VG97063
Weed Management in Pumpkin and other Cucurbit Crops

Ian Macleod
Serve-Ag Research

Know-how for Horticulture™

VG97063

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Weed Management in Pumpkin and other Cucurbit Crops

Conducted on behalf of

Horticultural Research and Development Corporation

Project VG97063 (Project Completion 30/6/00)

Final Report

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Media Summary

At the commencement of this project, there were no suitable herbicides registered for broadleaf weed control in cucurbit crops (Photograph 1). Products that were registered for use, only controlled grasses. Broadleaf weed control in commercial cucurbit production relied on mechanical cultivation (Photograph 2), hand weeding and plastic mulches, all of which had associated problems, including cost.

A total of 15 replicated small plot trials have been conducted in Tasmania, Queensland and Western Australia in cucurbit crops, including pumpkin and kabocha. These trials have been used to evaluate integrated weed management strategies involving experimental herbicides, organic mulches and brassica biofumigants.

Data collected in this work was used to gain national registration for Command, which occurred in 1999, for the control of weeds such as *Galinsoga parviflora* (potato weed), *Polygonum aviculare* (hogweed), *Nicandra physaloides* (wild hops) and *Portulaca oleracea* (pigweed). Command is currently the only herbicide registered for broadleaf weed control in cucurbit crops in Australia.

Other herbicides identified in this work were Frontier and Authority, neither of which are currently registered in Australia. Relevant information generated from this project has been supplied to the product manufacturers, who are considering the development of these products in Australia. In addition, Brodal, a product that is already registered for use in some crops in Australia, has potential for use in combination with Command for the control of *Raphanus raphanistrum* (wild radish).

Weed management practices involving a range of organic mulches, were evaluated. Cereals and ryegrass proved to be the most effective mulches, with suppression of broadleaf weeds such as *Solanum nigrum* (black nightshade) and *Trifolium repens* (white clover). While mulches provided effective weed control between the rows, a banded application of pre-emergent herbicide was required to control weeds within the row.

Technology transfer has occurred throughout the project using a number of methods. Regular field days have been conducted and papers presented at conference including the 12th Australian Weeds Conference. In addition, product-training sessions were held throughout Australia following the registration of Command.

Technical Summary

At the commencement of this project, there were no suitable herbicides registered for broadleaf weed control in cucurbit crops. Products that were registered for use, were efficacious only on grasses, and had long withholding periods. In addition, alternative weed management practices, such as cover crops and mulches, had received little attention for cucurbit production. Broadleaf weed control in commercial cucurbit production relied on mechanical cultivation, hand weeding and plastic mulches, all of which had associated problems, including cost.

A total of 15 replicated small plot trials have been conducted in Tasmania, Queensland and Western Australia in cucurbit crops, including pumpkin and kabocha. These trials have been used to evaluate a range of experimental herbicides, organic mulches and brassica biofumigants.

Mulches, including cereals, grasses and brassica biofumigants, were trialed as weed management techniques in cucurbits. Cereals and ryegrass proved to be the most effective mulches, with suppression of weeds such as *Solanum nigrum* (black nightshade), *Polygonum aviculare* (hogweed) and *Trifolium repens* (white clover). Weed supression with the cereal and ryegrass mulches is thought to be due to a combination of physical weed suppression, reduced soil disturbance when the crop was planted, and possibly some allelopathy. Mulches also influenced nitrogen availability, which was monitored using regular soil nitrate measurements. The growth and initial decomposition of the mulches after being sprayed off removed nitrogen from the soil. Later this nitrogen was released, resulting in high soil concentrations.

A total of 11 experimental herbicides were trialed in this work. Of these, four products showed high crop safety and effective weed control and were further evaluated. Data collected in this work was used to gain national registration for Command, which occurred in 1999. Command is a pre-emergent herbicide, which is registered for control of weeds such as *Galinsoga parviflora* (potato weed), *Polygonum aviculare* (hogweed), *Nicandra physaloides* (wild hops) and *Portulaca oleracea* (pigweed). Command is currently the only herbicide registered for broadleaf weed control in cucurbit crops in Australia.

Other herbicides identified in this work were Frontier and Authority, both of which are currently registered overseas but not in Australia. These products are active on a range of broadleaf and grass weeds, which are important in cucurbit production. In addition, crop safety of these herbicides is satisfactory in both pumpkin and kabocha crops on a range of soil types. All efficacy, crop safety and residue data generated from this project has been supplied to the manufacturers, who are considering the potential of registering these products in Australia. In addition, Brodal, a product which is already registered for use in some crops in Australia, was also identified as having potential for use in combination with Command for the control of *Raphanus raphanistrum* (wild radish).

Soil type has been found to strongly influence the efficacy and crop tolerance of residual pre-emergent herbicides evaluated in this project. Through the identification of the key soil properties which affect herbicide activity, it will be possible to give more accurate rate recommendations for pre-emergent herbicides. This work, funded by the HRDC, is currently being conducted as a joint project between the Tasmanian Institute of Agricultural Research (TIAR) and Serve-Ag Research.

Technology transfer has occurred throughout the project using a number of methods including field days and various publications. Following the registration of Command, product training sessions were held throughout Australia covering the use of Command in cucurbit crops. In addition, two papers which included information from this project were presented at the 12th Australian Weeds Conference. Australian and International weed researchers attended this conference.

Introduction

At the commencement of this project, there were no suitable herbicides registered for use in the majority of cucurbits, whilst the limited products registered for use in pumpkins only gave control of grasses, and have long withholding periods. Similarly, alternative weed management practices, such as cover crops and mulches, have received little attention for cucurbit production, and may offer a number of advantages over current practices.

Much of the current weed management is achieved by cultural practices such as the use of black plastic and mechanical methods, including hand hoeing. The costs and associated problems with this are prohibitive in most circumstances. As an example, the disposal of used plastic presents a significant environmental problem. Currently, many crops are contaminated with huge weed populations, with this situation impacting on future crops.

