

VG97062

Weed Management in Sweet Corn

Ian Macleod

Serve-Ag Research



Know-how for Horticulture™

VG97062

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Weed Management in Sweet Corn

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Project VG97062 (Project Completion 30/6/00)

Final Report

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Serve-Ag Research

September 30, 2000

HRDC Project VG97062

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Media Summary

Weed control in sweet corn currently relies on the use of a small number of herbicides, principally atrazine and metolachlor. Despite providing control of most broadleaf weed species, these herbicide strategies are weak on some grass weeds.

This three-year Horticultural Research and Development Corporation project evaluated a range of alternative herbicides to atrazine and also looked at improving grass weed control. A total of eleven replicated small plot herbicide trials in sweet corn were conducted in Queensland, New South Wales, and Tasmania. These trials generated crop safety and weed efficacy data for a range of products in several sweet corn varieties, climates, soil types and weed spectra.

A total of eight experimental herbicides were evaluated in this project. Four of these, Balance (isoxaflutole), Frontier (dimethenamid), Gardoprim (terbuthylazine) and Affinity (carfentrazone-ethyl), have shown suitable crop tolerance and weed efficacy over a number of sites. Balance, Frontier and Gardoprim are pre-emergent herbicides with activity on a range of broadleaf weeds and grass weed species. Affinity offers an option for post-emergent weed control, with activity on a range of broadleaf weeds, which are common in sweet corn. This product has no soil activity, so weed control is strictly post-emergent.

Providing data for the registration of new herbicides for sweet corn production was a key focus of this project. This required working with a number of herbicide manufacturers. Discussions have been held with manufacturers of Balance, Frontier, Gardoprim and Affinity regarding registration of these herbicides in sweet corn. Efficacy, crop safety and residue data collected as part of this project will be supplied to manufacturers to support registration or permit applications. This data will be used to develop product labels and product training. At this stage it is unclear which, if any of these products will be registered.

A major part of this project has been the transfer of findings to the sweet corn industry. Regular field days, involving growers, processors and agronomic staff have kept industry up to date with the progress of the project. Publications, such as the WA Vegie Link magazine, were also used to keep growers up to date with this project. In addition, results presented at meetings and conferences, including the annual Agricultural Research and Advisory Committee's (ARAC) events and the 12th Australian Weeds Conference (1999), have prompted enquires from all of the major sweet corn production regions across Australia.

Technical Summary

Weed control in sweet corn is reliant on a small number of herbicides, principally atrazine and metolachlor. Atrazine is able to provide effective control of a range of common broadleaf weed species, which occur in sweet corn. Despite the effective control of broadleaf weeds, grass weeds such as *Echinochloa crus-galli* (barnyard grass) are difficult to control. Increasing public pressure to reduce usage of triazine herbicides may influence the use of this product in the future. In addition, the dependence on the narrow spectrum of herbicides available also favours the buildup of herbicide resistant weed species.

A total of eleven replicated small plot herbicide trials in sweet corn were conducted in Queensland, New South Wales, and Tasmania. These trials generated crop safety and weed efficacy data for a range of products in several sweet corn varieties, climates, soil types and weed spectra.

A total of eight experimental herbicides were evaluated in this project. Four of these, Balance (isoxaflutole), Frontier (dimethenamid), Gardoprim (terbuthylazine) and Affinity (carfentrazone-ethyl) have shown suitable crop tolerance and weed efficacy over a number of sites.

Balance is a pre-emergent herbicide with activity on a number of broadleaf weeds including *Amaranthus powellii* (amaranthus), *Chenopodium album* (fat hen), *Solanum nigrum* (black nightshade), *Portulaca oleracea* (common pigweed) and *Argemone* spp (mexican poppy). Activity on grass species such as *Echinochloa crus-galli* is high, and at lower rates, is improved by the addition of Frontier. Crop safety of Balance is generally good, with rates of up to 160g tolerated on some soil types. However, on light textured soils, unacceptable crop damage has been observed, hence appropriate low rates must be used on these soils. Balance is seen as a suitable alternative to atrazine for broadleaf weed control in sweet corn.

Frontier is a pre-emergent herbicide which is active on broadleaf weeds, such as *Amaranthus* spp., *Sonchus oleraceus* (potato weed), and difficult to control grass species such as *Echinochloa crus-galli*. Crop safety is high, with rates of up to 3L tolerated on the heavier textured soils. Some crop damage has been observed on lighter soils, hence lower rates must be used on these soils.

Although Gardoprim is a triazine herbicide like atrazine, its comparatively low soil mobility and similar weed spectrum make it a suitable alternative. When applied pre crop emergence, crop tolerance to Gardoprim has been high on all soil types, providing acceptable control on a range of broadleaf weeds, including *Solanum nigrum*, *Amaranthus powellii* and *Chenopodium album*.

Containing the active ingredient carfentrazone-ethyl, Affinity offers another option for post-emergent control of broadleaf weeds in sweet corn. This product has no soil activity, so weed control is strictly post-emergent, and grass weeds are not controlled by Affinity. Common broadleaf weeds controlled by Affinity include *Amaranthus powellii*, *Chenopodium album* and *Solanum nigrum*.

