The effect of pre-plant herbicide application on growth of sweetpotato cuttings.

June 2021
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This project has been funded by Hort Innovation using the sweetpotato research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

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Summary

A pot trial was conducted to study the residual effect pre-plant herbicide applications used in land management prior to the planting of sweetpotato crops may have on sweetpotato cuttings when planted. 12 herbicides were tested at maximum rates. The two pre-emergents (metolachlor and pendimethalin) and the four pre- and post-emergent herbicides (imazethapyr, oxyfluorfen, prometryn and terbuthylazine) were all applied as pre-emergents 60 days prior to planting, simulating a crop rotation or fallow management application. Six post-emergent herbicides (2,4-DB, glyphosate, dicamba, fluroxypyr, glufosinate ammonium and MCPA) were applied 24 hours before planting simulating last minute pre plant weed control.

Glyphosate was the only post-emergent herbicide which did not show a residual effect, while fluroxypyr exhibited the strongest residual effect. Several pre-emergent herbicides, while not showing visual signs of affecting plant health, did have an effect on early storage root development. Imazethapyr most affected storage root development.

This trial highlights the need to carefully consider herbicide use in crop rotations used prior to planting a sweetpotato crop or weed management near planting.

Introduction

With an annual farm gate value of $90 M (ASPG pers.com.), sweetpotato is a nutritious root vegetable primarily grown in Queensland and northern New South Wales. Sweetpotato is vegetatively propagated and typically it is planted using unrooted apical cuttings taken from seedbed produced sprouts, although on occasions cuttings may be taken from field planted crops and occasionally back cuttings (cutting obtained from the middle portion of the vine) may also be used.

Being a root crop, sweetpotato is particularly sensitive to soil borne pests, the most destructive of these being nematodes that are estimated to cost the industry $20 M annually (ASPG pers. comm.). Nematodes reduce root size, the efficiency with which roots forage for water and nutrients, and can affect storage roots by causing cracking, internal and external lesions and galling (pimpling), (Overstreet 2013, Noling 2016). They can rapidly multiply with one female root knot nematode being able to lay up to 3,000 eggs.

Unfortunately for producers, nematodes are well suited to all Australia's main sweetpotato production soils. Surveys by DAF and Biological Crop Protection have indicated that root-knot nematodes are present in virtually all sweetpotato fields. Due to sweetpotatoes' susceptibility and the nematode's ability to rapidly increase in number, management strategies are being developed to manage this pest. These strategies utilise crop rotations, including fallows or cover crops and have a particular emphasis on controlling of sweetpotato volunteers, a preferred nematode host.

In addition to being a host for nematodes, weeds at planting can affect the later productivity of the crop. Seem et al. (2003), identified the critical weed free period for Beauregard variety is two to six weeks after transplanting. It is likely similar for other varieties. Monks et al. (2019) summarises numerous authors identifying detrimental impacts of weeds on growth, and storage root development, identifying that it is critical to plant sweetpotato vine cuttings into soils free of emerged and emerging weeds. As there are only five herbicide active ingredients registered for use in Australian sweetpotato crops (Australian Pesticides and Veterinary Medicines Authority – APVMA, accessed May 2021), preplant weed control is important.

A concern for sweetpotato growers is herbicides, which may possibly be used in crop rotations or fallow weed control, might have plant back periods (time it is safe to plant a crop after herbicide application) that could affect planted sweetpotato vine cuttings. There is minimal research on how herbicides, particularly those registered for *Ipomoea* sp. control, applied prior to planting may affect sweetpotato crops. This trial was developed to gain information on the plant-back effect of several pre- and post-plant herbicides that may potentially be used in fallow weed control, on transplanted sweetpotato vine cuttings.

Materials and Methods

A pot trial was conducted in the Walkamin Research Facility (WRF) open roof screenhouse (17°08'09" S, 145°25'37" E, 600 masl). A randomized split plot design with 13 treatments (Table 1), and three planting periods, replicated four times was used. The herbicides selected all have registration to kill an *Ipomoea* sp. weed, the family (Convolvulaceae) to which sweetpotato belongs. These herbicides could be used in fallow, crop rotation or pre-plant weed control before planting sweetpotato. Herbicides were applied at maximum label rates (Table 1).

Table 1. List of herbicides trialled

Active ingredient	Application time	Mode of action group	Rate /ha
2,4-DB 500 g/L	Post emergent	I	3.2 L/ha
glyphosate 570 g/L	Post emergent	M	3.7 L/ha
dicamba 500 g/L	Post emergent	I	560 mL/ha
fluroxypyr 333 g/L	Post emergent	I	1.8 L/ha
glufosinate ammonium 200 g/L	Post emergent	N	5 L/ha
imazethapyr 700 g/kg	Pre and post emergent	B	140 g/ha
MCPA 750 g/L	Post emergent	I	1.4 L/ha
metolachlor 720 g/L	Pre-emergent	K	4 L/ha
oxyfluorfen 240 g/L	Pre and post emergent	G	6 L/ha
pendimethalin 455 g/L	Pre-emergent	D	3.3 L/ha
prometryn	Pre and post emergent	C	2.2 kg/ha
terbuthylazine	Pre and post emergent	C	1.2 kg/ha
control (water)	nil	nil	-

Treatments

2,4-DB is a systemic herbicide that can be used to control annual and perennial broadleaf weeds. In the plant the 2,4-DB compound changes to 2,4-D and inhibits the growing points of stems and roots (Gupta. 2018). It is absorbed through foliage and translocated around the plant via the plants vascular system. It induces a response in plant auxins (a plant growth regulator) causing abnormal growth in the plant such as twisting, bending of stems and petioles; leaf curling and cupping, and development of abnormal tissues and secondary roots resulting in eventual plant death. Plant death can take three to five weeks (Cobb and Reade 2010, Cornell University undated).

Glyphosate is a non-selective herbicide for control of both grasses and broadleaf weeds. In the plant, glyphosate affects the manufacture of amino acids by affecting their production pathways. Production of anthocyanins, flavonoids lignin and chloroplasts are some compounds affected. Glyphosate is readily absorbed by leaves and translocated through the plant in the vascular system. Growth is affected soon after application. There is a general yellowing in the immature leaves and growing tips which then spreads. Plant death can occur within four to seven days with susceptible species and may take up to 20 days with less susceptible species (Cornell University undated). Glyphosate is rapidly and strongly adsorbed to soil particles, particularly as clay content and cation exchange capacities (CEC) increase and soil pH and phosphorus decrease. Due to this, it has little or no herbicide activity once it touches soil (Tu et al. 2001).

Dicamba is a selective herbicide for control of broadleaf weeds. It disrupts the plants transport systems and interferes with the metabolism of nucleic acid. It is readily absorbed through roots, stems and the foliage and then translocated through the plant in the vascular system. It induces a response in plant auxins (a plant growth regulator) causing abnormal growth in the plant such as twisting, bending of stems and petioles; leaf curling and cupping, and development of abnormal tissues and secondary roots resulting in eventual plant death. Symptoms may occur within hours of the herbicide application, but plant death may take three to five weeks (Cobb and Reade 2010, Cornell University undated).