The project VG97063 "Weed management in pumpkins and other cucurbit crops", is a three year HRDC funded project which commenced in 1997. This project follows on from previous work conducted by Serve-Ag Research under the project VG419 "An investigation into improved methods of weed control in kabocha and pumpkins". The aim of the project is to extend the findings of the earlier work to the major production areas, and to provide the necessary data to allow the registration of herbicides for broadleaf weed control in cucurbit crops.

Materials and Methods

Trial Details

Annual Report	Site Number	Number of Replicates	Plot Size (meters)	Soil Texture	Location	Crop	Variety
1997/98	1	4	1 x 10	Loamy Sand	Mutchilba North Queensland	Pumpkin	Butternut
1997/98	2	3	3 x 8	Sandy Clay Loam	Ulverstone North West Tasmania	Pumpkin	Sweet Grey
1997/98	3	4	1 x10	Sandy Loam	Manjimup Western Australia	Pumpkin	Butternut
1997/98	4	4	1.5 x 8	Clay	Forthside North West Tasmania	Pumpkin	Sweet Grey
1997/98	5	3	1 x 3	Sandy Clay Loam	Wesley Vale North West Tasmania	Cucurbit	Various Species
1997/98	6	4	3 x 5	Clay	Helidon South East Queensland	Pumpkin	-
1998/99	1	4	1.3 x 10	Sandy Loam	Mutchilba North Queensland	Pumpkin	Butternut
1998/99	2	4	3 x 8	Clay Loam	Wesley Vale North West Tasmania	Kabocha	Delica
1998/99	3	2	3.2 x 19	Clay Loam	Forthside North West Tasmania	Kabocha	Matchiti
1998/99	4	4	15m^2	Clay Loam	Manjimup Western Australia	Pumpkin	Jarrahdale
1999/00	1	4	3 x 8	Silt Clay Loam	Kindred North West Tasmania	Kabocha	Nishiki
1999/00	2	3	3.2 x 12	Silt Clay Loam	Forthside North West Tasmania	Kabocha	Nishiki
1999/00	3	4	1.5 x 10	Loam	Gatton South East Queensland	Pumpkin	Ken's Special
1999/00	4	4	1.5 x 10	Loamy Sand	Atherton North Queensland	Pumpkin	Ken's Special
1999/00	5	3	1.6 x10 1.6 x 6	Sandy Clay Loam	Wemen Northern Victoria	Water-melon	Shadow/ Tiger

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*
Authority	Sulfentrazone	750g/kg	Water Dispersible Granules	G
Broadstrike	Flumetsulam	800g/kg	Water Dispersible Granules	B
Command	Clomazone	480g/L	Emulsifiable Concentrate	F
Brodal	Diflufenican	500g/L	Suspension Concentrate	F
Dual	Metolachlor	720g/L	Emulsifiable Concentrate	K
Eclipse	Metosulam	714g/kg	Water Dispersible Granules	B
Frontier	Dimethenamid	900g/L	Emulsifiable Concentrate	K
Raft (EXP03316B)	Oxadiargyl	400g/L	Suspension Concentrate	G
Balance (RP97001)	Isoxaflutole	750g/L	Water Dispersible Granules	F
Spinnaker	Imazethapyr	200g/L	Aqueous Concentrate	B
Titus	Rimsulfuron	250g/kg	Water Dispersible Granules	B

Application Details

EQUIPMENT	Pressurised knapsack precision sprayers
NOZZLES	Flat Fan Jets
VOLUME	200 - 400 Litres per ha
PRESSURE	130 - 300kPa

Materials and Methods (cont.)

Weed List

Bayer Code *	Weed
ACNHI	*Acanthospermum hispidium* (starbur)
BRASU	*Brachiaria subquadripara* (green summer grass)
CHEAL	*Chenopodium album* (fat hen)
CYPRT	*Cyperus retrorsus* (sedge)
DATST	*Datura stramonium* (thornapple)
DIGAD	*Digitaria ciliaris* (summer grass)
DTTSS	*Dactyloctenium* spp. (button grass)
ELENI	*Eleusine indica* (crowsfoot grass)
ERACI	*Eragrostis ciliaris* (stink grass)
FUMSS	*Fumaria* spp. (fumitory or pinkweed)
GASPA	*Galinsoga parviflora* (potato weed)
HEOAM	*Heliotropium amplexicaule* (heliotrope)
LAMAM	*Lamium amplexicaule* (henbit or dead-nettle)
MELRE	*Melinis repens* (natal grass)
MTCVI	*Mitracarpus hirtus* (white-eye)
NICPH	*Nicandra physaloides* (apple of peru)
PLALA	*Plantago lanceolata* (narrow-leaf plantain)
POLCO	*Polygonum convolvulus* (black bindweed)
RAPRA	*Rapahus raphanistrum* (wild radish)
RCHBR	*Richardia brasiliensis* (brazilian white-eye)
SOLNI	*Solanum nigrum* (black nightshade)
SONOL	*Sonchus oleraceus* (sow thistle)
TRFSU	*Trifolium subterraneum* (sub-clover)
TRQPR	*Tridax procumbens* (tridax daisy)
TRFRE	*Trifolium repens* (white clover)
VERPE	*Veronica persica* (buxbaum's speedwell)
TRQPR	*Tridax procumbens* (tridax daisy)

* 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 Assessments

TIMING - 15-84 days after treatments were applied
SAMPLE SIZE - Whole Plot
METHOD - Subjective Rating
RATING SCALE - EWRS (Appendix i)
SUMMARISED RESULTS - Tables 1, 2 & 4
COMPLETE DATA - Appendix iv and Annual Reports

2. Weed Assessments

TIMING - 15-84 days after treatments were applied
SAMPLE SIZE - Whole Plot
METHOD - Subjective Rating
RATING SCALE - EWRS (Appendix ii)
SUMMARISED RESULTS - Tables 3 & 4
COMPLETE DATA - Appendix iv and Annual Reports

3. Weed Counts

TIMING - 20-35 days after treatments were applied
SAMPLE SIZE - Various quadrat sizes (0.5-1m^2)
METHOD - Seedlings counted in randomly placed quadrats
SUMMARISED RESULTS - Refer to Annual Reports
COMPLETE DATA - Refer to Annual Reports
STATISTICAL ANALYSES - Refer to Annual Reports