Providing data for the registration of new herbicides for sweet corn production was a key focus of this project. This required working with a number of herbicide manufacturers. Discussions have been held with manufacturers of Balance, Frontier, Gardoprim and Affinity regarding registration of these herbicides in sweet corn. Efficacy, crop safety and residue data collected as part of this project will be supplied to manufacturers to support registration or permit applications. This data will be used to develop product labels and product training. At this stage it is unclear which, if any of these products will be registered.

Introduction

Weed control in sweet corn relies on the use of a small number of herbicides, principally atrazine and metolachlor. Despite providing control of most broadleaf weed species, current herbicide strategies are weak on some grass weeds such as barnyard grass. Strong reliance on atrazine, which controls most common broadleaf weeds in sweet corn, is causing public concern, and it is possible that it may be taken off the market at some point in the future. In addition, the dependence on a small group of herbicides favours the build up of herbicide resistance in weed species.

This work, conducted as a three-year Horticultural Research and Development Corporation (HRDC) funded project, aims to develop a number of alternative herbicides for use in sweet corn. The main areas of focus are in improving grass weed control and developing products that offer alternatives to atrazine. Eleven trials were being conducted in sweet corn production areas across Australia to gain efficacy and crop tolerance data across a range of environments, crop varieties and weed spectra.

Materials and Methods

Trial Details

ANNUAL REPORT	97-98 Season			98-99 Season				99-00 Season			
SITE NUMBER	1	2	3	1	2	3	4	1	2	3	4
NUMBER OF REPLICATES	4	4	4	4	4	4	4	4	4	4	4
PLOT SIZE (METRES)	1.5 x 8	1.5 x 8	1.5 x 8	0.8 x 5	1.6 x 8	2 x 5	1.6 x 8	1.6 x 8	1.6 x 8	1.5 x 7	1.6 x 7
SOIL TYPE / TEXTURE	Alluvial Clay Loam	Sandy Clay Loam	Alluvial Clay Loam	Alluvial Sandy Loam	Alluvial Clay Loam	Black Clay Silt Clay Loam	Alluvial Silt Clay Loam	Alluvial Sandy Loam	Alluvial Silt Clay Loam	Black Clay	Alluvial Silt Clay Loam
VARIETY	Super Sweet	Golden Jubilee	Super Sweet	Golden Sweet	Super Sweet	Pacific H-5	Super Sweet	Golden Sweet	Super Sweet	Pioneer 32-45	Super Sweet
LOCATION / REGION	Turners Beach NW Tas	Gooloogong NSW	Turners Beach NW Tas	Bowen Qld	Turners Beach NW Tas	Lockyer Valley QLD	Forth NW Tas	Wemen Qld	Turners Beach NW Tas	Glenore Grove Qld	Forth NW Tas

Note – Further details for individual trial sites can be obtained from the annual reports for this project.

Materials and Methods (cont.)

Product Formulations

Product	Active Ingredient	Concentration of Active	Formulation	Herbicide Group*
Affinity (F8426)	Carfentrazone-Ethyl	400g/kg	Water Dispersible Granules	E**
Affinity (F8426)	Carfentrazone-Ethyl	240g/L	Emulsifiable Concentrate	E**
Atrazine	Atrazine	500g/L	Suspension Concentrate	C
Balance (RP97001)	Isoxaflutole	750g/kg	Water Dispersible Granules	F**
Broadstrike	Flumetsulam	800g/kg	Water Dispersible Granules	B
Command	Clomazone	480g/L	Emulsifiable Concentrate	F
Dual	Metolachlor	720g/L	Emulsifiable Concentrate	K
Facet	Quinclorac	750g/kg	Water Dispersible Granules	I
Frontier	Dimethenamid	900g/L	Emulsifiable Concentrate	K**
Gardoprim	Terbutylazine	500g/L	Suspension Concentrate	C
Primextra	Metolachlor Atrazine	227g/L 223g/L	Suspension Concentrate	K C
Starane	Fluroxypur	200g/L	Emulsifiable Concentrate	I
Titus	Rimsulfuron	250g/kg	Water Dispersible Granules	B**

*The herbicide group, used for resistance management, was developed by Avcare (Appendix iii).

**Yet to be confirmed.

Materials and Methods (cont.)