Fluroxypyr is a selective post-emergent herbicide for control of a wide range broadleaf weeds. Foliar absorption and translocation is the main route of the chemical into the plant, although there is minor root absorption. When absorbed in the plant it accumulates in the growing tissues and causes an auxin overdose which interferes with the plants ability to use nitrogen and produce enzymes. It causes abnormal growth eventually resulting in death. Fluroxypyr has some residual activity and growers need to be aware of plant back periods. Generally, there is little residual activity although, in soils containing less than 25% clay. Susceptible crops may require up to a 12 month break before planting. Hard water should also be avoided, or if unavoidable a water conditioning agent added (EPA 1998, Guo et al. 2019, Corveta Agriscience undated, Herbiguide[1] undated).

Glufosinate ammonium is a non-selective herbicide for the control of broadleaf weeds and grasses. It is not recognised as having residual herbicide activity. It is not actively translocated in the plant, so will only kill the foliage/stem areas it contacts. Due to rapid microbial breakdown, it has minimal if any root absorption. It causes peroxidation in the cell membranes and a build-up of ammonium in the plant that destroys cells and stops photosynthesis. Glufosinate ammonium usually causes yellowing and wilting within three to five days and death within one to two weeks. Bright sunlight, high humidity and moist soil increase the rate of plant death (Takano and Dayan 2020, Cornell University undated).

Imazethapyr is a pre- or post-emergence herbicide for control of broad leaf weeds and some grasses. It can have long term residual activity and plant back periods for some crops in dryland conditions can be up to 34 months. Some plant back periods may be reduced when greater than 2,000 mm of rainfall/irrigation has been applied (ADAMA 2019[1]). Imazethapyr is readily absorbed by foliage and slightly slower by roots. It is translocated around the plant in the vascular system. It works by inhibiting the production of a key enzyme required for the manufacture of certain amino acids (Cornell University undated). It has also been found to affect genes involved in the photosynthesis process (Sun et al. 2016). Susceptible plants growth may be inhibited within a few hours of application. The growing points may start dying within one to two weeks, followed by a slow yellowing and dying of the plant (Cornell University undated).

MCPA is a systemic post-emergence herbicide for control of broadleaf weeds. It is absorbed through foliage and translocated in the vascular system to growing points.

It can also be absorbed through the soil (Kogan and Henandez, 1991). It acts as the plant growth hormone, auxin, causing uncontrollable growth and eventual plant death (Anon. 2017). Plant symptoms can include twisting and bending, leaf cupping and curling, thickening and elongation of leaves, dying of the growing point and wilting. Death may take up three or more weeks (Nufarm undated).

Metolachlor is a short residual, pre-emergent herbicide for control of broadleaf and annual grasses. It is primarily absorbed from the soil through the germination coleoptile (shoot) although there can be root absorption. Metolachlor stops or reduces seedling growth by inhibiting the formation of long chain fatty acids. It can be translocated through the xylem. Metolachlor needs to be irrigated after application to ensure the chemical is in the weed seed zone. (Butts et al. undated, Kenso 2004, Mann undated). Metolachlor breaks down faster in high organic matter soil, particularly when they are warm and moist as microbial action is increased under these conditions (Long et al. 2014). Metolachlor is registered for use in sweetpotato, to be applied within 24 hours of transplanting sweetpotato vines before weeds have germinated, with sufficient irrigation to wet the soil through the weed zone (Kenso Agcare 2004).

Oxyfluorfen is a pre- and post-emergent selective herbicide for control of annual broadleaf and grassy weeds. It is rapidly absorbed by shoots, less so by roots and is poorly translocated through the plant. Oxyfluorfen works by attacking the fats and proteins of the plant cell membranes. This causes breakdown in the cell membrane and cell desiccation It is persistent and relatively immobile in soils and the soil surface should not be disturbed after application. Plant symptoms can include leaves having a water-soaked appearance, then followed by necrotic spots. Depending on the crop, plant back intervals may be as long as 180 days (Vanstone and Stobbe 1978, Anon 2017, ADAMA 2019[2], Fenimore undated).

Pendimethalin is a pre-emergence selective herbicide for control of annual grasses and some broadleaf weeds. It inhibits pre-emergent seedling development, by affecting root and shoot growth. It is readily absorbed by young roots, but there is minimal translocation. Cell division in young roots, particularly root tips is inhibited, and they become thick and stubby. Pendimethalin works best when it is thoroughly mixed in the soil, either by mechanical incorporation or watered in. With some crops pendimethalin may have a 12 month plant back period (BASF 2013, Cornell University undated).

Prometryn is a selective pre- and post-emergence herbicide for control of broadleaf weeds and some grasses. It is mainly absorbed through the roots, although it is also absorbed through foliage, and translocated in the xylem where it accumulates in meristems and leaves. It inhibits electron transports affecting the photosynthetic system. Prometryn requires rain or irrigation soon after spraying for best activity. It works best on germinating seedlings or young and actively plantlets growing in moist soil. Young plants may stop growing then yellow and slowly die over 3-4 weeks (EPA 1996, Nufarm 2009, Herbiguide[2] undated, OXON[1] undated). With some crops there may have a plant back period of six months (Nufarm 2009) to eight months (EPA 1996).

Terbuthylazine is a selective pre- and post-emergence herbicide for control of annual broadleaf weed and some grasses. It is mainly absorbed through the roots or seedlings and to some extent by emerging cotyledons. It can also be absorbed through foliage. It is translocated in the xylem and accumulates in meristems and leaves. It inhibits electron transport which affect the photosynthetic system. Plants may yellow and die. There may be a plant back period more than six months for some crops (Kuechler et al. 2003, FAR 2007, Nufarm 2009, Herbiguide[3] undated, OXON[2] undated)

Trial process

Polystyrene boxes (internal measurement 44.5 cm L x 27.5 cm W x 12.0 cm H) were filled to within 5 cm of the top with red basaltic Mapee soil, common to the Walkamin cropping area. Mapee soils are deep red uniform light to medium clay soils formed from basalt (Malcolm and Heiner 1996). The soil was taken from a newly cultivated fallow block on WRF. In the past 10 years, there was no recorded use of herbicide on this block. Complete fertilizer in the form of slow-release pellets (N_{14} $P_{1.4}$ $K_{9.0}$ $S_{7.0}$ $Ca_{3.6}$ + Si, Fe, Mg, Mn, Zn, Cu, B, Mo) was incorporated into the soil mix which was then watered to field capacity. Three days later boxes were lightly watered, and the following day pre-emergent herbicides were applied.