4 Soil Nitrate

TIMING - Refer to Annual Reports
SAMPLE SIZE - 200g of soil bulked from all replicates
SAMPLE DEPTH - 0-30cm
SUMMARISED RESULTS - Refer to Annual Reports
COMPLETE DATA - Refer to Annual Reports

Table 1 - Pumpkin Crop Tolerance

Pre-emerge	EWRS Rating	No. of Sites
Authority 125g	1.2	2
Authority 250g	1.6	7
Authority 500g	2.4	8
Authority 1kg	1.5	1
Command 250mL	1.6	3
Command 250mL + Authority 125g	1.3	2
Command 250mL + Authority 250g	2.3	1
Command 250mL + Frontier 750mL	2.0	1
Command 250mL + Frontier 1L	1.2	2
Command 500ml	2.4	5
Command 500mL + Authority 250g	1.5	3
Command 500ml + Authority 500g	3.0	3
Command 500ml + Brodal 200ml	1.0	1
Command 500ml + Dual 2L	1.0	1
Command 500ml + Frontier 1.5L	3.1	4
Command 500mL + Frontier 2L	1.1	2
Command 1L	1.4	8
Command 1L + Authority 250g	1.0	2
Command 1L + Authority 500g	1.5	1
Command 1L + Authority 1kg	1.8	1
Command 1L + Dual 2L	1.0	2
Command 1L + Frontier 1 L	1.0	2
Command 1L + Frontier 1.5L	1.5	1
Command 1L + Frontier 3L	2.3	1
Command 1.5L	1.0	2

Table 1 - Pumpkin Crop Tolerance (cont.)

Pre-emergence	Post-emergence	EWRS Rating	No. of Sites
Command 2L		1.1	3
Command 500mL + Titus 60g		3.0	1
Command 500mL	Eclipse 7g	4.7	1
Command 500mL	Spinnaker 300mL	3.3	1
Dual 2L		1.0	2
Frontier 750mL		2.0	1
Frontier 750mL + Authority 250g		2.5	1
Frontier 1L		1.0	4
Frontier 1L + Authority 250g		1.2	2
Frontier 1.5L		2.2	6
Frontier 1.5L + Authority 250g		2.7	1
Frontier 1.5L + Authority 500g		2.8	1
Frontier 2L		1.2	2
Frontier 3L		2.2	3
Frontier 4L		1.1	2
Spinnaker 300mL		4.7	1
Raft 625mL		1.4	2
Raft 1L		4.0	1
Raft 1.25L		3.0	2
	Broadstrike 40g	5.3	1
	Eclipse 7g	5.0	1

Table 2 - Kabocha Crop Tolerance

Pre-emergence	Post-emergence	EWRS Rating	No. of Sites
Authority 250g	Brodal 100ml	3.7	1
Authority 500g		1.5	1
Authority 500g	Brodal 100ml	4.0	1
Authority 1kg		1.8	1
Balance 150g		7.0	1
Command 500ml + Authority 500g		1.3	1
Command 500ml + Brodal 200ml		2.0	1
Command 500ml + Frontier 2L		2.0	1
Command 1L		1.5	1
Command 1L	Eclipse 3.5g	6.8	1
Command 1L	Eclipse 7g	7.5	1
Command 1L + Authority 500g	Brodal 100ml	4.3	1
Command 1L + Frontier 1.5L	Eclipse 3.5g	7.8	1
Frontier 1.5L	Eclipse 3.5g	7.5	1
Frontier 2L		2.0	1
Frontier 2L+ Authority 500g		3.0	1
Frontier 4L		3.5	1
Raft 500ml		4.3	1
Raft 1L		6.0	1
	Balance 75g	6.5	1

*Table 3 - Weed Susceptibility**

Pre-emergence	Post-emergence	ACNHI	BRASU	CHEAL	CYPRT	DATST	DIGAD	DTTSS	ELENI	ERACI
Authority		S-MS	MS-MR	S-MS	MR-R	S	MS-MR	MS	MS-MR	R
Authority	Brodal			S						
Command		S-MS	S	S-MS	R	S-MS	MS-MR	S	MS-MR	R
Command + Authority		S		MS	MS	S	MS-MR	S	S	R
Command + Authority	Brodal			S						
Command + Brodal				S						
Command	Eclipse			S						
Command + Frontier		S	S	MR		S	S		MS-MR	MR-R
Command + Frontier	Eclipse			S						
Command + Dual		S	MS		R	S	S		S	
Command + Brodal		MS			R	MS				
Command + Titus										
Dual		S	S				R		S	
Raft		MS-MR	MS-MR	S	R	MS	MS-MR		S-MS	
Frontier		MS-MR	MS	S-MS	MS	R	S-MS	S	MR-R	MR-R
Frontier + Authority				MS				S	R	R
Frontier	Eclipse			S						
Balance				S						
	Balance			MR						

* 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).

Table 3 - Weed Susceptibility (cont.)*

Pre-emergence	Post-emergence	FUMSS	GASPA	HEOAM	MELRE	PLALA	POLCO	RAPRA
Authority		S	S	S	R		MS	MS-MR
Authority	Brodal							S
Balance								S
Command		MR	S	R	R		S	MS-MR
Command + Authority		S	S	S	R	S	S-MS	MS
Command + Authority	Brodal							S
Command + Brodal				MR			S	S
Command	Eclipse	MR						S
Command + Frontier		S	S-MS	MS	MR-R	MS-S	MS	MR
Command + Frontier	Eclipse							S
Command + Dual				MS			S	S
Command	Spinnaker	MS						S
Command + Titus		MS						MS
Dual								MS
Frontier		S	S	S-MS	MS-MR		MR-R	S-MS
Frontier + Authority		S	S		R		S	MS
Frontier	Eclipse							S
Raft				S			S	S
Spinnaker		MS						MS
	Balance							S
	Broadstrike	MR						S
	Eclipse	MS						S

* 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).