Application Details

EQUIPMENT	Pressurised knapsack precision sprayers
NOZZLES	Flat Fan Jets
VOLUME	189-250 L/ha
PRESSURE	200 - 280 kPa

Weed List

Bayer Code *	Weed
ACNHI	<i>Acanthospermum hispidum</i> (starbur)
AMAPO	<i>Amaranthus powellii</i> (amaranthus)
AMASS	<i>Amaranthu</i> spp. (amaranthus)
ARGOC	<i>Argemone</i> spp. (mexican poppy)
CHEAL	<i>Chenopodium album</i> (fat hen)
CYPRO	<i>Cyperus rotundus</i> (nut grass)
DIGSA	<i>Digitaria ciliaris</i> (crab grass)
ECHCG	<i>Echinochloa crus-galli</i> (barnyard grass)
GASPA	<i>Galinsoga paviflora</i> (potato weed)
HIBTR	<i>Hibiscus trionum</i> (bladder ketmia)
POROL	<i>Portulaca oleracea</i> (common pigweed)
SOLNI	<i>Solanum nigrum</i> (black nightshade)
SONOL	<i>Sonchus oleraceus</i> (sow thistle)
TRBTE	<i>Tribulus terrestris</i> (cats head)
URTSS	<i>Urtuca</i> spp. (nettles)

* Codes as outlined in "Important Crops of the World and their Weeds" (2nd edn. 1992), published by Business Group Crop Protection, Bayer Ag, Germany.

Materials and Methods (cont.)

Assessment Details

1. Crop Tolerance

TIMING - 8 - 49 days after treatments were applied
SAMPLE SIZE - Whole Plot
METHOD - Subjective Rating
RATING SCALE - EWRS (Appendix i)
SUMMARISED RESULTS - Table 1
COMPLETE DATA - Appendix iv and Annual Reports

2. Weed Assessments

TIMING - 8 - 49 days after treatments were applied
SAMPLE SIZE - Whole Plot
METHOD - Subjective Rating
RATING SCALE - EWRS (Appendix ii)
SUMMARISED RESULTS - Table 2
COMPLETE DATA - Annual Reports

3. Weed Counts

TIMING - 17 - 34
SAMPLE SIZE - 0.25 - 0.5m²
METHOD - Seedlings counted in randomly placed quadrats
SUMMARISED RESULTS - Graph 1
COMPLETE DATA - Annual Reports
STATISTICAL ANALYSES - Annual Reports

Results (cont)

Table 1 - Crop Tolerance

Pre-emergence	Post-emergence	Av. EWRS	No. of sites
Atrazine 500mL		2.0	1
Atrazine 4L		1.8	5
Atrazine 4L + Command 500mL		2.0	1
Atrazine 4L + Frontier 1.5L		2.0	1
Balance 30g		5.8	1
Balance 60g		3.6	2
Balance 66.6g		1.4	2
Balance 66.6g + Atrazine 2.5L		1.3	1
Balance 80g		1.8	2
Balance 100g		2.4	6
Balance 100g + Atrazine 2.5L		1.0	1
Balance 120g		2.0	1
Balance 133g + Atrazine 2.5L		1.0	1
Balance 150g		1.9	2
Balance 150g + Atrazine 2L		2.7	1
Balance 150g + Atrazine 2.5L		2.3	1
Balance 160g		2.5	2
Balance 230g		2.3	1
Balance 300g		2.7	1
Command 250ml + Frontier 500mL		6.5	1
Command 250ml + Frontier 1.5L		1.6	2
Command 250mL + Frontier 2L		3.8	4
Command 250ml + Frontier 1.5L	Affinity 20g	3.0	1
Command 500ml + Frontier 1.5L		2.6	3
Dual 2L		1.0	1
Dual 2L	Atrazine 4L	2.1	2
Dual 4L		2.1	8
Facet 600g		1.0	1
Frontier 500mL + Balance 30g		5.3	1
Frontier 500mL	Affinity 20g	3.3	1
Frontier 1L		3.2	5
Frontier 1L	Affinity 50ml	1.0	1

Results (cont.)

Table 1 - Crop Tolerance (cont.)

Pre-emergence	Post-emergence	Av. EWRS	No. of sites
Frontier 1.5L		2.3	4
Frontier 1.5L	Affinity 30g	4.3	1
Frontier 1.5L + Balance 80g		2.1	2
Frontier 1.5L + Balance 100g		2.1	3
Frontier 2 L		3.4	4
Frontier 3L		1.9	6
Frontier 4 L		3.6	4
Gardoprim 750mL		2.0	1
Gardoprim 1.5L		2.1	2
Gardoprim 2L		1.5	1
Gardoprim 3L		1.9	4
Primextra 5L		2.2	7
Titus 60g	Titus 60g	8.0	1
	Affinity 20g	2.5	2
	Affinity 30g	5.0	1
	Affinity 50ml	4.3	2
	Affinity 100ml	4.6	2
	Atrazine 500mL	2.5	1
	Atrazine 4L	2.4	8
	Atrazine 4L + Starane 1L	3.5	7
	Broadstrike 25g	5.3	4
	Titus 60g	5.4	4

Results (cont.)

