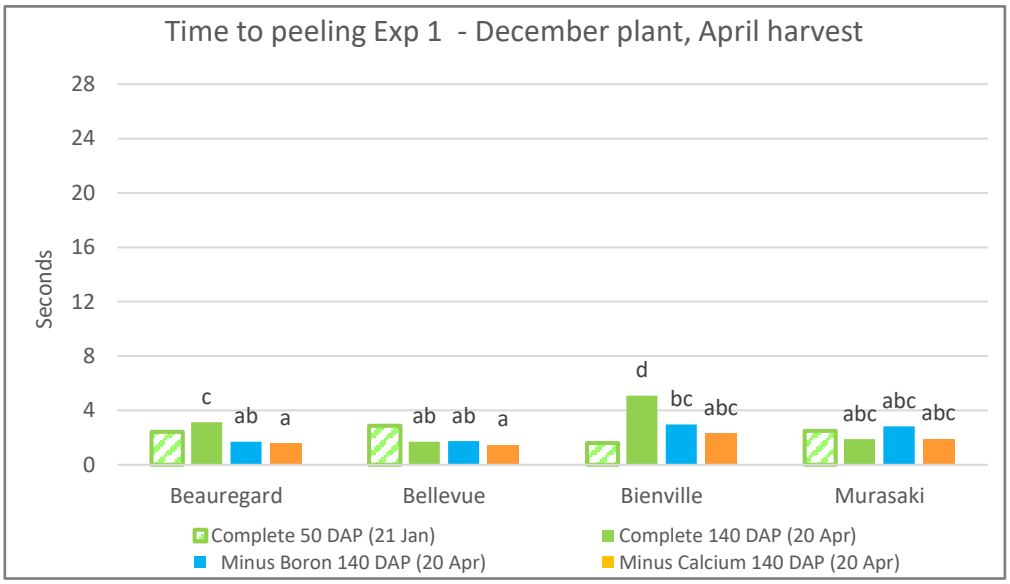


Figure 5: Experiment 1 mean time to peeling for various cultivars under different nutrient treatments (P = 0.027). Treatments followed by the same letter(s) are not significantly different.

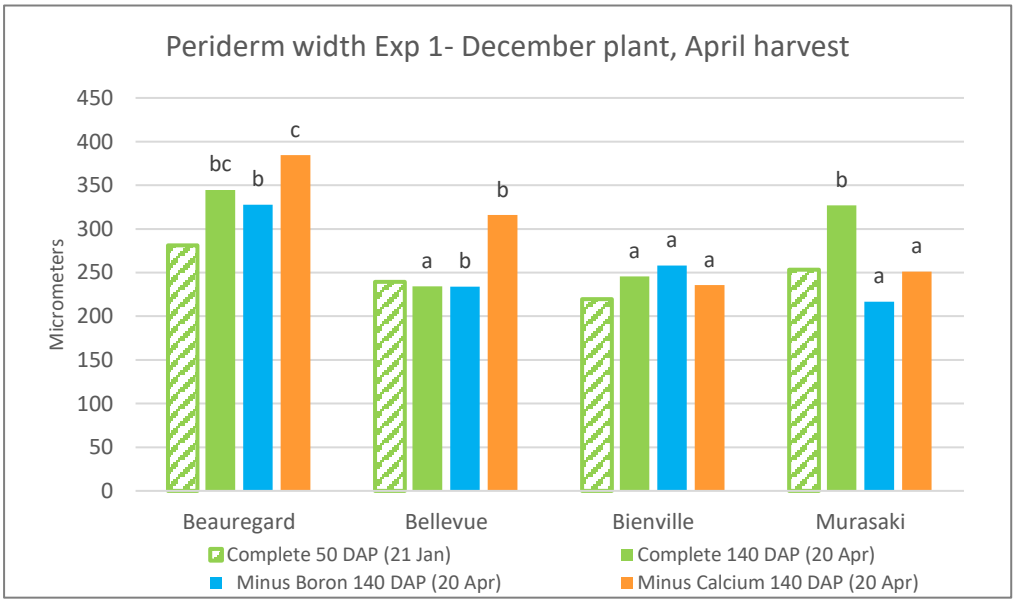


Figure 6: Experiment 1 mean periderm width for different cultivars under different nutrient treatments at 140 DAP (P < 0.001). Treatments followed by the same letter(s) are not significantly different.

Experiment 2 at 140 DAP

Root morphological attributes

Nutrient treatments did not show any significant differences across all varieties in root length, root diameter and roots per plant (Table 3). With an outlier removed, Bienville, roots had significantly higher root weights (52g each) in the minus boron and minus calcium treatments than in the control (16g), with a three-fold increase. Although not significant, the following differences were observed within varieties. Beauregard, the minus calcium and control treatments had heavier roots than the minus boron treatment. In Bellevue, the minus boron and control treatments had higher root weight than the minus calcium treatment. Whilst in Murasaki, the minus boron treatment had a higher root weight than the minus calcium and control treatments.

Time to skinning/peeling

At 50 DAP, All plants received the same nutritional treatment, so the only differences are related to varieties. At 140 DAP, significant variations in treatments for time to peeling/skinning were noted in Bellevue and Bienville where the minus boron and minus calcium treatments took significantly longer time to peel compared with their respective nutrient treatments (Table 2). In Beauregard and Murasaki, there were no significant statistical differences between nutrient treatments, however, the minus calcium treatment took longer time to peel than the minus boron and control treatments. Individual variety analysis showed significant differences in nutrient treatments for Bellevue (P = 0.009), with the minus boron treatment taking 13 seconds to peel compared with the 6 seconds for the minus calcium and control treatments.