Table 3 - Weed Susceptibility (cont.)*

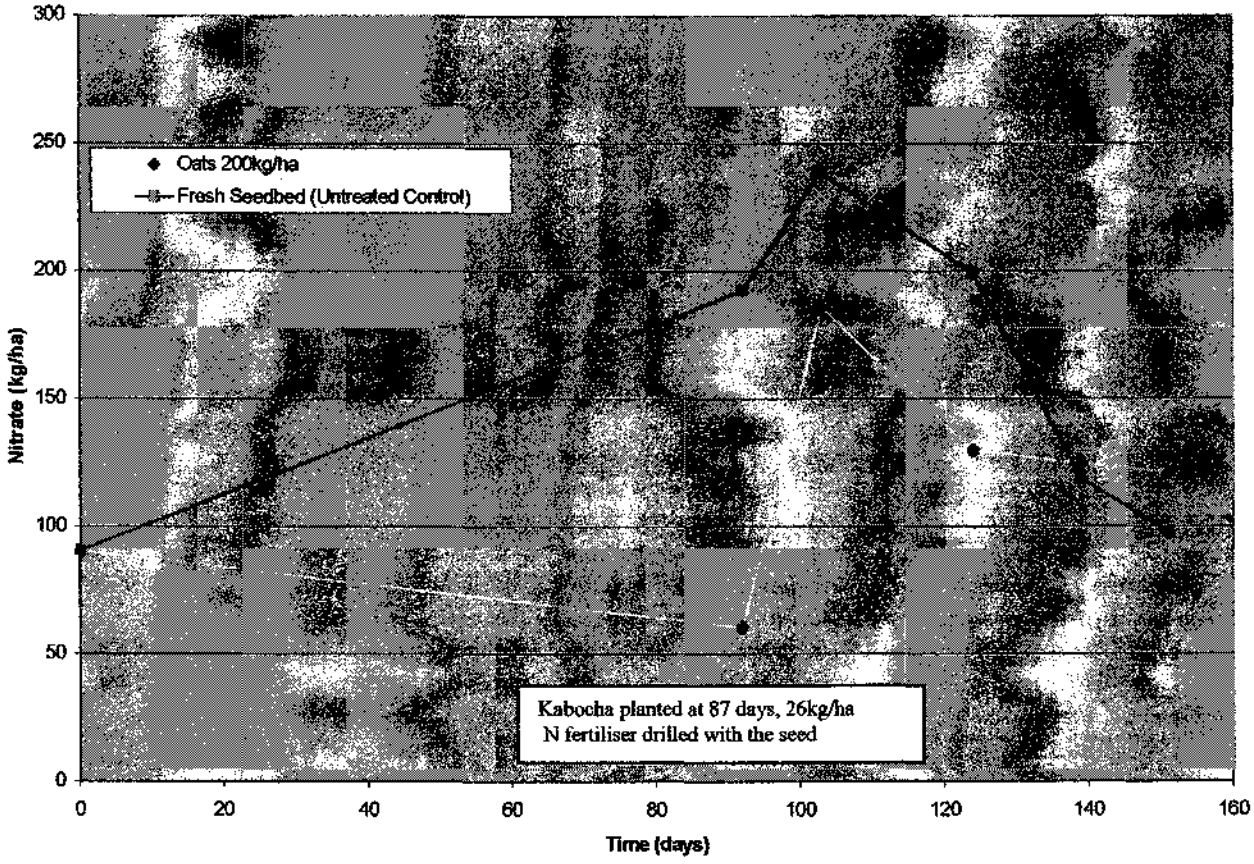
Pre-emergence	Post-emergence	RCHBR	SOLNI	SONOL	TRFRE	TRQPR	TRFSU	TRQPR	LAMAM	MTCVI	NICPH
Authority		S				S		MS		S	S
Authority	Brodal		S				S-MS		S		
Balance			S				S		S		
Command		MS-MR				S		MS-R		MS-R	S-MS
Command + Authority		S		S-MS	S	S		S		MS	S
Command + Authority	Brodal		S				MS		S		
Command	Eclipse		S				MS		MS		
Command + Frontier				S	MS	S-MS					MS
Command + Frontier	Eclipse		S				S		S		
Command + Dual											S
Command + Brodal											S
Dual											MS
Frontier		S-MS				S-MS		S		S	MS-MR
Frontier + Authority		S				S		S		S	
Frontier	Eclipse		S				S		S		
Raft			S				S		S		MS-MR
	Balance		S				MS		S		

* 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).

Table 4 - Mulch Trial Assessment (Site 2 - FVRS 1999/00)

No.	Treatment		Crop Assessment	Individual Weed Ratings		
	Mulch	Pre-emergence		SOLNI	CHEAL	VERPE
1a	Ryegrass 50kg		1.00	4.33	2.33	4.67
1b	Ryegrass 50kg	Command 633ml + Frontier 1.9L	2.33	3.33	1.00	4.00
2a	Oats 200kg		1.00	3.00	1.00	3.00
2b	Oats 200kg	Command 633ml + Frontier 1.9L	2.67	2.00	1.00	1.00
3a	Ryecorn 200kg		1.00	4.00	1.33	2.00
3b	Ryecorn 200kg	Command 633ml + Frontier 1.9L	2.33	3.00	1.00	1.33
4a	Wheat 200kg		1.33	3.33	1.00	4.33
4b	Wheat 200kg	Command 633ml + Frontier 1.9L	2.33	2.33	1.00	3.00
5	Weed Check 20kg		1.00	8.00	5.67	6.33
6	BQ Mulch 10kg		1.33	7.33	5.00	6.67
7	Fresh Seedbed	Command 500ml + Authority 500g	1.00	2.67	1.67	3.33
8	Fresh Seedbed	Command 500ml + Frontier 1.5L	1.67	5.67	3.33	1.00
9	Stale Seedbed	Command 500ml + Frontier 1.5L	1.00	2.67	1.00	1.00
10	Fresh Seedbed - Untreated Control		1.00	1.00	9.00	9.00

Graph 1 - Soil Nitrogen (Site 2 - FVRS 1999/00)



Discussion

Authority

Sulfentrazone, the active ingredient in Authority, belongs to the triazolinone chemical group and acts by causing membrane disruption, which is initiated by the inhibition of protoporphyrinogen oxidase. Sulfentrazone is relatively persistent in the soil, having a half-life of around 110 to 280 days.