Table 2 - Weed Susceptibility*

Pre-emergence	Post-emergence	ACHNI	AMAPO	AMASS	ARGOC	CHEAL	CYPRO	DIGSA
Atrazine		S	S	S	S	S	R	S
Atrazine + Command			S			S		
Atrazine + Frontier			S			S		
Balance		S	S-MS	S	S	S	R	S
Balance + Atrazine		S	S	S	S	S	R	
Command + Frontier		S	S	S	S	S	R	S
Command + Frontier	Affinity		S					
Dual	Atrazine		S			S		
Dual		MR	MR	S	S	MR	R	
Frontier		S	S-MS	S	S	S-MS	MR-R	S
Frontier + Balance			S			S		S
Frontier	Affinity					S		S
Gardoprim			S			S		S
Primextra		S	S	S	S	S	R	
Titus	Titus		S			S		
	Affinity		S			S		MR
	Atrazine	S	S	S	S	S	R	MS
	Atrazine + Starane	S	S	S	S	S	R	
	Broadstrike		MR	R	R	R	R	
	Titus	MR	S	R	MR	MR	R	

* Susceptibility of weeds to various herbicides based on EWRS (Appendix i) - **S**-susceptible (1 - 4), **MS**-moderately susceptible (4 - 5.5), **MR**-moderately resistant (5.5 - 7), **R**-resistant (7 - 9).

Results (cont.)

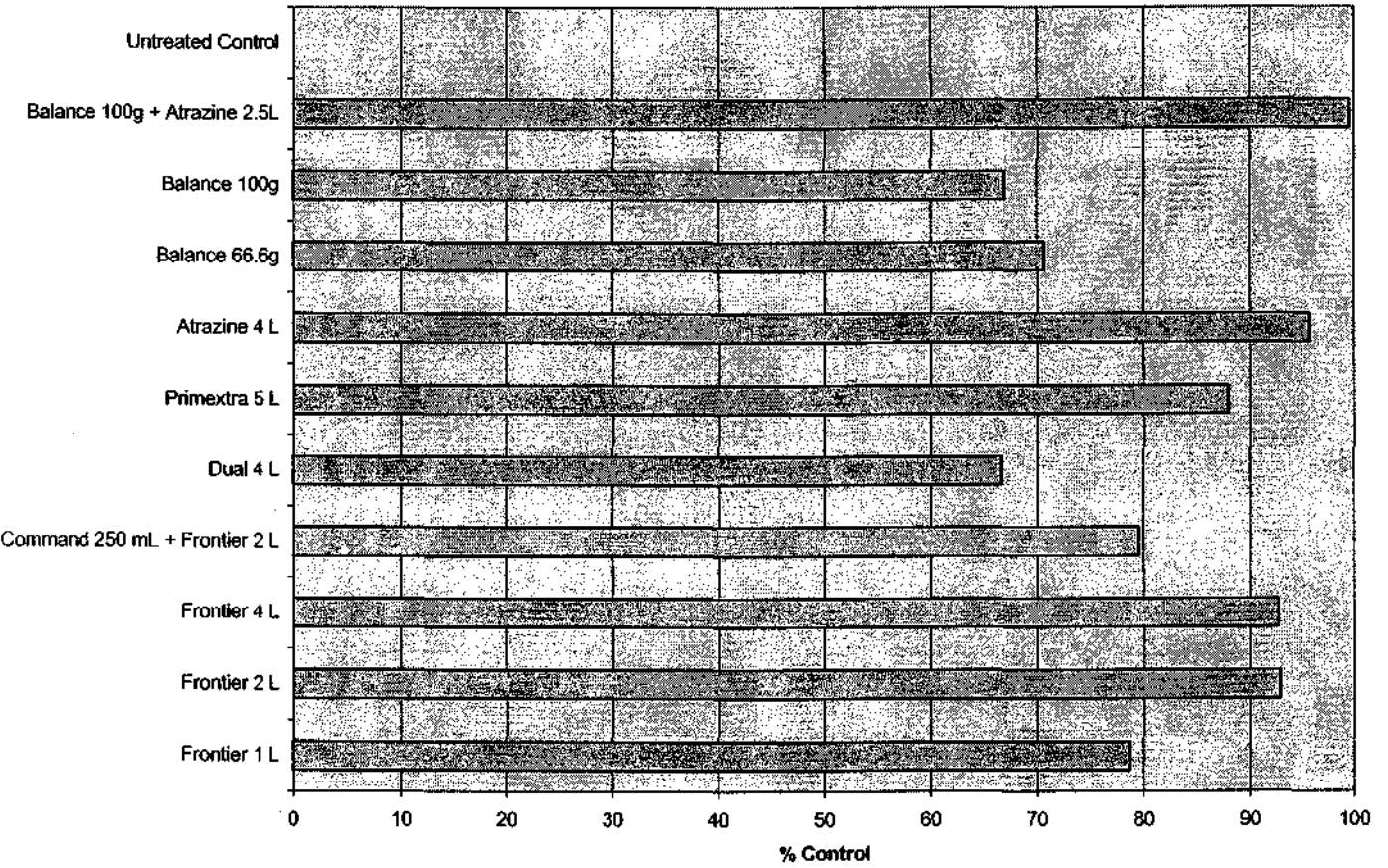
Table 2 - Weed Susceptibility* (cont.)