Periderm thickness

At 50 DAP, all plants received the same nutritional treatment so the only differences are related to varieties. Bellevue roots had significantly thicker periderms than Murasaki roots which were also significantly thicker than both Beauregard and Bienville roots. At 140 DAP, nutrient treatments were not significantly different across all varieties for periderm thickness (Table 3). Beauregard and Murasaki had thicker periderms in the control treatments, whilst Bellevue and Bienville had thicker periderms in the minus boron and minus calcium treatments. Individual variety analysis showed significant differences in nutrient treatments for Bienville ($P < 0.004$) with the minus boron and minus calcium treatments having significantly thicker periderms than the control.

Table 3: Summary of nutrient treatment effects on various sweetpotato varieties root morphological attributes in experiment 2 at 140 DAP. Treatments in the same column followed by the same letter(s) are not significantly different.

Experiment 2		Root morphological attributes – mean values					
Variety	Treatment	Root weight (g)	Root length (cm)	Root diameter (mm)	No of Roots per plant	Time to peeling (Sec)	Periderm width (µm)
Beauregard	Complete	36bc	9	30	8	7.50ab	301
	-Ca	36bc	8	28	9	8.58ab	335
	-B	30ab	8	24	6	7.03ab	304
Bellevue	Complete	46bc	8	30	7	5.00ab	353
	-Ca	33ab	8	25	9	5.67ab	284
	-B	43bc	9	29	7	13.25b	318
Bienville	Complete	16a	6	21	4	4.75a	273
	-Ca	52c	8	29	4	25.17c	329
	-B	52c	7	31	5	7.17ab	349
Murasaki	Complete	33ab	4	28	6	8.83ab	332
	-Ca	29ab	5	29	6	10.92ab	340
	-B	45bc	5	31	4	6.25ab	292
P-value		0.096 (ns)	0.808 (ns)	0.628 (ns)	0.162 (ns)	0.019	0.914 (ns)
Interaction		0.002	0.773 (ns)	0.06 (ns)	0.381 (ns)	0.002	0.1 (ns)

ns = not significant ($P > 0.05$); complete = complete Hoagland solution; -Ca = minus calcium; -B = minus boron

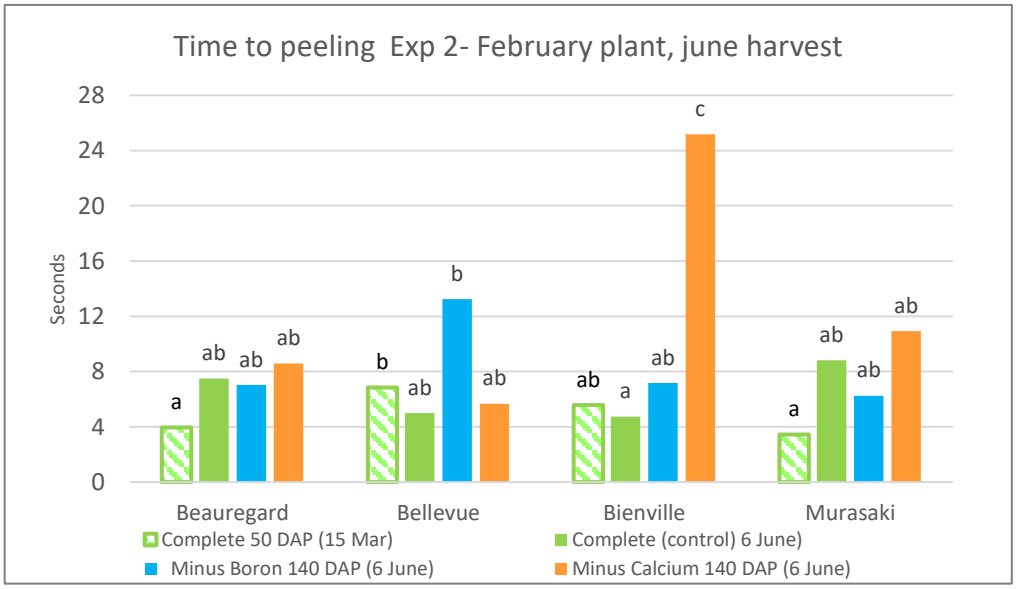


Figure 7: Experiment 2 mean time to peeling for different cultivars under different nutrient treatments at 140 DAP ($P = 0.002$). Treatments followed by the same letter(s) are not significantly different.