Authority has pre-emergent activity on a number of broadleaf weeds including NICPH, SOLNI and CHEAL. Authority was also compatible with either Frontier or Command (Photograph 3), improving control of a range of weeds (Table 3)

Crop safety of Authority on pumpkin and kabocha was acceptable, with rates of up to 1kg being safe on heavy textured soils (Tables 1 & 2). Some damage was observed on light textured soils with rates of 500g. Rates of 250g are therefore suggested on these soil types.

Authority is currently registered overseas in crops such as soybeans. In Australia, Authority is still under development, and registrations are not expected for at least two years. All of the efficacy and crop tolerance data, and residue samples collected as part of this project, have been forwarded to the manufacturer to support the registration of Authority in pumpkins and kabocha.

Preliminary screening trials have shown Authority to have sufficient tolerance to warrant further evaluation in other cucurbit crops such as zucchini and melons.

Command

Command is a residual herbicide with pre- and early post-emergent activity on a range of broadleaf and grass weeds. This product has been developed globally in a range of crops including soybeans, rice and potatoes. Clomazone is taken up by the roots and shoots of emerging weeds, and acts by inhibiting the synthesis of both chlorophyll and carotenes in the plant. This is achieved by the inhibition of the conversion of acetate to isoprenoid compounds, which are the precursors to both chlorophyll and carotenes.

Efficacy, crop safety and residue data generated from this project was used to gain registration of Command in August 1999. Command is registered as a pre-emergent broadleaf weed herbicide in pumpkins and squash in all Australian states. This was a significant achievement, as Command is the only herbicide registered for broadleaf weed control in pumpkins and kabocha in Australia. An extract from the Command label covering its use in pumpkins and kabocha is in included as appendix vi.

Command has shown excellent crop safety at 1L, in both pumpkins and kabocha, across a range of sites. The current label rate is 1L, however data has been supplied to the manufacturer to support a modification of the label rate. The revised label will include rates between 500ml to 1L. 1L will be recommended for heavy textured soils, while 500ml is sufficient to control weeds on light textured soils. This rate also ensures crop safety, and reduces the chance of damage to susceptible crops, which may follow pumpkins in the crop rotation.

Command is registered for the control of a range of broadleaf weeds, but does not control weeds such as *Raphanus raphanistrum*, *Amaranthus* spp. and *Fumitory* spp. Frontier, Authority and Brodal applied alone, or as a tank mix with Command, improve control of certain weed species. For this reason it is important for these products to be made available to growers to enable them to control the broad spectrum of weeds occurring in various pumpkin and kabocha production regions.

Discussion (cont)

Frontier

Frontier is a pre-emergent herbicide with activity on a range of grass and broadleaf weeds. The product was developed principally for grass weed control in corn, but is also used in crops such as soybeans and sugar beet. Dimethenamid, the active ingredient in Frontier, belongs to the chloroacetamide chemical group and is taken up primarily by emerging shoots (coleoptile), and acts by reducing cell division and growth.

Frontier has activity on a range of broadleaf weeds including NICPH, RCHBR, GASPA and FUMSS, as well as a range of grass weeds such as DTTSS and DIGAD. Frontier can be tank mixed with Command or Authority to broaden the weed spectrum (Table 3).

Frontier has generally shown excellent crop safety on both pumpkin and kabocha, however some damage has been observed with higher rates on light textured soils (Tables 1 & 2).

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 pumpkins and squash has been collected and forwarded to BASF.

Preliminary screening trials have shown Frontier to have sufficient tolerance to warrant further evaluation in other cucurbit crops such as zucchini and melons.

Dual

Dual is a pre-emergent herbicide with the active ingredient being metolachlor. Like Frontier, Dual is a group K herbicide and has activity on diverse sites of action of target weeds. Dual has short residual pre-emergent activity on many grasses and broadleaf weeds, and is registered for use in a range of crops including brassicas, canola, green and navy beans, as well as maize.

Dual and a tank mix of Dual and Command were evaluated as pre-emergent herbicide treatments in pumpkins. Crop tolerance to Dual, and mixes of Dual and Command, was acceptable. Dual gave effective control of ACHNI, BRASU and CHEAL. When used in combination with Command, efficacy on several weed species, including NICPH, DIGAD and RAPRA, was improved, and acceptable control was achieved (Table 3).

Brodal

Diflufenican, the active ingredient of Brodal, is a group F herbicide, which acts by inhibiting the synthesis of photosynthetic pigments. Brodal has a relatively limited spectrum of activity, but provides excellent control of weeds belonging to the *Brassica* family.

Tolerance of both Pumpkin and Kabocha to Brodal was generally high. Brodal was evaluated as a tank mix with Command. This mix provided excellent control of CHEAL, RAPRA, POLCO and NICPH, as well as some activity on ACNHI and DATST (Table 3).

Brodal is particularly effective for control of brassica weeds such as RAPRA, which other products developed in this work are weak on. The use of this product in pumpkins and kabocha would be relatively small. For this reason, it is recommended that Brodal be made available through the AusVeg Minor Use program.

Discussion (cont)

Other Herbicides Evaluated

Raft, Balance, Spinnaker, Eclipse, Titus and Broadstrike were evaluated but, due to poor crop safety or a limited weed spectrum, are not recommended for further development in pumpkin or kabocha crops.

Mulches

Cover crops and living mulch weed management systems offer several advantages over conventional chemical control and tillage methods. Advantages of these weed management systems include the control of erosion, by both wind and water, improved soil structure, crop yield and quality.

In general, mulches provided efficacious weed control throughout the growth of the crop. Wheat (Photograph 4), rye corn and oats were found to be the most effective of all mulches in controlling weeds, possibly due to alleopathic effects. The ability of cereal crops and stubble to suppress weed emergence has been well documented.