Pre-emergence	Post-emergence	ECHCG	GASPA	HIBTR	POROL	SOLNI	SONOL	TRBTE	URTSS
Atrazine		MS-MR		S	S	S	S	S	
Balance		S	S	MS	S	S-MS	S	S	S
Balance + Atrazine		S	S	S	S	S			
Command + Frontier		S		R	S-MR	S-MS	S	MS	S
Command + Frontier	Affinity	S	S-MS			S			
Dual	Atrazine	S				S			
Dual		S	S-MS	R	R	MS-MR			S
Frontier		S-MS	S	MS-R	S-MS	S-MS	S	MS	S
Frontier + Balance		S	S-MS			S	S	S	S
Frontier	Affinity					S	S	S	
Gardoprim		MS				S-MS	S	S	S
Primextra		S		S	S	S-MS			
Quinclorac			S						
	Affinity	MR-R				S	S	MS	S
	Atrazine	S-MR		S	S	S	S	MS	S
	Atrazine + Starane	S-MS		S	S	S			S
	Broadstrike	S-R		R	S-R	MS			
	Titus	S-R		R	S-R	MR			

* Susceptibility of weeds to various herbicides based on EWRS (Appendix 1) - **S**-susceptible (1 - 4), **MS**-moderately susceptible (4 - 5.5), **MR**-moderately resistant (5.5 - 7), **R**-resistant (7 - 9).

Results (cont.)

Graph 1 - ECHCG % Control (Pre-emergent treatments, Site 3 1998/1999)



Discussion

Frontier

Dimethenamid, the active ingredient in Frontier, belongs to the chloracetamide chemical group. This product is active on broadleaf weeds, such as *Amaranthus* spp. and *Galinsoga parviflora*, and many grass weeds, such as *Digitaria ciliaris* and *Echinochloa crus-galli*. Tank mixes of Frontier with products such as Balance and Atrazine broaden the weed spectrum, particularly on broadleaf weeds (Table 2, Graph 1)

Crop safety of Frontier was generally high, although unacceptable crop damage was evident at one site (Site 1 Annual Report 1999/00). The soil at this site was very low in organic carbon (0.73%) and only 8% clay. Soil properties, such as organic carbon and clay content, have been identified as important characteristics in determining crop safety and weed efficacy of soil active herbicides. On soils with low organic carbon and clay, low rates will need to be used to prevent crop damage.

Frontier was formerly a Sandoz product. Following the merger of Sandoz with Ciba (to form Novartis), the product was sold to BASF. In Australia, BASF normally distribute products through AgrEvo. AgrEvo has merged with Rhone-Poulenc to form Aventis, and BASF have now joined with Cyanamid. The status of Frontier in Australia is currently uncertain, however all data to allow the registration of Frontier in sweet corn has been collected and forwarded to BASF.

Command

Clomazone, the active ingredient of Command, belongs to the isoxazolidione chemical group and acts by inhibiting the synthesis of photosynthetic pigments. Command is a residual product that has both pre- and early post-emergent activity on a number of weeds, including *Galinsoga paviflora*, *Solanum nigrum* and *Chenopodium album* (Table 2).

Tried in tank mixes with Frontier, Command has improved the efficacy of Frontier on broadleaf weeds such as *Solanum nigrum* and *Chenopodium album*. The crop safety of this mix was generally good, however damage at Site 1, (Site 1 Annual Report 1999/00) during the first assessment was unacceptable, with the crop recovering by later assessments. The crop damage at this site is likely to have been due to the soil factors discussed above.

Although Command is registered in Australia in other vegetable crops, such as beans, cucurbits and potatoes, registration in sweet corn is currently not a priority due to greater suitability of other products evaluated.

Gardoprim

Terbutylazine, the active ingredient in Gardoprim, is a triazine that has similar efficacy to atrazine, but is less mobile in the soil. Gardoprim has activity pre- and post-emergence, and is already registered for use in sweet corn and other vegetable crops overseas.

Gardoprim demonstrated excellent crop safety at rates between 750ml and 3L, and was efficacious on a range of broadleaf weed species, including *Solanum nigrum*, *Amaranthus powellii*, *Tribulus terrestris* and *Galinsoga paviflora* (Tables 1 & 2).

Gardoprim is currently being developed in Australia in a range of crops. At this stage the product manufacturer is not intending on applying for registration in sweet corn.

Discussion (cont.)

Balance

Balance is an isoxazole compound with both pre- and early post-emergent weed activity. This product is currently under development in Australia by Aventis, and registration is expected in the future. However the manufacturers are not willing to register this product in sweet corn.

Crop safety of Balance was high at all sites, with efficacious control on broadleaf weeds such as *Solanum nigrum*, *Amaranthus powellii* and grass weeds such as *Echinochloa crus-galli*. This product was compatible for tank mixing with Command or Frontier, with improvements to weed efficacy on a range of weeds (Table 2, Graph 1)

Affinity

Affinity (carfentrazone-ethyl), is an aryl triazolinone contact, non-residual herbicide. Work in other countries has shown Affinity to have a wide broadleaf weed spectrum, controlling weeds such as *Solanum nigrum*, *Chenopodium album* and *Amaranthus powellii*. This product is soon to be registered in Australia for use in cereal crops.