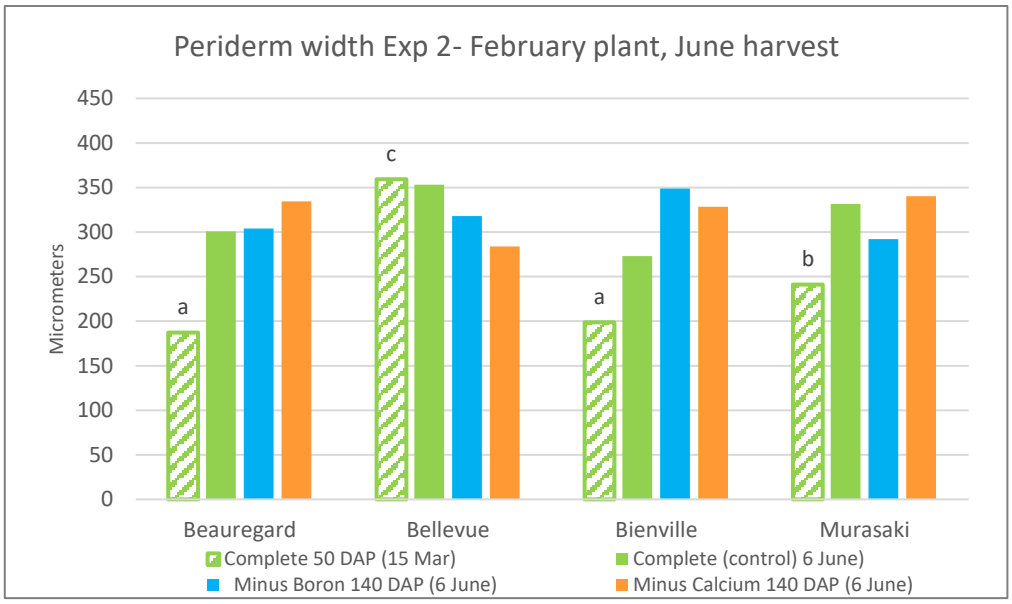


Figure 8: Experiment 2 mean periderm width for different cultivars under different nutrient treatments at 140 DAP ($P < 0.001$). Treatments followed by the same letter(s) are not significantly different.

Gene-environment interaction (GxE)

Planting dates for trials 1 and 2 had no significant effect on the nutrient treatments performance ($P > 0.05$). However, a significant interaction between planting date and variety was noted for root weight ($P = 0.044$), root length ($P = 0.004$), root diameter ($P = 0.01$), total nodes per plant ($P = 0.004$) and periderm width ($P < 0.001$). Beauregard had a significantly higher average root weight in trial 1 (49 g) than trial 2 (31 g). No significant differences in root weight were observed for Bellevue, Bienville and Murasaki. A similar trend was observed for root diameter. Bienville had significantly longer roots in trial 2 than trial 1 with an average of 7 cm and 5 cm, respectively. The average periderm thickness was greater in trial 2 than trial 1 for all nutrient treatments for Bienville and Murasaki. Bellevue had a greater periderm thickness in trial 2 than trial 1 for the complete and minus boron nutrient treatments whilst Beauregard had a larger periderm width for trial 1 than trial 2 for all nutrient treatments.

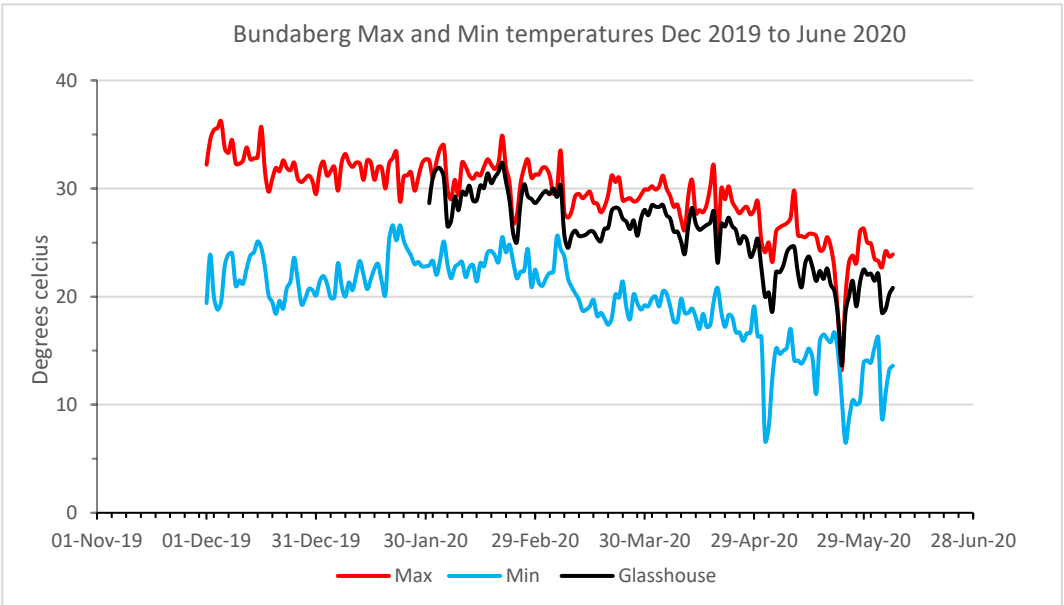


Figure 9: Bundaberg minimum and maximum temperatures and glasshouse logger data recordings, December 2019 to June 2020.

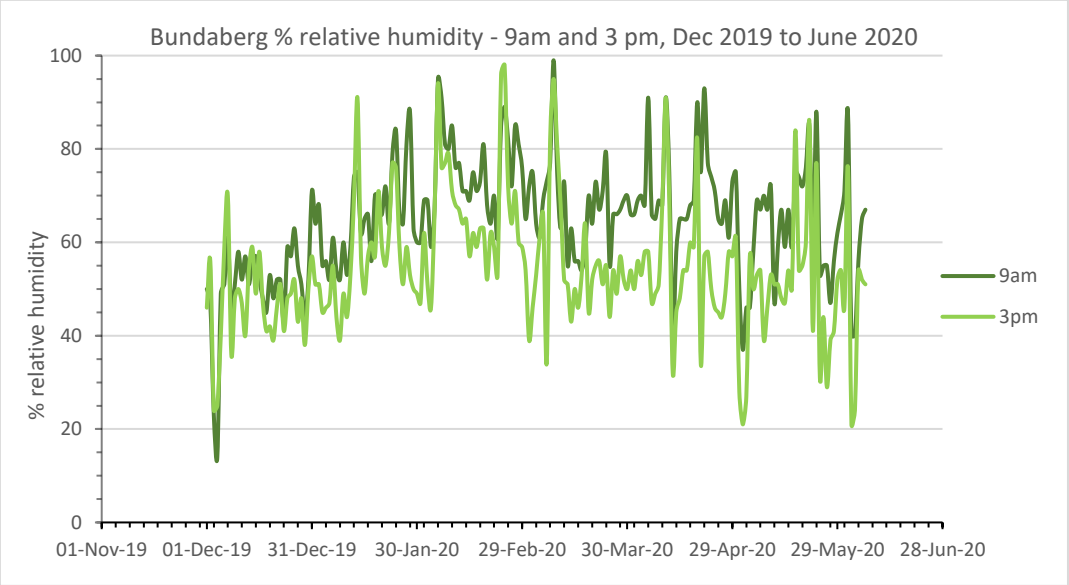


Figure 10: Bundaberg relative humidity, December 2019 to June 2020.