Pre-emergent herbicides, imazethapyr, metolachlor, oxyfluorfen, pendimethalin, prometryn and terbuthylazine were applied 60 days before planting to simulate their application at the planting of a rotation crop prior to sweetpotatoes. After pre-emergent spray application, the boxes were watered to ensure the herbicide was incorporated into the soil profile as per label recommendations. Post-emergent weed herbicides, 2,4-DB, glyphosate, dicamba, fluroxypyr, glusosinate ammonium and MCPA were applied to the bare soil 24 hours before the first planting of sweetpotato vines. All herbicides were applied using a 500 ml hand sprayer containing 200 ml of spray solution. The spray was applied to provide coverage of the box (similar to that achieved from a field spray unit).

Orleans was the sweetpotato variety used in the trial. Three plantings, each of one cutting were made into each box (plot). Planting 1 was made 24 hours after the post-emergent herbicide application, planting 2 was 9 days later and planting 3 was 16 days after the herbicide application. The vine cuttings for each planting were selected in the morning, stored in a bucket with 15 cm of water and planted in the cool of the late afternoon. All the cuttings were apical vine cuttings 28-32 mm long with 3 nodes within 15 cm of the cut end of the vine. Cuttings were planted horizontally at a depth of 2 cm, with the apical end tip and leaves above the soil (image 1). As soon as the vines were planted, the pots were watered to field capacity.

The trial was lightly watered three times per week, except when conditions were wet. When possible, daily observations were made of the plants. If this was not possible observations were made on the second day. A five point rating scale was given to the visual symptoms the plants were showing;

1. Plants are healthy growing and showing no sign of herbicide application or other issues affecting crop growth.

2. Plants are showing symptoms which may affect plant growth, such as wilting of leaves or stems. This may have reduced growth to some degree but if symptoms remain at this level, the plants will continue to grow.
3. Plants showing moderate effects affecting their growth. The plants are wilting strongly or have bleaching, burnt or senesced leaves and stem. They still have a visual assessment of 50% green leaves and stems and may or may not be able to grow out of this damage.
4. Plant showing considerable effect of the herbicide application. They still have some green leaves or stems, but it is unlikely they will be able to grow out of the damage.
5. Plants dead.

In addition to the rating a description was made of the visual appearance of the plot, (e.g., stems wilting, leaves bleached or leaves bronzed, leaves senescing). The trial concluded 38 days after planting 1 was made.

Image 1. Planting 1 (bottom middle in box), planting 2 (bottom right in box) and planting 3 (top left in box)

Results

In Planting 1, five of the herbicides, 2,4-DB, dicamba, fluroxypyr, glusosinate ammonium and MCPA killed the planted vine cuttings within10 days of planting. There appeared to be an anomaly in the dicamba replication 1, plot and glusosinate ammonium replication 4, plot. In both of these plots the herbicide application appeared to have no effect. For dicamba, the plants in the other three replications were all dead by day 10, and by day 13 for the glusosinate ammonium treatments. All the herbicides which caused plant death were post-emergents applied 24 hours before planting. During the first 10 days, the other treatments, including the control, showed a slight to moderate sign of wilting, probably transplant shock. Of the treatments that did not result in plant death, the metolachlor treatment did show slightly more wilting for the first 14 days than did the other treatments (figure 1).

Planting 2, which occurred 10 days after the post-emergent herbicide application showed a reduction in plant death from the herbicide treatments. Three of the four replications of the fluroxypyr treatment were dead by 13 days after planting. This was 22 days after the herbicide application and the plant in the remaining replication was only just surviving. By day eight after planting (17 days after post-emergent herbicide application) plants in two of the four the glusosinate ammonium treated plots were dead. The plants in the two remaining plots although sick and weak with strongly yellowed or senesced leaves began to reshoot and new vines were developing by the trial’s conclusion. Plants in the MCPA treatment also showed apical senescence wilting and yellowing of leaves. Although not killing the plants, there was a noticeable visual effect on their growth. The health of these plants improved throughout the trial, looking healthy by its completion. There was minimal disruption to plant growth in the other treatments (Figure 2).

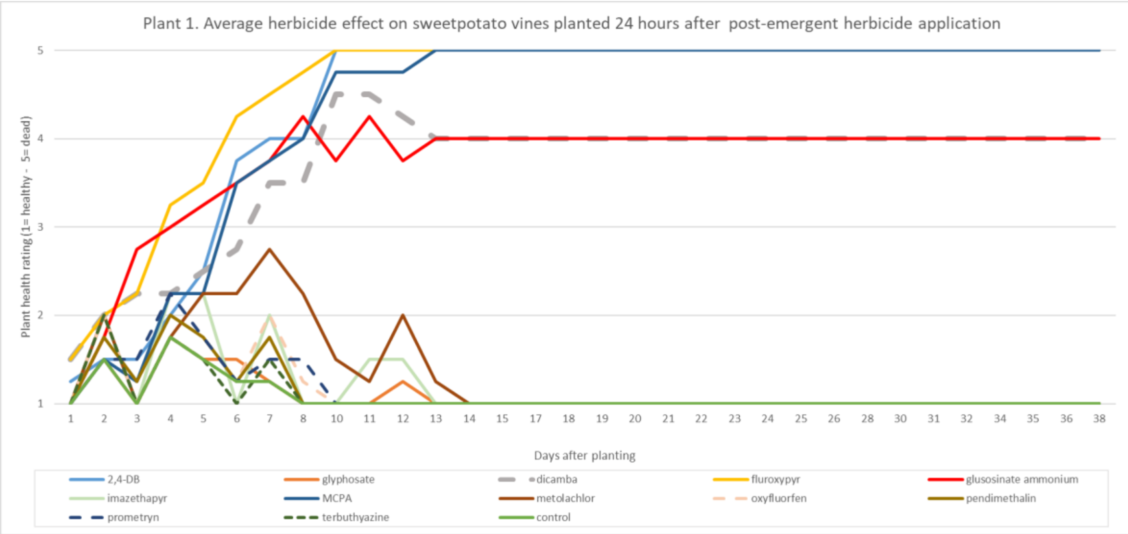

Figure 1. Sweetpotato vine cutting establishment and growth when planted 24 hours after herbicide application