Affinity was evaluated post crop-emergence in sweet corn. While there was some damage to the crop, evident as burning around the leaf margins, crop tolerance was acceptable, with the crop recovering quickly from the herbicide damage (Table 1).

Efficacy on weeds such as *Chenopodium album* and *Solanum nigrum* was acceptable when Affinity was used alone. A pre-emergent application of Frontier improved the control on broadleaf weeds such as *Amaranthus powellii*, *Chenopodium album* and *Solanum nigrum*, as well as grass weeds such as *Digitaria ciliaris* and *Echinochloa crus-galli*, to an acceptable level (Table 2, Graph 1).

Broadstrike and Titus

Broadstrike was trialed post crop-emergent treatment, while Titus was evaluated pre- and post-crop emergence. Neither of these products had potential for development in sweet corn due to poor crop tolerance or unacceptable weed efficacy.

Registered Products

Atrazine, Primextra, Dual, and Starane are all registered for use in sweet corn production and have been included for comparison against experimental herbicide treatments.

Atrazine, a triazine herbicide, was used pre- and post-crop emergence, and controlled a wide spectrum of broadleaf weeds, including *Amaranthus powellii*, *Cyperus rotundus*, *Acanthospermum hispidum*, *Portulaca oleracea* and *Solanum nigrum*. Activity on grass weeds such as *Echinochloa crus-galli* is limited (Table 2, Graph 1). Primextra, a mixture of Dual and Atrazine, improved efficacy on grass weeds. Starane, a post-emergence herbicide with the active Fluroxypur, was also evaluated as a tank mix with Atrazine. The activity of Atrazine on grass weeds was improved slightly, however crop tolerance was reduced

Dual is a pre-emergent herbicide with the active ingredient being metolachlor. Like Frontier, Dual is a group K herbicide (Appendix iii). Dual is active on a wide range of grass weeds such as *Echinochloa crus-galli*, with some broadleaf weed activity. Broadleaf weed activity of Dual was improved by post-emergence applications of Atrazine.

Technology Transfer

Grower and Industry Information Sessions

Regular field days were held throughout the project. Field days allowed growers, processors and agronomic staff to see some of the new herbicide technology being developed for sweet corn production, and the input of field day participants was valuable in developing the project.

Findings from the project were presented at a number of meetings and conferences, including the annual Tasmanian Agricultural Research and Advisory Committee's (ARAC) events, the 12th Australian Weeds Conference (1999), and these presentations have prompted enquires from all of the major sweet corn production regions across Australia.

Product Development

Providing data for the registration of new herbicides for sweetcorn production was a key focus of this project. This required working with a number of herbicide manufacturers. Discussions have been held with manufacturers of Balance, Frontier, Gardoprim and Affinity regarding registration of these herbicides in sweet corn. Efficacy, crop safety and residue data collected as part of this project will be supplied to manufacturers to support registration. This data will be used to develop product labels and product training. At this stage it is unclear which, if any of these products will be registered.

Publications

Detailed reports were produced annually covering all trials conducted. These reports were sent to the HRDC and product manufacturers. A range of other written material was produced, such as milestone reports, conference proceedings and an article for the "WA Vegie Link" magazine, which is distributed to growers.

Technology Transfer

Table 3 – Technology Transfer

Technology Transfer Activity	Date
Field day held with growers and agronomic staff	February 1998
Annual report sent to all voluntary contributors and the HRDC.	July 1998
Presentation of the project at the annual ARAC presentations.	August 1998
Meeting with BASF in Sydney to discuss registration of Frontier	December 1998
Meeting with BASF staff in North Carolina, to discuss Frontier	March 1999
Presentation of the project at the annual ARAC presentations.	July 1999
Presentation at the 12 th Australian Weeds Conference – Hobart	September 1999
Annual report sent to all voluntary contributors and the HRDC.	August 1999
Field visit with Harvest Moon and Serve-Ag agronomic staff.	January 2000
Meeting with BASF in Brisbane to discuss registration of Frontier	February 2000
Article for the WA Vegie link magazine	August 2000
Presentation of the project at the annual ARAC presentations.	August 2000
Annual report sent to all voluntary contributors and the HRDC.	September 2000

Recommendations

- BASF to proceed with the registration of Frontier.
- Use data collected to support a Minor Use Permit for Balance in sweet corn.

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Appendices

EWRS SCALE :-
(for crop tolerance)

RATING	%	EFFECT
1	0	Healthy plant
2	0.1 - 2	Very mild symptoms
3	2.1 - 5	Mild but clearly recognisable symptoms
4	5.1 - 10	More severe symptoms without necessarily an effect on yield
	-----	Limit of commercial acceptability
5	10.1 - 18	Reduction in yield expected
6	18.1 - 30	
7	30.1 - 45	
8	45.1 - 70	
9	70.1 - 100	Heavy damage to total kill

EWRS SCALE :-
(for weed control)

RATING	% EFFECT	
1	100	Complete weed kill
2	99.9 - 98	
3	97.9 - 95	
4	94.9 - 90	
	-----	Limit of commercial acceptability
5	89.9 - 82	
6	81.9 - 70	
7	69.9 - 55	
8	54.9 - 30	
9	29.9 - 0	Little to no effect on weeds