Results summary

No splitting was observed in either experiment in Qld. LSU Ag centre trials on variety Georgia Jet have demonstrated that roots can start to split as early as 30 DAP if conditions are favourable. At 30 DAP storage roots are typically two to three cm in diameter and five to ten cm in length.

Preliminary findings indicate that there are varietal differences with reference to root weight, root length, root diameter, total nodes and roots per plant, periderm thickness and time to peeling. Nutrient treatment application had a significant effect on time to peeling of Bienville roots, with the minus calcium treatment taking significantly longer to peel than the complete Hoagland and minus boron treatments. Beauregard and Bellevue roots had the thickest periderms in the minus calcium treatments. Periderm width is hypothesised to influence skin hardening. The lack of boron or calcium had no significant effect on root weight, root length, root diameter and total nodes and roots per plant.

Periderm width values were generally higher in all varieties in experiment two conducted during cooler weather than experiment one conducted during summer. A gene-environmental analysis showed that trial planting date had no significant effect on nutrient treatments performance albeit variety response variations were evident for root morphological attributes assessed.

Project team resources developed during the project:

- Protocol for Hoagland's nutrient preparation for sweetpotatoes
- Standard safe preparation procedure for the Hoagland nutrient preparation
- Risk assessment for Hoagland nutrient preparation
- Protocol for removing roots from sand culture and capturing root development data
- Protocol for hydraulic periderm quantification exercise
- Standard safe operating procedure for hydraulic periderm quantification exercise
- Standard safe operating procedure for removing roots from sand culture and capturing root development data

Appendix 2. Louisiana LSU experiments Nov 2020

Final Report: PW18001 Investigation of skin hardening and splitting disorders in sweetpotatoes

Submitted by:
Arthur Villordon
Sweet Potato Research Station
LSU AgCenter
avillordon@agcenter.lsu.edu

Executive Summary

The ‘‘Georgia Jet’ clone maintained by the LSU AgCenter showed increased incidence of storage splitting when grown with nitrate relative to ammonium as source of nitrogen. Storage root splitting can be unambiguously observed as early as 20 to 30 days after planting. In addition, the periderm color of storage roots grown in nitrate was substantially lighter relative to the roots grown with ammonium. Two experiments were conducted to investigate the possible role of phosphorus in ‘Georgia Jet’ storage roots provisioned with nitrate. The first experiment showed a trend for reduced splitting with increased phosphorus but extreme variability in response masked any likely statistical differences. A replicate experiment failed to show splitting in the controls. However, storage root size was significantly reduced when storage roots were grown with ammonium. It is noteworthy to mention that the replicate experiment was conducted during the summer, where the ambient greenhouse temperatures were relatively higher. It is hypothesized that nitrate presence predisposes ‘Georgia Jet’ storage roots to splitting, and this response is influenced by temperature. Based on the experimental data, follow-up studies need to account for temperature in addition to the nitrogen source. Experimental evidence also support the hypothesis that phosphorus and boron are directly or indirectly involved in storage root splitting in susceptible varieties.

General conditions for the greenhouse studies

The greenhouse experiments are were conducted at the LSU AgCenter Sweet Potato Research Station, Chase, La, USA (32°6’N, 91° 42’W). Plant materials were obtained either from bedded virus-tested storage roots or extant plants derived from virus-tested in vitro plants. Unless otherwise indicated, the nutrient solution used was half-strength Hoagland nutrient solution with nitrogen supplied as nitrate only (Solution 1). This is the same formulation used in trials at the Bundaberg Research Facility. Cuttings were typically planted (2 nodes under the growth substrate surface) in 10-cm-diameter polyvinyl chloride pots (height=30 cm) with detachable plastic bottoms. The growth substrate was washed sand of uniform particle size (majority in the 0.05-0.2-mm range). The greenhouse temperature regime was 29C for 14 hr (day) and 18C for 10 hr (night). Supplementary lighting was provided with LED grow lights for 14 hr per day. Photosynthetic photon flux (PPF) typically ranged from 300 to 800 m^{-2} s^{-1}. The moisture of the growth substrate was maintained at ≈65 to 75% of field capacity (≈12% volumetric water content). Growth substrate moisture was measured with ECH2O soil moisture sensors (Model EC-5, Decagon Devices, Inc.) inserted vertically at the 2-7 cm depth. All experiments were arranged in a randomized complete block design where a pot (one plant per pot) was considered a replicate. The number of replicates varied from four to five depending upon the availability of bench space.

Study 1. Exposure to simulated and natural low temperature and splitting (1 Aug to 22 Oct 2019).

Rationale

Exposure to low temperature has been implicated with increased incidence of splitting in sweetpotato grown in field conditions. In radish and carrots, there is evidence to suggest that temperature affects firmness by influencing strength of cell walls. Currently, there is limited data on the possible effects of low temperature on storage root splitting in sweetpotato. This study attempted to generate preliminary data on the possible role of low temperature on storage root splitting in sweetpotato.