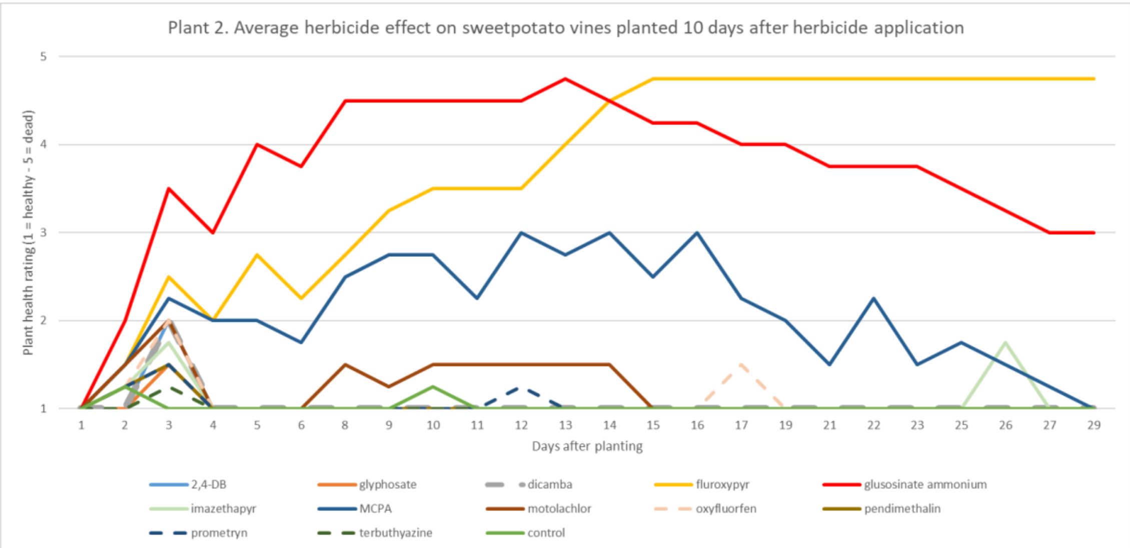

Figure 2. Sweetpotato vine cutting, establishment and growth when planted 10 days after herbicide application

As can be seen by the control treatment in Planting 3 (Figure 3), the vine cuttings did not establish as well in planting three as they had in the other plantings, probably due in some part to compaction and waterlogging of the soil in the pots from constant rain. Fluroxypyr treatments again showed a negative relationship to plant health, with plants in three of the four replications dying by 14 days after planting (31 days after post-emergent herbicide application) and the fourth replication remaining at a four rating (senesced apical tip, senesced new leaves and pale yellow stem with only a single green leaf). MCPA and dicamba treatments appeared to slightly affect the plants and metolachor showed small effect till day nine after which the plants regained their health (Figure 3).

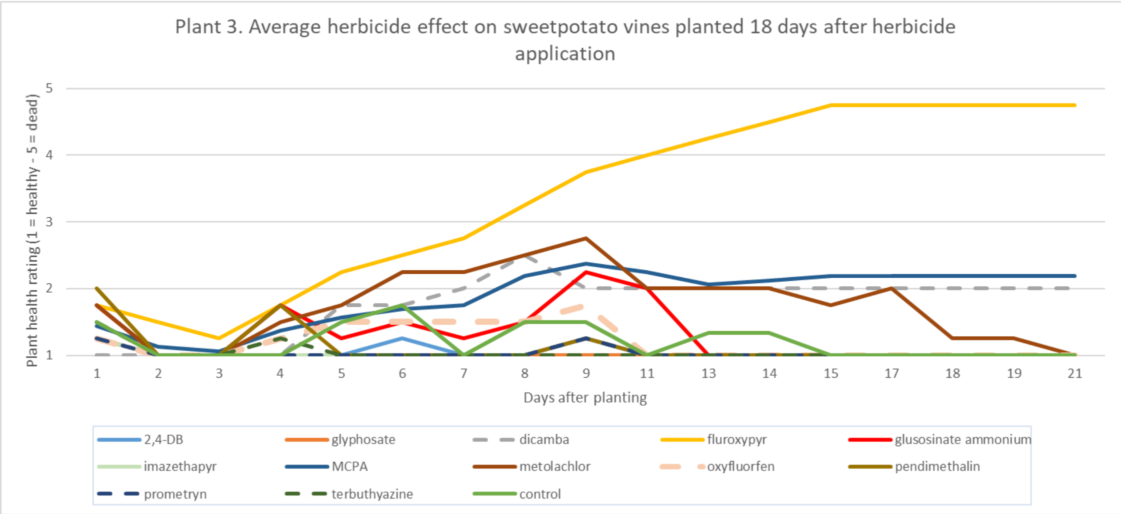

Figure 3. Sweetpotato vine cutting, establishment and growth when planted 18 days after herbicide application

In Planting 1. there was no significant difference between any treatment in the number of storage roots produced by vines. There were differences in other storage root parameters. The average storage root diameter was significantly smaller for imazethapyr and metolachlor treatments than the other treatments (Figure 4). This also occurred for average storage root length (Figure 5). In both these measurements the glusosinate ammonium results should be treated with caution as they represent the one abnormal replication.

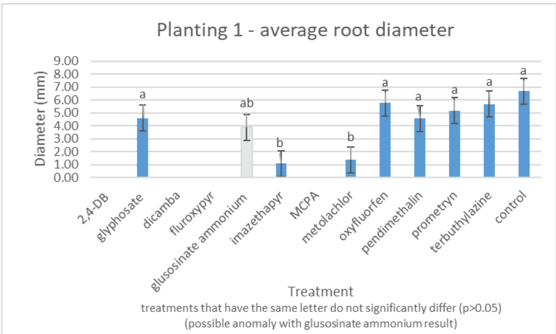

Figure 4. Average diameter of storage roots in Planting 1.

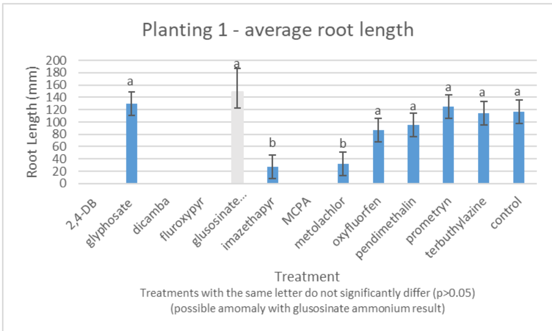

Figure 5. Average length of storage roots in Planting 1.

The control treatment in Planting 1 has the greatest average root volume, which was significantly similar to the terbuthylazine and prometryn treatments. Oxyfluorfen, glyphosate and pendimethalin treatments while equivalent to terbuthylazine, prometryn and glyphosate, were significantly better than metolachlor and imazethapyr (Figure 6). As previously stated, care needs to be taken when interpreting the glusosinate ammonium result.

The control treatment produced the heaviest storage roots in Planting 1. This was statistically equivalent to terbuthylazine, prometryn and glyphosate treatments. Prometryn, pendimethalin glyphosate and oxyfluorfen were also statistically similar in root weights. Both imazethapyr and metolachlor treatments were significantly less than the other treatments (Figure 7).

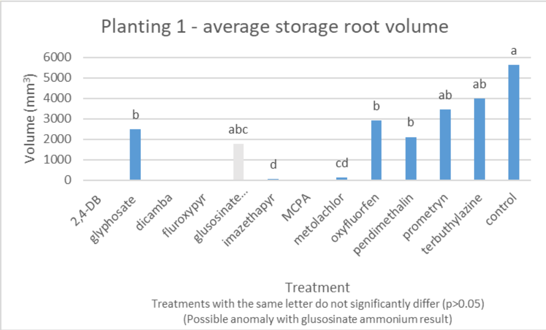

Figure 6. Average volume of storage roots in Planting 1.