The suppression of weeds was dependent upon the type and density of the mulch. High seedling rate, e.g. ryegrass at 100kg/ha and oats at 300kg/ha, were more efficacious in comparison to ryegrass at 25kg/ha and oats at 100kg/ha. The higher seedling rates would have increased the physical suppression of the weeds and any alleopathic effects of these mulches. The use of mulches can also reduce weed pressure in a crop, by reducing soil disturbance through cultivation at planting or inter-row weeding, which stimulates weed germination.

In addition, the weed suppression offered by mulches may decrease the use of herbicides in these crops. Banded applications of Command + Frontier to cereal mulches further improved the weed control in the planted row (Table 4) (Photographs 5 & 6). Soil disturbance at planting stimulates the germination of weeds. As mulches cannot be planted in the crop drill runs, because of the suppression of crop emergence, banded herbicide applications are required for successful weed control.

Two brassica biofumigants, BQ Mulch and Weedcheck, were also evaluated. These mulches were incorporated into the soil prior to the sowing of the crop, and while resulting in more rapid cycling of nitrogen than the cereal mulches, did not result in acceptable weed control.

Nitrogen nutrition was monitored at the sites where mulches were evaluated. Soil and sap nitrogen levels were found to be directly affected by the mulch type, rainfall events and changes in soil temperature. Analysis for correlation between soil nitrate and sap nitrate indicated that there was no correlation between soil and sap nitrate levels. Correlation was not expected, as squash grown in mulched plots displayed some suppression, and therefore lower sap nitrate, relative to the non-mulched areas.

Fluctuations in soil nitrate present difficulties for managing the nutrient status of a crop, to prevent over or under supply. Variations are generally linked to the stage of mulch decomposition, as well as rainfall events and fluctuations in soil temperature. Increased moisture availability and higher soil temperatures, leading to increased microbial activity, result in increased microbial activity and, hence, greater levels of soil nitrogen. Increase in soil nitrate later in crop development, suggested the return of nitrogen to the soil following microbial breakdown (Graph 1).

Technology Transfer

Grower and Industry Information Sessions

Regular field days and visits were made to trial sites throughout the life of the project. These involved agronomic / field staff, growers, processing company staff and chemical company representatives. Field days and visits have allowed participants to observe the efficacy and crop safety of the various herbicide strategies, and the input of participants aided in the planning of future trials. The Forthside Vegetable Research Station annual field days in 1998 and 2000, also provided an opportunity for the public, growers, industry representatives and other researchers to compare the effect of mulching treatments on crop tolerance and weed efficacy, to herbicide strategies, as well as integrated methods of weed control.

A number of presentations at various conferences and meetings were conducted throughout the project, including the Tasmanian Agricultural Research and Advisory Committee's (ARAC's) annual presentations. These presentations allowed communication of results to growers, processing companies, agronomic / field staff and other researchers.

Two papers were presented at the 12th Australian Weeds Conference in 1999. The first paper "Mulch management for weed control and improved crop quality" discussed the benefits and complications associated with the uses of mulches for weed management in cucurbit crops. The second paper, "Clomazone: a new herbicide for broadleaf and grass weed control for various crops in Australia" gives a summary of the weed efficacy of Command, and the markets it was being introduced into in Australia, which included cucurbit crops.

Publications

Publicity of the project in the HRDC annual reports and the 1999 Australians Weeds Conference proceedings generated inquiries from cucurbit production areas across Australia. These reports kept growers up to date with the project, particularly regarding the registration of new products. An article was also published in Melon Runner magazine during 1999.

Product Development

Product development to the registration phase was an important aspect of this project, which required close liason with a number of companies. Regular meetings were held with staff from the various chemical companies to facilitate product registration, particularly of Command. Discussions working toward the registration of Frontier and Authority are continuing.

Following the registration of Command in cucurbit crops during 1999, training seminars were carried out in, or near, a number of the major production centers in Australia. In total, more than 30 training sessions have been conducted and brochures have been distributed covering the use of Command in pumpkin and kabocha crops.

Note: A brief outline of individual technology transfer events is included in Table 5.

Table 5 – Technology Transfer

Technology Transfer Activity	Date
Presentation at the Forthside Vegetable Research Station open day.	February 1998
Publication of Article in Australian Melon Growers magazine.	June 1998
Annual report sent to all voluntary contributors and the HRDC.	June 1998
Presentation of the project at the annual Tasmanian ARAC presentations.	August 1998
Meeting with BASF in Sydney to discuss registration of Frontier.	December 1998
Field visit with Harvest Moon and Serve-Ag agronomic staff.	January 1999
Meeting with FMC and BASF staff in North Carolina, to discuss Command and Frontier.	March 1999
Meeting with FMC in Brisbane to discuss the registration of Command.	June 1999
Presentation of the project at the annual Tasmanian ARAC presentations.	July 1999
Annual report sent to all voluntary contributors and the HRDC.	September 1999
Presentation of two papers at the 12th Australian Weeds Conference, Hobart.	September 1999
Training sessions covering the use of Command in cucurbit crops held in Launceston, Devonport, Hobart, Griffith, Sydney, Perth, Mildura, Swan Hill, Myrtleford, Broome, Kunnanurra, Manjimup, Mt Gambier, Gatton, Bundaberg, and Brisbane.	February 1999 - December 1999
Field visit with Harvest Moon and Serve-Ag agronomic staff.	January 2000
Training sessions covering the use of Command in cucurbit crops in Mareeba, Cairns, Tully and Ayr.	February 2000
Presentation at the Forthside Vegetable Research Station open day.	February 2000
Meeting with BASF and FMC in Brisbane to discuss registration of Frontier and Authority.	February 2000
Meeting with FMC in Tasmania to discuss registration of Authority	March 2000
Presentation of the project at the annual Tasmanian ARAC presentations.	August 2000
National registration for Command as a pre-emergent herbicide for cucurbit crops approved.	August 2000
Annual report sent to all voluntary contributors and the HRDC.	September 2000

Recommendations

- FMC to proceed with registration of Authority in pumpkin and kabocha.
- BASF to proceed with registration of Frontier in pumpkin and kabocha.
- Further evaluation of Frontier and Authority in other cucurbit crops, such as melons.
- Growers to request a minor use permit for Brodal for control of wild radish (*Raphanus raphanistrum*) in pumpkin and kabocha crops.
- Evaluate cereal mulches in combination with herbicide banding in commercial pumpkin and kabocha crops.
- Information generated in this project should be used to support the commercial use of Command.