Approach

The cultivars used were 'Evangeline', 'Bellevue' and 'Beauregard'. Low substrate temperatures were simulated by wrapping pots in coils attached to a water chiller (Fig. 1A). Pots in the control treatment were also wrapped in coil and insulation but not chilled. All plants were initially grown with the standard temperature regime. After 60 days, low night substrate temperature treatments (substrate temperature = 15C) were imposed on designated pots. At this stage, storage root widths approached ≈2.5 cm (Fig. 1B). Storage root samplings were made 10 and 20 days after the imposition of the low temperature treatments (Fig. 1B). Some pots were also taken outside and exposed to near freezing (below 5C; Fig. 2) temperatures during the early to middle part of October 2019.

Results

Storage root splitting was not observed in storage root samples subjected to low temperature treatments. All storage roots were subjected to simulated drops to replicate conditions during harvest. These simulated drops on hard surfaces also did not result in splitting. These experiments rule out the possible direct role of low temperature on storage root splitting. However, this does not rule out a possible contributing role on splitting as a result of subsequent re-warming of soil temperatures and a possible interaction with nutrient application, i.e., KNO_3, typical of crops that go through a winter stage.

Figure 1. Experimental setup for simulating low temperature in growth substrate (A). 'Bellevue' storage roots subjected to low temperature treatment (B).

Figure 2. Some experimental units were taken out of the greenhouse and exposed to near-freezing night temperatures in mid-October 2019.

Study 2. Ammonium vs. nitrate effects on storage root splitting (23 Oct to 12 Dec 2019)

Rationale

The LSU 'Georgia Jet' clone routinely splits under field conditions. In greenhouse conditions, splitting can be observed as early as 30 days. Although the 'Georgia Jet' storage root splitting might be a different system compared to splitting at harvest in Australian growing conditions, it can provide some insights about the mechanism of splitting and possible ways to reduce this incidence. In prior preliminary studies, 'Georgia Jet' plants that were supplied with nitrate form of nitrogen produced storage roots with increased splitting incidence relative to plants that were supplied with ammonium. Very little data is available about the response of other cultivars like 'Beauregard' and 'Evangeline' to ammonium and nitrate treatments. Such findings could shed light on the possible role of nitrogen source on storage root splitting.

Approach

The varieties used were 'Georgia Jet', 'Beauregard', and 'Evangeline'. Plants were provided with half strength Hoagland's nutrient solution with either nitrate or ammonium as the nitrogen source. Storage roots were sampled at 50 days and assessed for splitting.

Results

- Splitting was observed in 'Georgia Jet' storage roots sampled from plants grown with nitrate relative to plants supplied with ammonium (Figs. 3, 4)
- No splitting was observed in 'Evangeline' and 'Beauregard'

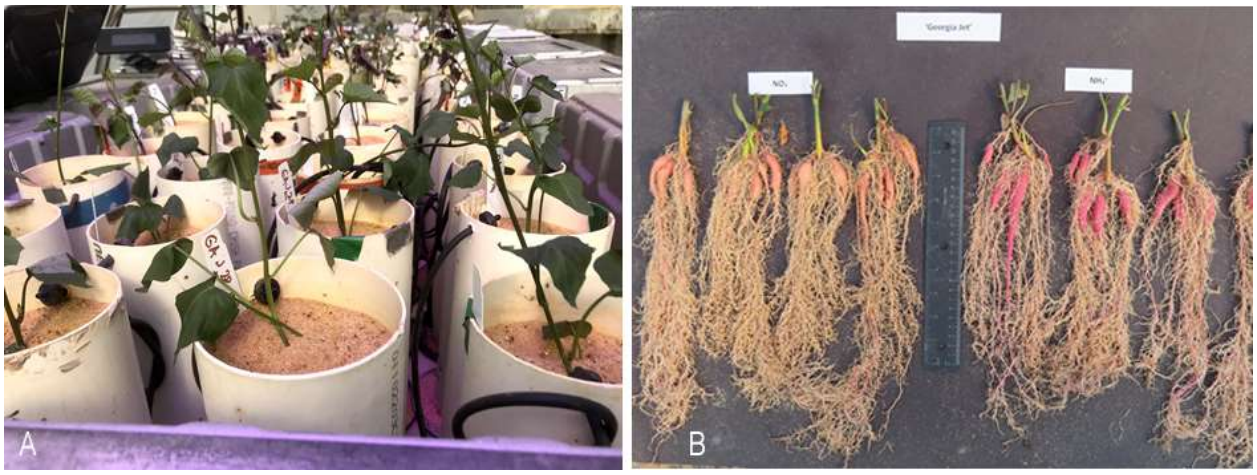


Figure 3. General view of the trial (A). 'Georgia Jet' storage root sampled at the conclusion of the study (B).

Figure 4. Detail views of Georgia Jet storage roots from plants grown with ammonium (A) and splitting in storage roots from plants grown with nitrate (B).