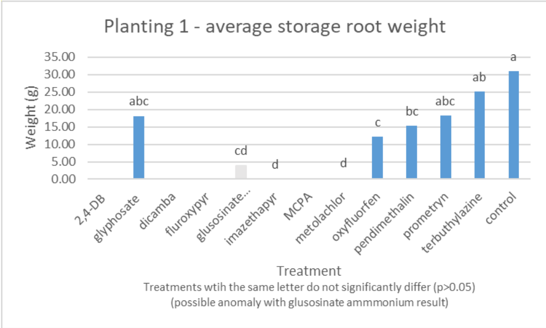

Figure 7. Average weight of storage roots in planting 1.

There were differences in the average length of vines in the various treatments of Planting 1. Terbuthylazine, prometryn and the control treatments statistically had the longest vines, followed by glyphosate and pendimethalin treatments. Oxyfluorfen, metolachlor and imazethapyr treatments had significantly shorter vines than the other treatments. The glusosinate ammonium result should be regarded as an anomaly (Figure 8)

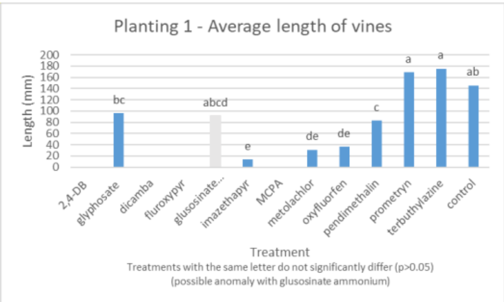

Figure 8. Average length of sweetpotato vines in Planting 1.

In Planting 2, the dicamba, 2,4-DB, pendimethalin, prometryn, oxyfluorfen and glyphosate treatments were all significantly similar, and produced the largest diameter storage roots. The control treatment produced significantly thinner roots than the dicamba and 2,4-DB treatments and was similar to all other treatments. Although glusosinate ammonium produced the thinnest roots, they were statistically similar to fluroxypyr, imazethapyr, terbuthylazine, MCPA, metolachlor and the control (Figure 9).

Glyphosate, 2,4-DB, dicamba, prometryn and oxyfluorfen treatments produced the longest roots in Planting 2. Glusosinate ammonium, fluroxypyr and imazethapyr treatments, while producing the shortest roots, were statistically similar to the control, MCPA and terbuthylazine treatments (Figure 10).

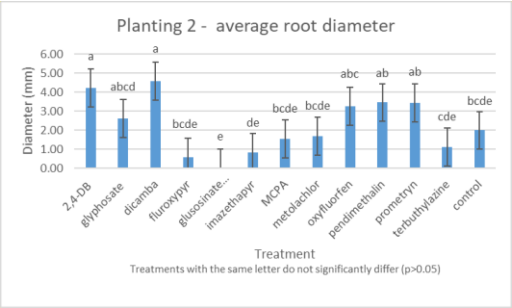

Figure 9. Average diameter of storage roots in Planting 2.

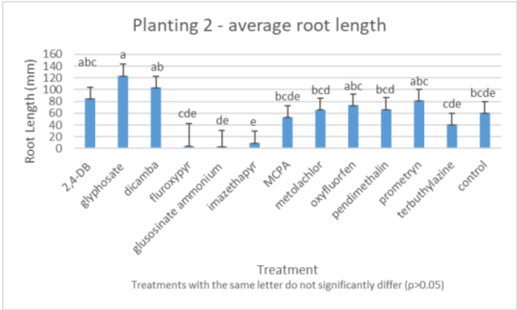

Figure 10. Average length of storage roots in Planting 2.

Dicamba, 2,4-DB, prometryn, oxyfluorfen, pendimethalin and glyphosate were all statistically similar in storage root volume in Planting 2. The control treatment had a slightly smaller volume. Glusosinate ammonium, imazethapyr, fluroxypyr, terbuthylazine metolachlor and MCPA all had significantly smaller root volumes (Figure 11).

Average root weight in Planting 2 identified dicamba and 2,4-D as having significantly higher average root weight than glusosinate ammonium and imazethapyr treatments. Dicamba also had significantly heavier roots than MCPA and terbuthylazine treatments. There was no significant difference between the control and all other treatments (Figure 12).

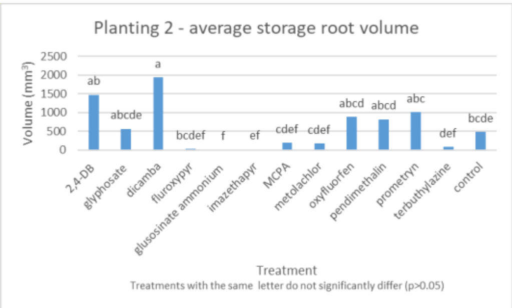

Figure 11. Average volume of storage roots in Planting 2.

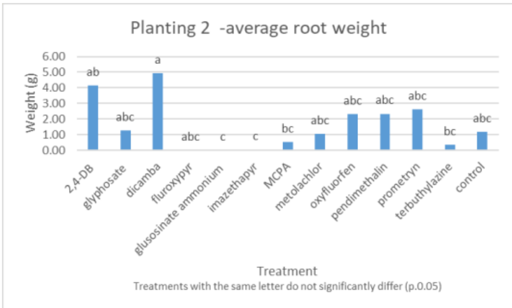

Figure 12. Average weight of storage roots in planting 2.

Planting 2 control treatment had on average the longest plant vines, but this was only significantly different to MCPA, fluroxypyr, glusosinate ammonium and imazethapyr treatments (Figure 13).

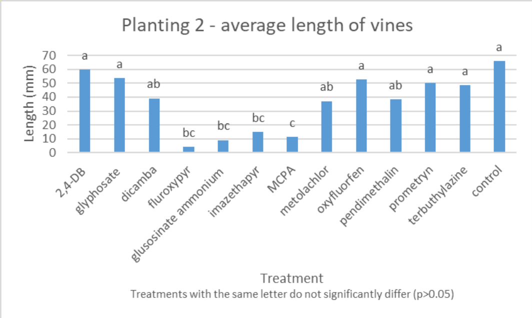

Figure 13. Average length of sweetpotato vines in Planting 2.

No root development data is presented for Planting 3. The vines were only in the soil for 21 days, before the trial harvest. During this period there was minimal root development. Vine length measurements were made at harvest. While there was a trend for the metolachlor, MCPA and imazethapyr treatments to have shorter vine lengths than the other treatments, this was not significantly different to any other treatment (Figure 14). No data was available for the fluroxypyr treatment as three of the four replications had died and the fourth was barely surviving.