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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	Heavy damage to total kill
8	45.1 - 70	
9	70.1 - 100	

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	Nicotinanilide 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

Cucurbit Crop Tolerance Data - Pumpkin

Pre-emergence	Post-emergence	Site	Season	Crop
Authority 125g		3	1997/1998	1.0
Authority 125g		6	1997/1998	1.3
Authority 250g		1	1997/1998	3.8
Authority 250g		2	1997/1998	2.3
Authority 250g		3	1997/1998	1.0
Authority 250g		6	1997/1998	1.1
Authority 250g		1	1998/1999	1.0
Authority 250g		4	1998/1999	1.0
Authority 250g		3	1999/2000	1.0
Authority 500g		1	1997/1998	8.5
Authority 500g		2	1997/1998	2.3
Authority 500g		3	1997/1998	1.0
Authority 500g		6	1997/1998	1.2
Authority 500g		1	1998/1999	1.0
Authority 500g		4	1998/1999	1.0
Authority 500g		3	1999/2000	1.0
Authority 500g		4	1999/2000	3.3
Authority 1kg		4	1999/2000	1.5
Command 250mL		1	1997/1998	1.8
Command 250mL		3	1997/1998	1.0
Command 250mL		6	1997/1998	1.9
Command 250mL + Authority 125g		3	1997/1998	1.0
Command 250mL + Authority 125g		6	1997/1998	1.5
Command 250mL + Authority 250g		1	1997/1998	2.3
Command 250mL + Frontier 750mL		1	1997/1998	2.0
Command 250mL + Frontier 1L		3	1997/1998	1.0
Command 250mL + Frontier 1L		6	1997/1998	1.4
Command 500mL		1	1997/1998	1.3
Command 500mL		3	1997/1998	1.0
Command 500mL		6	1997/1998	2.0
Command 500mL		3	1999/2000	1.0
Command 500mL		4	1999/2000	6.8
Command 500mL	Eclipse 7g	2	1997/1998	4.7
Command 500mL	Spinnaker 300mL	2	1997/1998	3.3
Command 500mL + Authority 250g		2	1997/1998	2.3
Command 500mL + Authority 250g		3	1997/1998	1.0
Command 500mL + Authority 250g		6	1997/1998	1.3
Command 500mL + Authority 500g		1	1997/1998	6.3
Command 500mL + Authority 500g		3	1999/2000	1.0
Command 500mL + Authority 500g		4	1999/2000	1.8
Command 500mL + Brodal 200ml		3	1999/2000	1.0
Command 500mL + Dual 2L		3	1999/2000	1.0
Command 500mL + Frontier 1.5L		1	1997/1998	2.3
Command 500mL + Frontier 1.5L		2	1997/1998	2.0
Command 500mL + Frontier 1.5L		3	1999/2000	1.0
Command 500mL + Frontier 1.5L		4	1999/2000	7.3
Command 500mL + Frontier 2L		3	1997/1998	1.0
Command 500mL + Frontier 2L		6	1997/1998	1.2
Command 500mL + Titus 60g		2	1997/1998	3.0
Command 1L		1	1997/1998	1.5
Command 1L		2	1997/1998	2.7
Command 1L		3	1997/1998	1.0
Command 1L		6	1997/1998	1.2
Command 1L		1	1998/1999	1.0
Command 1L		4	1998/1999	1.0
Command 1L		3	1999/2000	1.0
Command 1L		4	1999/2000	2.0

Cucurbit Crop Tolerance Data - Pumpkin (cont.)

Pre-emergence	Post-emergence	Site	Season	Crop
Command 1L + Authority 250g		1	1998/1999	1.0
Command 1L + Authority 250g		4	1998/1999	1.0
Command 1L + Authority 500g		4	1997/1998	1.5
Command 1L + Authority 1kg		4	1997/1998	1.8
Command 1L + Dual 2L		1	1998/1999	1.0
Command 1L + Dual 2L		4	1998/1999	1.0
Command 1L + Frontier 1L		1	1998/1999	1.0
Command 1L + Frontier 1L		4	1998/1999	1.0
Command 1L + Frontier 1.5L		4	1997/1998	1.5
Command 1L + Frontier 3L		4	1997/1998	2.3
Command 1.5L		1	1998/1999	1.0
Command 1.5L		4	1998/1999	1.0
Command 2L		1	1997/1998	1.3
Command 2L		1	1998/1999	1.0
Command 2L		4	1998/1999	1.0
Dual 2L		1	1998/1999	1.0
Dual 2L		4	1998/1999	1.0
Frontier 750mL		1	1997/1998	2.0
Frontier 750mL + Authority 250g		1	1997/1998	2.5
Frontier 1L		3	1997/1998	1.0
Frontier 1L		6	1997/1998	1.1
Frontier 1L		1	1998/1999	1.0
Frontier 1L		4	1998/1999	1.0
Frontier 1L + Authority 250g		3	1997/1998	1.0
Frontier 1L + Authority 250g		6	1997/1998	1.3
Frontier 1.5L		1	1998/1999	1.0
Frontier 1.5L		1	1997/1998	3.3
Frontier 1.5L		2	1997/1998	2.7
Frontier 1.5L		4	1998/1999	1.0
Frontier 1.5L		3	1999/2000	1.0
Frontier 1.5L		4	1999/2000	4.5
Frontier 1.5L + Authority 250g		2	1997/1998	2.7
Frontier 1.5L + Authority 500g		4	1999/2000	2.8
Frontier 2L		3	1997/1998	1.0
Frontier 2L		6	1997/1998	1.3
Frontier 3L		2	1997/1998	2.7
Frontier 3L		3	1999/2000	1.0
Frontier 3L		4	1999/2000	3.0
Frontier 4L		3	1997/1998	1.0
Frontier 4L		6	1997/1998	1.2
Raft 625mL		1	1998/1999	1.8
Raft 625mL		4	1998/1999	1.0
Raft 1L		3	1999/2000	4.0
Raft 1.25L		1	1998/1999	5.0
Raft 1.25L		4	1998/1999	1.0
Spinnaker 300mL		2	1997/1998	4.7
	Broadstrike 40g	2	1997/1998	5.3
	Eclipse 7g	2	1997/1998	5.0