Appendix iii

Herbicide grouping based on mode of action (Developed by Avcare)

Group	Mode of Action	Chemical Group
A	Inhibitors of acetyl CoA carboxylase	Aryloxyphenoxypropionate ("fops") Cyclohexanedione ("dims")
B	Inhibitors of acetolactate synthase	Sulfonyl urea Imidazolinone Sulfonamid
C	Inhibitors of photosynthesis at photosystem II	Triazine Triazinone Urea Nitrile Benzothiadiazole Acetamide Pyridazinone Phenyl-pyridazinone Uracil
D	Inhibitors of tubulin formation	Dinitroaniline Benzoic acid
E	Inhibitors of mitosis	Thiocarbamate Carbamate Organophosphorus
F	Inhibitors of carotenoid biosynthesis	Nicotinamide Triazole Pyridazinone
G	Inhibitors of protoporphyrinogen oxidase	Diphenyl ether Oxidiazole
H	Inhibitors of protein synthesis	Thiocarbamate
I	Disrupters of cell growth	Phenoxy Benzoic acid Pyridine
J	Inhibitors of fat synthesis	Alkanoic acid
K	Herbicides with diverse sites of action	Amide Organoarsenic Carbamate Aminopropionate Benzofuran Phthalamate Nitrile
L	Inhibitors of photosynthesis at photosystem I	Bipyridyl
M	Inhibitors of EBSP synthase	Glycine (glyphosate; glyphosate-trimesium)
N	Inhibitors of glutamine synthetase	Glycine

Appendix iv - Complete Data

Pre-transplant	Post transplant	Crop Rating	Site	Season
Frontier 1L		2.75	1	97-98
Frontier 2L		2.25	1	97-98
Frontier 4L		3.50	1	97-98
Command 250mL + Frontier 2L		2.50	1	97-98
Dual 4L		2.50	1	97-98
Primextra 5L		3.00	1	97-98
Atrazine 4L		2.50	1	97-98
	Atrazine 4L	2.75	1	97-98
	Atrazine 4L + Starane 1L	3.75	1	97-98
	Titus 60g	2.50	1	97-98
	Broadstrike 25g	2.50	1	97-98
Balance 150g		2.50	1	97-98
Balance 230g		2.25	1	97-98
Balance 150g + Atrazine 2.5L		2.25	1	97-98
Frontier 1L		2.50	2	97-98
Frontier 2L		3.50	2	97-98
Frontier 4L		4.50	2	97-98
Command 250mL + Frontier 2L		3.50	2	97-98
Dual 4L		2.00	2	97-98
Primextra 5L		1.75	2	97-98
Atrazine 4L		1.00	2	97-98
	Atrazine 4L	2.00	2	97-98
	Atrazine 4L + Starane 1L	2.00	2	97-98
	Titus 60g	1.00	2	97-98
	Broadstrike 25g	1.25	2	97-98
Balance 66.6g		1.25	2	97-98
Balance 100g		2.00	2	97-98
Balance 133g + Atrazine 2.5L		1.00	2	97-98
Frontier 1.5L		2.67	3	97-98
Frontier 3L		2.00	3	97-98
Atrazine 4L + Frontier 1.5L		2.00	3	97-98
Command 500mL + Frontier 1.5L		2.33	3	97-98
Dual 4L		2.00	3	97-98
Primextra 5L		2.33	3	97-98
Atrazine 4L		2.33	3	97-98
	Atrazine 4L	4.67	3	97-98
	Atrazine 4L + Starane 1L	6.33	3	97-98
Titus 60g	Titus 60g	8.00	3	97-98
Balance 150g		1.33	3	97-98
Balance 300g		2.67	3	97-98
Balance 150g + Atrazine 2L		2.67	3	97-98
Atrazine 4L + Command 500mL		2.00	3	97-98
Frontier 1L		5.25	1	98-99
Frontier 2L		6.75	1	98-99
Frontier 4L		5.50	1	98-99
Command 250mL + Frontier 2L		8.00	1	98-99
Dual 4L		4.00	1	98-99
Primextra 5L		3.50	1	98-99
Atrazine 4L		2.25	1	98-99
	Atrazine 4L	2.00	1	98-99
	Atrazine 4L + Starane 1L	4.00	1	98-99
	Titus 60g	9.00	1	98-99
	Broadstrike 25g	8.50	1	98-99
Balance 66.6g		1.75	1	98-99
Balance 100g		5.50	1	98-99
Balance 66.6g + Atrazine 2.5L		1.25	1	98-99
Frontier 1.5L		2.25	2	98-99
Frontier 3L		2.25	2	98-99
Command 500mL + Frontier 1.5L		2.00	2	98-99
Dual 4L		2.25	2	98-99
	Atrazine 4L	2.50	2	98-99
	Atrazine 4L + Starane 1L	2.50	2	98-99
Balance 100g		2.00	2	98-99
Gardoprime 3L		2.25	2	98-99
Frontier 1.5L + Balance 100g		2.75	2	98-99
	Affinity 50mL	4.00	2	98-99