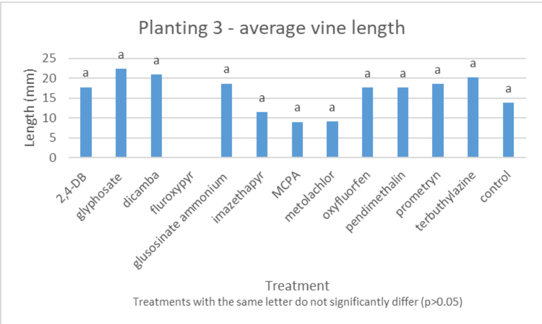

Figure 14. Average length to sweetpotato vines in Planting 3.

Discussion

The only herbicides which killed the planted sweetpotato cuttings were the post-emergent herbicides. Of the five herbicide treatments that killed or severely injured sweetpotato cuttings in Planting 1, fluroxypyr was most destructive across all three planting periods (Figure 15). The fluroxypyr label identifies that if soils have less than 25% clay susceptible crops may require up to a 12 month break (Corveta Agriscience undated). Even on the red volcanic Mapee soil with a clay content of 51% (Malcolm and Heiner 1996), fluroxoypyr still showed a strong residual activity, indicating that sweetpotato is sensitive to this herbicide when it is used at high rates. Cotton is identified as having a 28 day plant back and the indications of this trial are that the plant back for sweetpotato would be no less and potentially very much longer.

2,4-DB persistence had been identified by Howerda and Ekanayake (1991), but no time period was given. This trial found that while 2,4-DB was lethal to sweetpotato 24 hours after application, the persistence quickly dropped away and was minimal if at all at the second planting (Figure 15).

Tokana and Dayan (2020) identified glusosinate ammonia as having a one to seven days residual. This trial found that high rates of glusosinate ammonium showed strong herbicidal effects on sweetpotato for at least 16 days after planting, indicating that planted sweetpotato cuttings may be quite susceptible to this herbicide (Figure 15). By 16 days after spray application the effect of glusosinate ammonium on sweetpotato transplant growth had reduced considerably.

Like glusosinate ammonium, although with reduced effect, the MCPA treatments killed the sweetpotato cuttings at the first planting and were still showing an effect at the second planting. Planting 3 still showed a slightly greater effect that the control treatment (Figure 15). Dicamba a chemical similar to MCPA, both being phenoxyalkonoic acids, showed minimal if any effect at Planting 2 and a similar response at Planting 3, where there was slight wilting of the plants (Figure 15).

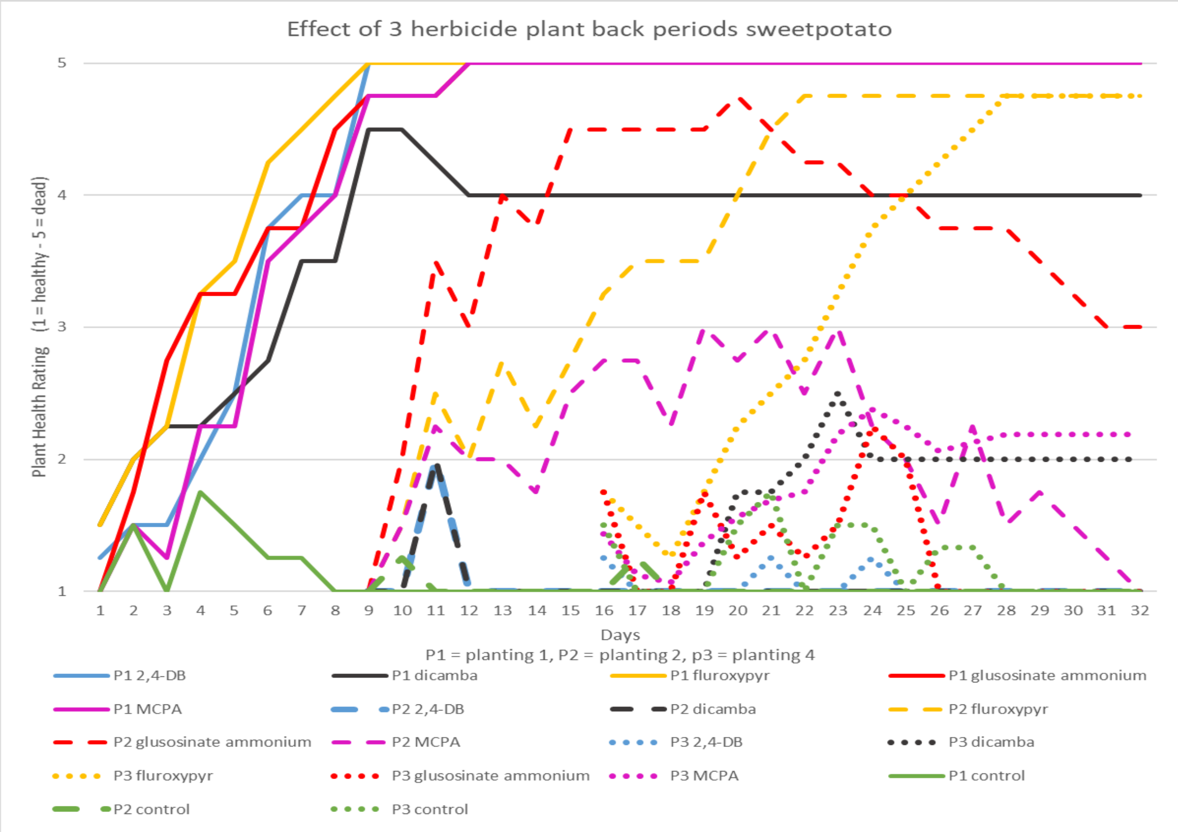

Figure 15. The effect of different plant back periods on lethality of five herbicides to planted sweetpotato cuttings.

Glyphosate was the only post-emergent herbicide to show no plant back effect on sweetpotato. This agrees with the Tu et al. (2001) who states glyphosate has little or no residual activity once it touches soil as it is rapidly and strongly absorbed to soil particles, particularly as clay content and CEC increases.

There were no serious visual effects on the sweetpotato cuttings from the pre-emergent and pre/post-emergent herbicides which had been applied 60 days before Planting 1. Compared to the other pre-emergents, metolachlor did show slightly more distressed/wilted plants for the first 13 days after planting in both Plant 1 and Plant 3, but there may also be an element of transplant shock in this result.

Interestingly, where there does appear to be effects from the pre-emergent herbicides is in the developing storage roots. For all root measurements (root diameter, root length, root volume and root weight) in both Planting 1 and Planting 2, imazethapyr produced significantly lower than the best values. The vines of imazethapyr treated plants were also significantly shorter in Planting1 and Planting 2 and one of the shorter vines (not significant) in Plant 3. Imazethapyr is known to have long term residual effects on some plants, particularly in dry conditions the residual can last up to 34 months. In irrigated cropping where the rainfall/irrigation in excess of 2,000 mm this may reduce to 18 months. This trial shows that 69 days after application imazethapyr still had a strong effect on sweetpotato root development.