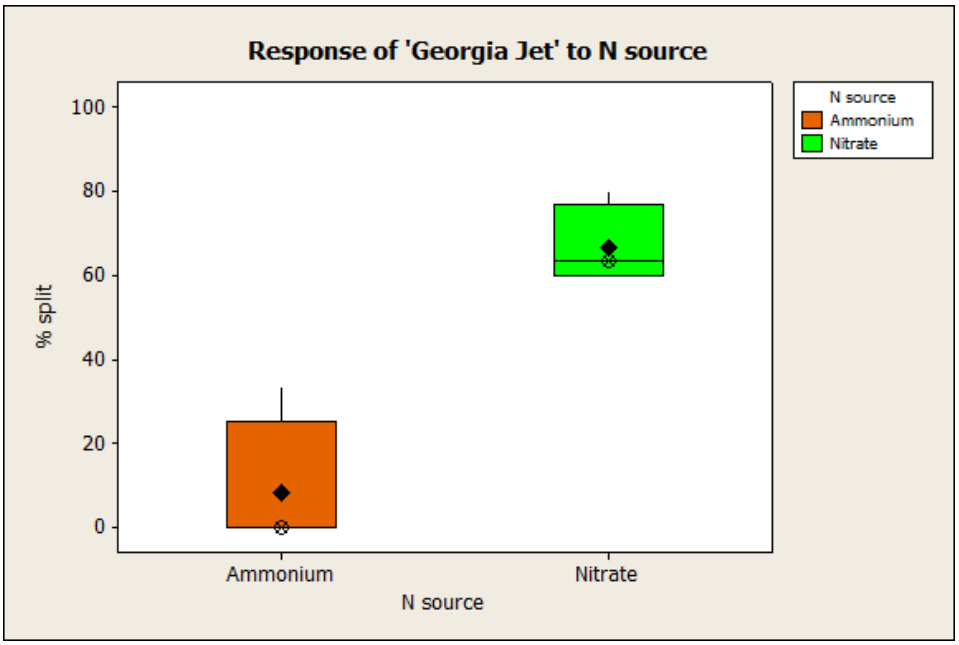


Figure 5. Box plots of 'Georgia Jet' storage root percent splitting response to ammonium and nitrate treatments. Bold horizontal lines indicate median values. Boxes represent the interquartile range (IQR, or middle 50%) of values for each feature. Upper box plot whiskers represent the last data point within the range of 75% quantile + 1.5 IQR, lower box plot whiskers represent the last data point within the range of 25% quantile–1.5 IQR. Dots represent outliers (values smaller or larger than the median ± 1.5 times the interquartile range).

Study 3. Phosphorus and storage root splitting follow-up work (12 Jan to 17 March 2020)

Rationale

In the prior study, it was observed the splitting was more prevalent in plants grown with nitrate as the nitrogen source vs ammonium. This follow-up work investigated the possible role of phosphorus (P) availability in Ga Jet plants provided with nitrate as the N source. P was given priority due to its well-documented role in root architecture development and root system adaptations to variation in P availability.

Approach

Three experimental treatments were used in this study: Hoagland's nutrient solution without P (0P), 16 ppm P (1X), and 32 ppm P (2X).

Figure 6. 'Georgia Jet' storage roots from plants grown with 0, 16 (1X) and 32 ppm (2X) P and sampled at 50 days (A). Storage root samples from plants provided with 0 P (B).

Figure 7. 'Georgia Jet' storage root samples from plants provided with 16 ppm P (1X) (A) and 32 ppm P (2X) (B).