Appendix iv - Complete Data

Pre-transplant	Post transplant	Crop Rating	Site	Season
	Affinity 100mL	4.00	2	98-99
Frontier 1L		1.00	3	98-99
Frontier 2L		1.00	3	98-99
Frontier 4L		1.00	3	98-99
Command 250mL + Frontier 2L		1.00	3	98-99
Dual 4L		1.00	3	98-99
Primextra 5L		1.00	3	98-99
Atrazine 4L		1.00	3	98-99
	Atrazine 4L	1.00	3	98-99
	Atrazine 4L + Starane 1L	1.00	3	98-99
	Titus 60g	9.00	3	98-99
	Broadstrike 25g	9.00	3	98-99
Balance 66.6g		1.00	3	98-99
Balance 100g		1.00	3	98-99
Balance 100g + Atrazine 2.5L		1.00	3	98-99
Frontier 1.5L		2.25	4	98-99
Frontier 3L		2.75	4	98-99
Command 500mL+ Frontier 1.5L		2.00	4	98-99
Dual 4L		2.00	4	98-99
	Atrazine 4L	3.00	4	98-99
	Atrazine 4L + Starane 1L	5.00	4	98-99
Balance 100g		2.75	4	98-99
Gardoprim 3L		2.75	4	98-99
Frontier 1.5L + Balance 100g		2.50	4	98-99
	Affinity 50mL	4.50	4	98-99
	Affinity 100mL	5.25	4	98-99
Frontier 500mL	Affinity 20g	3.25	1	99-00
Frontier 1L		4.50	1	99-00
Balance 30g		5.75	1	99-00
Balance 60g		6.25	1	99-00
Gardoprim 750mL		2.00	1	99-00
Gardoprim 1.5L		2.50	1	99-00
	Affinity 20g	2.00	1	99-00
Frontier 500mL + Balance 30g		5.25	1	99-00
Command 250mL + Frontier 500mL		6.50	1	99-00
	Atrazine 500mL	2.50	1	99-00
Atrazine 500mL		2.00	1	99-00
Frontier 1.5L	Affinity 30g	4.25	2	99-00
Frontier 3L		1.25	2	99-00
Balance 80g		1.50	2	99-00
Balance 160g		2.00	2	99-00
Gardoprim 1.5L		1.75	2	99-00
Gardoprim 3L		1.50	2	99-00
	Affinity 30g	5.00	2	99-00
Frontier 1.5L + Balance 80g		2.00	2	99-00
Command 250mL+ Frontier 1.5L		1.25	2	99-00
Primextra 5L		2.25	2	99-00
Dual 2L	Atrazine 4L	2.00	2	99-00
Frontier 1L	Affinity 50mL	1.00	3	99-00
Frontier 3L		1.00	3	99-00
Balance 60g		1.00	3	99-00
Balance 100g		1.00	3	99-00
Gardoprim 3L		1.00	3	99-00
Quinclorac 600g		1.00	3	99-00
Command 500mL+ Frontier 1.5L		1.00	3	99-00
Frontier 1.5L + Balance 100g		1.00	3	99-00
Dual 4L		1.00	3	99-00
	Atrazine 4L	1.00	3	99-00
Dual 2L		1.00	3	99-00
Frontier 1.5L	Affinity 20g	3.00	4	99-00
Frontier 3L		2.00	4	99-00
Balance 80g		2.00	4	99-00
Balance 120g		2.00	4	99-00
Balance 160g		3.00	4	99-00
Gardoprim 2L		1.50	4	99-00
	Affinity 30g	3.00	4	99-00
Frontier 1.5L + Balance 80g		2.25	4	99-00
Command 250mL + Frontier 1.5L		2.00	4	99-00
Primextra 5L		1.75	4	99-00
Dual 2L	Atrazine 4L	2.25	4	99-00

Appendix v - Residue Samples

Residue samples

Crop Part	Site	Product	Rate/Ha	Sampling Date	Total Samples
Cob	Turners Beach	Balance	80g	21/2/00	2
Cob	Turners Beach	Balance	160g	21/2/00	2
Cob	Turners Beach	Frontier	1.5L	21/2/00	2
Cob	Turners Beach	Frontier	3L	21/2/00	2
Cob	Turners Beach	Untreated		21/2/00	4
Cob	Forth	Balance	80g	31/3/00	2
Cob	Forth	Balance	160g	31/3/00	2
Cob	Forth	Frontier	1.5L	31/3/00	2
Cob	Forth	Frontier	3L	31/3/00	2
Cob	Forth	Untreated		31/3/00	4

Photographs



Photograph 1 - Trial site at Bowen, Queensland



Photograph 2 - Balance (foreground) providing control of a range or broadleaf and grass weed species. Untreated control (background).



Photograph 3 - Untreated control plot in a trial at the Lockyer Valley, Queensland. (Compare with the Frontier treatment below)



Photograph 4 - Frontier provides excellent control of grass weeds and some broadleaf species, Lockyer Valley