Although registered for post-plant use in sweetpotato, metolachlor also appeared to influence the sweetpotato root development parameters with the effect reducing slightly between Planting 1 and Planting 2. While there has been no previous trial work done on plant back effects of using metolachlor, there have been several USA trials studying the effect of metolachlor on sweetpotato growth. Porter (1995) stated that metolachlor had no significant effect on sweetpotato varieties and Meyers et al. (2012) quotes Monks et al. (1998) as also finding no adverse effect from use of metolachlor. On the other hand, both Meyers et al. (2012), Abukari et al. (2015)[1] and Abukari et al. (2015) [2] showed metolachlor effects on sweetpotato growth. Predominately the effect of metolachlor becomes more noticeable as the rate of active ingredient increases. This effect may also be compounded by increased levels of irrigation, particularly if the herbicide is applied just after transplanting, Meyers et al. (2012), Abukari et al. (2015)[1] and Abukari et al. (2015) [2]. Their recommendation is to apply as low a dose as possible and follow weather forecasts to avoid irrigation when heavy rainfall events are predicted (Meyers et al. 2015, Abukari et al. 2015[2], Smith and Miller undated). As this trial applied metolachlor at maximum rates and there was considerable rain (150 mm rainfall from Plant 1 till harvest) over the trial period, the results show, given adverse conditions there can be a herbicide effect 60 days after application.

In Planting 1, oxyfluorfen treatments produced significantly lower root volumes, root weights and length of vines than the control treatment. This difference was not seen in Planting 2. Xue and Dai, 2020 found that oxyfluorfen applied at up to three days before planting gave the crop good weed control without affecting the crop. Lewthwaite et al. (2010) found oxyfluorfen had potential to be phytotoxic to sweetpotato when applied as a post-emergent. ADAMA 2019[2]) does identify potatoes need a 60 day plant back period, brassicas, capsicum and carrots require 90 days plant back and for onions it may be as long as 180 days.

Similar to oxyfluorfen in Planting 1, pendimethalin treatments produced significantly lower root volumes, root weights and length of vines than the control treatment
In an earlier trial studying management of volunteer sweetpotato roots, conducted as part of the Hort Innovation project PW 17001 *Integrated pest management of nematodes in sweetpotatoes*, the pendimethalin treatment while not affecting plant emergence or vine length did cause misshapen true leaves. This effect did not occur in this trial. Lewthwaite and Triggs (2000) found that pendimethalin did reduce yields compared to some other herbicides and hand weeding and Meyers et al. 2019 found pendimethalin produced varying results stating that sweetpotato stunting following pendimethalin application is minimal and temporary. BASF (2013) identifies plant back periods of two months for carrots, parsnips, and potatoes, five months for turnips radish and onions and up to 12 months for beetroot, spinach and silverbeet.
This trial while not continuing to full storage root development does support the theory that pendimethalin may have an influence on root development in the early stages of plant growth.

Prometryn was applied as a pre-emergent was not significantly different to the control or best treatments in any of attribute. Studies on prometryn in sweetpotato are minimal. An undated Chinese study abstract by Zhang et al. found prometryn detrimental to sweetpotato. Nufarm (2009) identifies a possible plant back period of up to six months in Australia when high rates of prometryn have been used. In the USA, a plant back of up to eight months is recognised (EPA 1996).

Terbuthylazine was not significantly different to the control or best treatments in any attribute in Planting 1, and in Planting 2 it did not significantly differ from the control treatment, although it was smaller for root diameter, root length, storage root volume and average root weight. Terbuthylazine may have a plant back period as long as 12 months with a minimum rainfall of 175 mm (Nufarm 2020). In this trial 458 mm of the rain had fallen between spray application and planting, assisting in the reduction of the plant back for sweetpotato. There is minimal, if any research on the effects of terbuthylazine on sweetpotato.

This trial did highlight that sweetpotato is sensitive to many herbicides and that growers need to be especially aware of plant back periods, particularly if looking at controlling weeds near planting. There are also factors which can influence a herbicides life in the soil. Melo et al. 2016 has identified them as;

- Soil – microorganisms, humidity, texture, structure, porosity, organic carbon content and pH
- Environmental conditions – temperature, management, rainfall and the plant growth
- Physico-chemical properties of the chemical – degree of retention, half-life, ionization constant, dose, vapour pressure and solubility.

The results produced by this trial were with a Walkamin soil, growing in summer during the wet season, so they may well vary when crops are planted in other regions and at different times of the year with different rainfall and temperature effects. Care must always be taken to read herbicide labels before use, and to consider the length of the plant back period required before planting the next sweetpotato crop.

Acknowledgements

The author would like to acknowledge the funding and support provided by Hort Innovation through Australian sweetpotato grower levies and DAF. Thank you to the staff at Walkamin Research Facility for their assistance and hosting the trial on their facility. I would also like the thank Simon Godfrey, Oaklands Farming, for providing the planting material and Dr. Carole Wright for analysis of the results and the DAF sweetpotato team for their insightful comments and thoughts.

References

Abukari I.A., Shankle M.W. and Reddy K.R. (2015)[1] S-metolachlor and rainfall effects on sweetpotato (*Ipomoea batatas* L. [Lam]) growth and development. *Scientia Horticulturae* Vol 185 98-104

Abukari I.A., Shankle M.W. and Reddy K.R. (2015)[2] Sweetpotato (*Ipomoea batatas* L. [Lam]) response to S-metolachlor and rainfall under three temperature regimes. *American Journal of Plant Sciences* Vol 6 702-717

ADAMA (2019[1]) Spinnaker®700 WG herbicide product label.

ADAMA (2019[2]) Cavalier herbicide product label.

Anonymous (2017) Grownotes™: Technical Grains Research and Development Corporation (GRDC)

BASF (2013) Stomp®Xtra herbicide product label

Butts T.R., Barber L.T., Brabham C., Burgos N.R., Norsworthy J.K. and Willett C.D. (undated) Metolachlor Herbicides: What are the facts? Agriculture and Natural Resources publication FSA2185. Division of Agriculture, Research and Extension, University of Arkansas

Cobb A.H. and Reade J.P.H. (2010) Auxin-type herbicides. Chapter 7 in Herbicides and Plant Physiology, second edition. Cobb A.H. and Reade J.P.H. (eds). Chichester, West Sussex, UK: Wiley-Blackwell. pp 133-156

Cornell University (undated) Weed Ecology and Management Laboratory https://weedecology.css.cornell.edu/herbicide/herbicide.php?id=1

Corveta Agriscience (undated) Starane® Advanced herbicide product label.