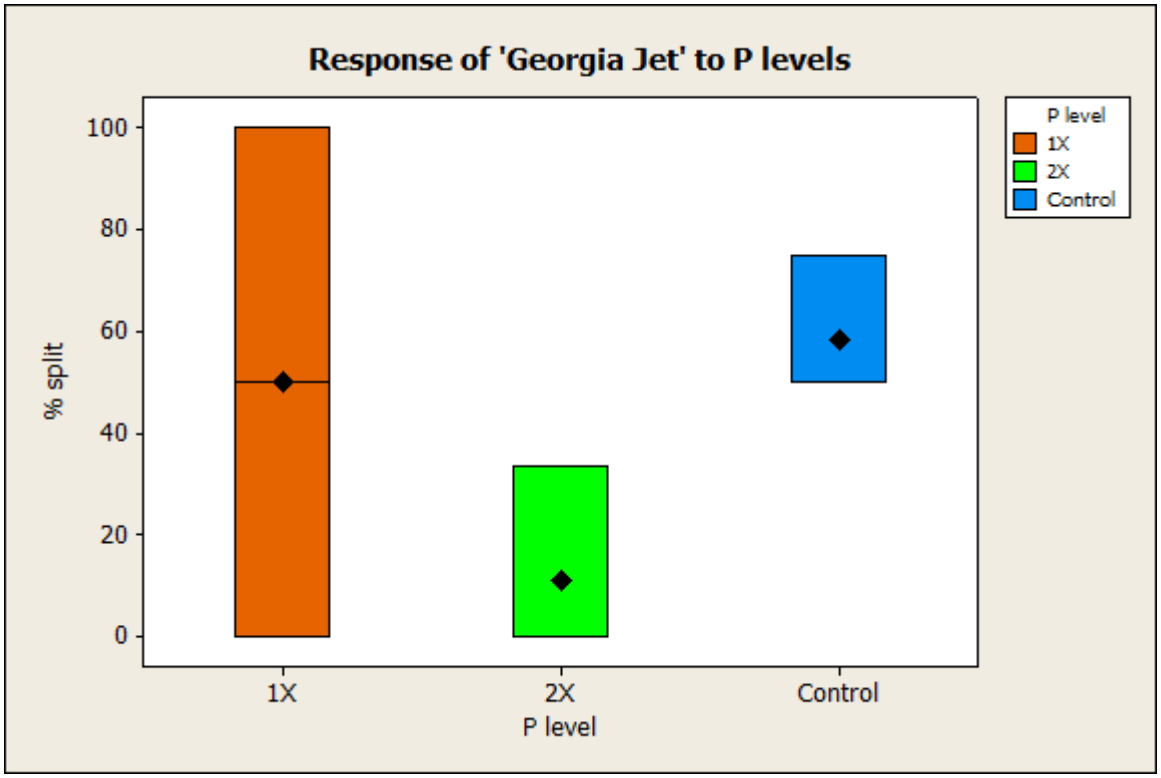


Figure 8. Box plots of 'Georgia Jet' storage root percent splitting response to phosphorus treatments. Bold horizontal lines indicate median values. Boxes represent the interquartile range (IQR, or middle 50%) of values for each feature. Upper box plot whiskers represent the last data point within the range of 75% quantile + 1.5 IQR, lower box plot whiskers represent the last data point within the range of 25% quantile–1.5 IQR. Dots represent outliers (values smaller or larger than the median ± 1.5 times the interquartile range). Control = 0 P; 1X = 16 ppm P; 2X=32 ppm P.

Results

- Splitting was observed in 'Georgia Jet' storage roots sampled from plants grown with nitrate relative to plants supplied with ammonium
- No splitting was observed in 'Evangeline' and 'Beauregard'

Study 4. Phosphorus and storage root splitting follow-up work (May to June 2020)

Follow-up studies were conducted to investigate if increasing P availability reduced splitting in 'Georgia Jet' provided with nitrate as a source of N. 'Beauregard' and 'Murasaki' cultivars were also included.

Figure 9. Follow-up studies on Georgia Jet plants

Results

- We failed to observe splitting in the controls (‘Georgia Jet” plants grown with nitrate as source of N).

Figure 10. ‘Georgia Jet’ storage roots from plants grown with 0, 16 and 32 ppm P and sampled at 50 days (A). Storage root samples from plants provided with 0 P (B).

Follow-up studies: Possible role of B in periderm thickness/splitting

Rationale

Experimental results from the Bundaberg trials support the hypothesis of a possible boron mediated genotype effects in periderm thickness determination. At the Sweet Potato Research Station, current research focuses on the role of nutrients in determining root architecture, storage root formation, shape and quality, hence these follow-up trials can be conducted past the life of the project. The DAF QLD partners will be regularly updated on findings from these follow-up studies, as well as possible subsequent work.

General Conclusions:

- The experimental evidence supports the hypothesis of that nitrogen form (nitrate vs ammonium) plays a role in genotype-specific splitting in sweetpotato
- Preliminary data do not currently support the role of P in reducing splitting in 'Georgia Jet'.
- The lack of splitting from experiments conducted during the summer phase (higher greenhouse temperatures) suggest that environmental conditions, i.e., temperature, mitigates the role of nitrate in genotype-specific splitting in 'Georgia Jet'

Appendix 3. Summary trip report Nov 2019 Arthur Villordon

Summary trip report Arthur Villordon

Trip Report - Project Startup Meeting
Project Title: Investigation of skin hardening and splitting disorders in sweetpotatoes
Project Funding: Hort Innovation Australia
Collaboration: Sandra Dennnien (Gatton Research Station) and Rachael Langenbaker (Bundaberg Research Station), DAF, QLD
Arthur Villordon, LSU AgCenter Sweet Potato Research Station (SPRS)

1-3 November 2019

Travel
Monroe Regional (MLU) - Dallas-Fort Worth (DFW) - Sydney Airport (SYD) - Brisbane Airport (BNE). Overnight in BNE

Monday 4 November

Travel
BNE - Bundaberg Airport (BDB)

Activities

- Introduction to BRS (Fig. 1)
- Initial meeting with research team
- Visit to Greensill Farming Group packing shed to observe splitting and skinning (Figs. 2, 3)

Figure 1. Tour of greenhouse and support facilities, BRS, QLD.

Figure 2. Research team visit to Greensill Farming Group sweetpotato packing shed, Bundaberg, QLD.

Project notes:

- 'Beauregard' variety storage roots do not typically split, especially for the planting/harvest dates considered
- The research team met with the management staff to discuss possible variables that might have contributed to splitting.
- The following variables were identified for possible follow-up:
    - Prolonged dry conditions followed by irrigation
    - Provision of potassium fertilizer to "restart" storage root bulking

Figure 3. Splitting seen in 'Beauregard' storage roots being run through the packing line, Greensill Farming Group sweetpotato packing shed, Bundaberg, QLD.

Tuesday 5 November

Activities

- Project meeting & greenhouse visits (BRS) (Fig. 4)
- Visits to Windermere Farms (Figs. 5, 6)

Figure 4. Research team checking on the status of stock plants, BRS, Bundaberg, QLD.

Figure 5. Checking on a field planted with ‘Orleans’ variety, Windermere Farms, Bundaberg, QLD.

Figure 6. Splitting was not observed in 'Orleans' but some grooving was reported for certain harvest dates. Possible causes were discussed for possible follow-up. Windermere Farms, Bundaberg, QLD.

Project notes

- The grower suggested that the grooving was associated with a "second set" of storage roots following the winter phase of the crop

Wednesday 6 November

Activities

- Project meeting continued (BRS)
  - Review of nutrient solutions to be used for greenhouse trials (link to solutions)
  - Review of experimental treatments to be used in Bundaberg and SPRS locations
  - Testing of nutrient solution in greenhouse

Thursday 7 November

Activities

- Project meeting wrap-up (BRS)
- Visits to Prichard Farms to observe splitting in 'Northen Star' variety
- Project Reference Group (PRG) meeting
  - PRG provided valuable feedback to the proposed methodology, in particular synching planting dates with known incidence of splitting at harvest
  - Varieties considered for testing: 'Beauregard', 'Bellevue', 'Muraski', 'Bienville' (Bundaberg)
  - In addition to the above varieties, 'Georgia Jet' and 'Evangeline' will be tested in SPRS
- Presentation to growers

Figure 7. Research team visit with Mike Prichard to observe splitting in 'Northern Star.'