EPA (1996) Prometryn. R.E.D. Facts, United States Environmental Protection Agency https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/fs_PC-080805_1-Feb-96.pdf

EPA (1998) Pesticide Fact Sheet – Fluroxypyr. United States Environmental Protection Agency (EPA) https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-128959_30-Sep-98.pdf

FAR (2007) Terbuthylazine. In Weeds, Pests & Diseases, Arable Extra No. 71. Foundation for Arable Research (FAR), New Zealand

Fenimore S. (undated) Contact Herbicides. Presentation. University of California-Davis, Salinas, CA.
https://wric.ucdavis.edu/PPTs/FENNIMORE_Contact_herbicides-Nov05.pdf

Guo M., Shen J., Song E., Dong S., Wen Y., Yuan X. and Guo P. (2019) Comprehensive evaluation of fluroxypyr herbicide on physiological parameters of spring hybrid millet. *Peer J.* 7:e7794 18pp

Gupta P.K. (2018) Toxicity of Herbicides in Veterinary Toxicology (Third edition)
https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/2-4-db/pdf

Herbiguide[1] (undated) Fluroxypyr
http://www.herbiguide.com.au/Descriptions/hg_fluroxypyr_mode_toxicity_fate_properties_regulations.htm

Herbiguide[2] (undated) Prometryn 900
http://www.herbiguide.com.au/Descriptions/hg_Prometryn_900.htm

Herbiguide[3] (undated) Terbuthylazine
http://www.herbiguide.com.au/Descriptions/hg_Terbuthylazine.htm

Holwerda H.T. and Ekanayake I.J. (1991) Establishment of sweet potato stem cuttings as influenced by size, depth of planting, water stress, hormones and herbicide residues for two genotypes. *Scientia Horticulturae* Vol 48: 193-203.

Kenso Agcare (2004) Metoken 720 Herbicide product label

Kuechler T., Deufer B., Resseler H., Schulte M. and Cornes D. (2003) Terbuthylazine in maize – a model example of product stewardship and safe use. Brit. Crop Prot. Conf. Proc. pp 953-958. Glascow Scotland, UK

Kogan M. and Hernandez G. (1991) Localised applications of MCPA and glyphosate to young kiwifruit plants. *New Zealand Journal of Crop and Horticultural Science*. Vol 19 (4) 345-348

Lewthwaite S.L., and Triggs C.M. (2000) Weed control in sweetpotatoes. *New Zealand Plant Protection Society* Vol 53 262-268

Lewthwaite S.L., Triggs C.M. and Scheffer J.J.C. (2010) Evaluation of alternative herbicide systems for the sweetpotato crop. Seventeenth Australasian Weeds Conference. Zydenbos S.M. (ed) 26-30 September, Christchurch: New Zealand

Long Y.H., Li R.T. and Wu X.M. (2014) Degradation of S-metolachlor in soil as affected by environmental factors. *J Soil Sci. Plant Nutr*. Vol 14 (1)

Malcolm D.T. and Heiner I.J. (1996) The soils of Walkamin Research Station. Research Establishments Publication QR96000. Department of Primary Industries (DPI), Queensland.

Mann R. (undated) Metolachlor Herbicide. Pesticide and Fertilizer Management, Minnesota Department of Agriculture https://www.mda.state.mn.us/metolachlor-herbicide

Melo C.A.D., Dias R. de C., Mendes K.F., Assis A.C. de L.P. and dos Reis M.R. (2016) Herbicides carryover in systems cultivated with vegetable crops. *Revista Brasileira de Herbicidas* Vol 15 (1) 67-78

Meyers S.L., Jennings K.M. and Monks D.W. (2012) Response of sweetpotato cultivars to S-metolachlor rate and application time. *Weed Technology* Vol 26 474-479

Meyers S.L., Chaudhari S., Jennings K.M., Millar D.K. and Shankle M.W. (2019) Response of sweetpotato to pendimethalin application rate and timing. *Weed Technology* Vol 34 301-304

Monks D.W., Jennings K.M., Meyers S.L., Smith T.P. and Korres N.E. (2019) Sweetpotato: Important Weeds and Sustainable Weed Management. Chapter 31 in Weed Control: Sustainability, hazards and risks in cropping systems worldwide. Korres N.E., Burgos N.R. and Duke S.O. (eds) CRC Press. pp 581-596.

Noling J.W. (2016) Nematode Management in Sweet Potatoes (including Boniatos). ENY-030 Department of Entomology and Nematology, University of Florida/IFAS Extension.

Nufarm (undated) Rediscover Phenoxies; A guide to phenoxy herbicides. Nufarm UK Ltd.: West Yorkshire, UK

OXON[1] (undated) Prometryn. OXON http://oxon.it/product/24/prometryn

OXON[2] (undated) Terbuthylazine OXON http://oxon.it/product/27/terbuthylazine

Overstreet C. (2013) Diseases caused by nematodes. In, Compendium of Sweetpotato Diseases, Pests and Disorders. 2nd edition. Clark C.A., Ferrin D.M., Smith T.P and Holmes G.J. (eds). The American Pytopathological Society, St. Paul: Minnesota

Porter W.C. (1995) Response of sweetpotato cultivars to metolachlor. Abstract. *HortScience* Vol 30 (3) 441

Seem J.E., Creamer N.G. and Monks D.W. (2003) Critical weed-free period for 'Beauregard" sweetpotato (*Ipomoea batatas*). *Weed Technology* Vol 17 686-695

Smith T.P. and Miller D.K. (undated). Weed management in sweetpotato. Louisiana State University Agricultural Center. Pub.3007 11/07

Smith T.P., Overstreet C., Clark C. and Sistrunk M. (2017) Nematode Management; Louisiana Sweet Potato Production. LSUAgCenter. www.LSUAgCenter.com

Sun C., Chen C., Jin Y., Song H., Ruan S., Fu Z., Asad M.A.U. and Qian H. (2016) Effects of the herbicide imazethapyr on photosynthesis in PGR-5 and NDH-deficient *Arabidopsis thaliana* at the biochemical, trascriptic and proteomic levels. *Journal of agricultural and food chemistry* 64: 4497-4504

Takano H.K. and Dayan F.E. (2020) Glufosinate-ammonium: a review of the current state of knowledge. *Pest Manag Sci* 76: 3911-3925

Tu M., Hurd C. and Randall J.M. (2001) Glyphosate. in Weed Control Methods Handbook.Tu M., Hurd C., and Randall J.M. (eds). The Nature Conservancy. http:tncwees.ucdavis.edu pages 7e-1 - 7e-10.

Vanstone D.E. and Stobbe E.H. (1978) Root uptake, translocation and metabolism of nitrofluorfen and oxyfluorfen by fababeans (*Vicia faba*) and green foxtail (*Setaria viridis*). *Weed Science* Vol 26 (4) 389-392

Xue G. and Dai Q.W. (1992) Good control effects of oxyfluorfen on weeds in sweetpotato fields. *Plant Protection.* Vol 2 50. Abstract https://www.cabi.org.isc/abstract/19932330465

Zhang Y., Zhang C., Lu X., Liu Z., Ma S. and Ma C. (undated) The bioactivity and safety to sweet potato of several soil treatment herbicides (Abstact) Plant Protection Research Institute, Tai'an Academy of Agricultural Sciences, Tai'an, Shandong, China