Figure 8a,b. Splitting observed in freshly dug 'Northern Star' variety storage root samples. Soil samples were collected to determine if nematodes were present in the field. Follow-up activities were discussed.

Friday 8 November

Travel

Travel by car from Bundaberg to Rockhampton

Activities

- Meet-up with Eric Coleman (Aus Sweetpotato Seed) for travel to Rockhampton
- Visit bedding operations in Bundaberg prior to travel to Rockhampton (Figs. 9a,b and 10)

Figure 9a. Virus-tested seed of 'Bellevue' variety being bedded in Bundaberg.

Figure 9b. Bedded seed of 'Bellevue' variety being covered in Bundaberg.

Figure 10. Figure 9a. Virus-tested seed of 'Orleans' variety being bedded in Bundaberg.

Saturday 9 November

Activities

- Tour of Aus Sweetpotato Seed facilities and seed production fields (Eric and Kristy Coleman)
- Visit Wolfenden Farms

Figure 11. Newly-built truck wash equipment at entrance to Aus Sweetpotato Seed, Rockhampton

Figure 12. View of Aus Sweetpotato Seed in storage facility.

Figure 14. ‘Bellevue’ variety storage root development.

Figure 15. Grooving observed in ‘Orleans’ storage roots. Possible causes were

discussed for follow-up work.

Sunday 10 November

- **Downtime**

Monday 11 November

Travel
Travel from Rockhampton Airport to BNE, travel by car from BNE to Cudgen, NSW

Activities
- Visit to Prichard Farms
- Presentation to growers

Figure 16. Research team visit to Prichard Farms, Cudgen, NSW.

Figure 17. ‘Orleans” plant beds, Prichard Farms, Cudgen, NSW.

Figure 18. Rachael Langenbaker, research project team member and experimentalist, BRS, DAF, Bundaberg, shows ‘Orleans’ storage roots samples at Prichard Farms, Cudgen, NSW.

Figure 19. ‘Orleans” storage roots with possible nematode symptoms sampled from an ongoing nematode study, Prichard Farms, Cudgen, NSW.

Tuesday 12 November

Travel
Travel by car from Cudgen to BNE.

Tuesday 13 November

Travel
Travel from BNE to Auckland Airport (AKL)

Appendix 4. Sweetpotato grower research update December 2019

Sweetpotato research update – December 2019.

Following on from our last update on the nematode project in June 2019, here is a December update for all current projects from the DAF sweetpotato research team.

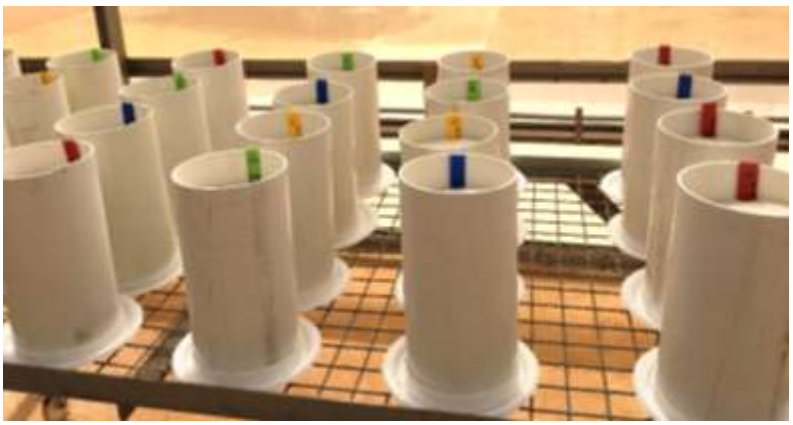
Pilot Project PW18001 – Investigation of skin hardening and splitting/skinning disorders in sweetpotatoes

Project inception

- A monitoring and evaluation plan, a stakeholder engagement plan and a risk register have been developed.
- For efficiencies the Project reference group will consist of the same members as PW17001
- The first meeting has been conducted, including discussion on design of the pot trials.

Project collaborator visit

- Project collaborator and sweetpotato physiology expert, Professor Arthur Villordon from Louisiana State University visited Bundaberg and Cudgen from the 4th to the 12 of November.
- Prof Villordon visited 6 farms and provided an update on both proposed research under the project and research conducted in Louisiana in Bundaberg on the 7th of November and Cudgen on the 11th of November.



Pot trials

- The first trial was planted on the 4th of December in the sweetpotato screen house at Bundaberg research facility.
- The second trial will be planted on the 17th of February 2020. Both trials will investigate the role of Calcium and Boron in skin hardening.
    - 4 cultivars, Beauregard, Bienville, Bellevue and Murasaki.
    - 2 treatments, minus Calcium and minus Boron with 6 replicates giving a total of 144 pots.
    - Application of complete nutrients delivered three times per week using a standardised nutrient solution protocol.
    - First harvest will be conducted at 50 days after planting. Roots will be assessed for skin thickness and susceptibility to skinning.
    - From 51 to 140 days plants will receive nutrients minus Calcium or minus Boron.
    - The final harvest will take place at 140 days after planting. Roots will be assessed for skin thickness and susceptibility to skinning.
- The Louisiana trials will be conducted at the LSU Sweetpotato research Station, Chase and will investigate the role of potassium, phosphorus and two different forms of nitrogen on skin hardening.