Appendix iv

Cucurbit Crop Tolerance Data – Kabocha

Pre-emergence	Post-emergence	Site	Season	Crop
Authority 250g	Brodal 100ml	2	1998/1999	3.75
Authority 500g		1	1999/2000	1.50
Authority 500g	Brodal 100ml	2	1998/1999	4.00
Authority 1kg		1	1999/2000	1.75
Balance 150g		2	1998/1999	7.00
Command 500ml + Authority 500g		1	1999/2000	1.25
Command 500ml + Brodal 200ml		1	1999/2000	2.00
Command 500ml + Frontier 2L		1	1999/2000	2.00
Command 1L		1	1999/2000	1.50
Command 1.0L + Authority 500g	Brodal 100ml	2	1998/1999	4.25
Command 1.0L + Frontier 1.5L	Eclipse 3.5g	2	1998/1999	7.75
Command 1.0L	Eclipse 3.5g	2	1998/1999	6.75
Command 1.0L	Eclipse 7g	2	1998/1999	7.50
EXP03316B 1.0L		2	1998/1999	6.00
EXP03316B 500ml		2	1998/1999	4.25
Frontier 1.5L	Eclipse 3.5g	2	1998/1999	7.50
Frontier 2L		1	1999/2000	2.00
Frontier 2L+ Authority 500g		1	1999/2000	3.00
Frontier 4L		1	1999/2000	3.5
	Balance 75g	2	1998/1999	6.50

Extract from the Command® 480EC Herbicide label

CROP	WEEDS CONTROLLED	RATE	CRITICAL COMMENTS
Cucurbits (Pumpkins, squash, rockmelons, watermelon, cucumber & zucchini)	Apple of Peru (*Nicandra physalodes*), Blackberry nightshade (*Solanum nigrum*), Fat hen (*Chenopodium album),* Pig Weed (*Portulaca oleracea*), Potato Weed (*Galinsoga parviflora*), Amaranth (*Amaranthus powellii*) (Suppression only)	1 L/ha	Apply post plant pre-emergence before weeds emerge. Some cucurbit varieties may show differing levels of tolerance to Command. In some situations, one or more of the following conditions such as; sandy soils, soils of low organic matter, or soils of low pH, may cause an increase in the activity of Command and crop damage may occur. It is recommended to test on a small area to ensure tolerance is acceptable before adoption on a wider scale. For more specific information consult with your local dealer.

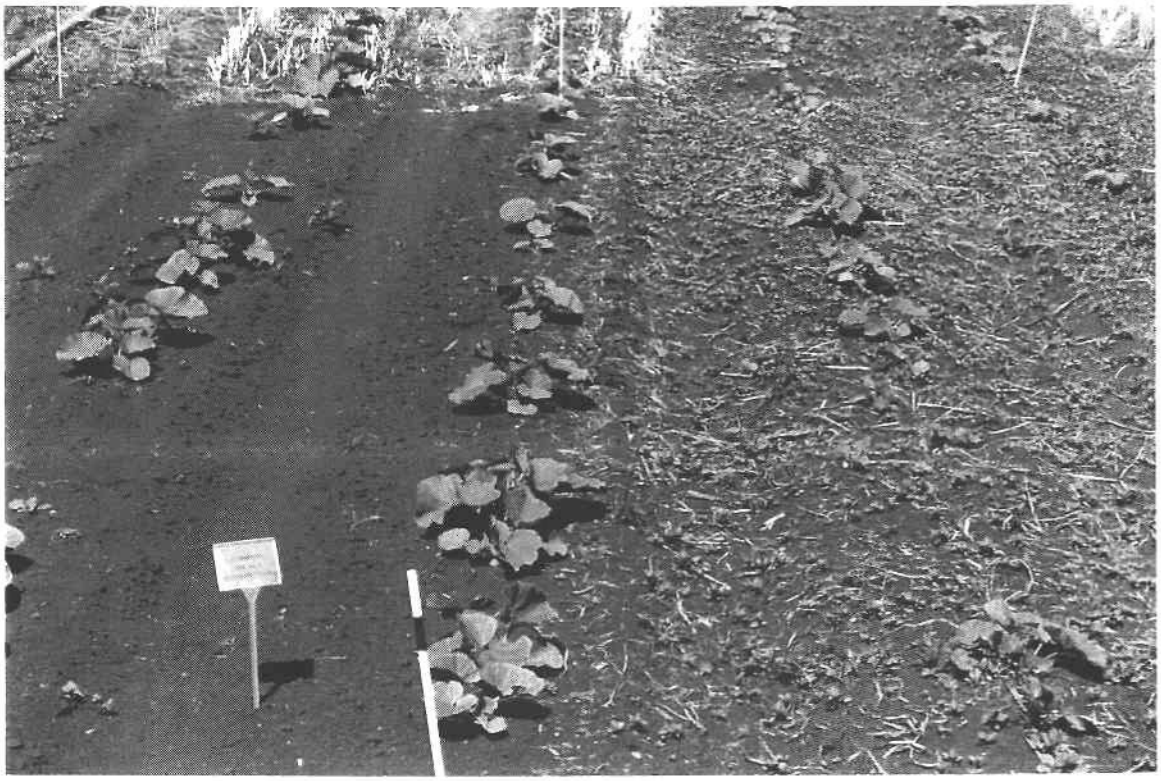
Appendix vi

Residue Samples

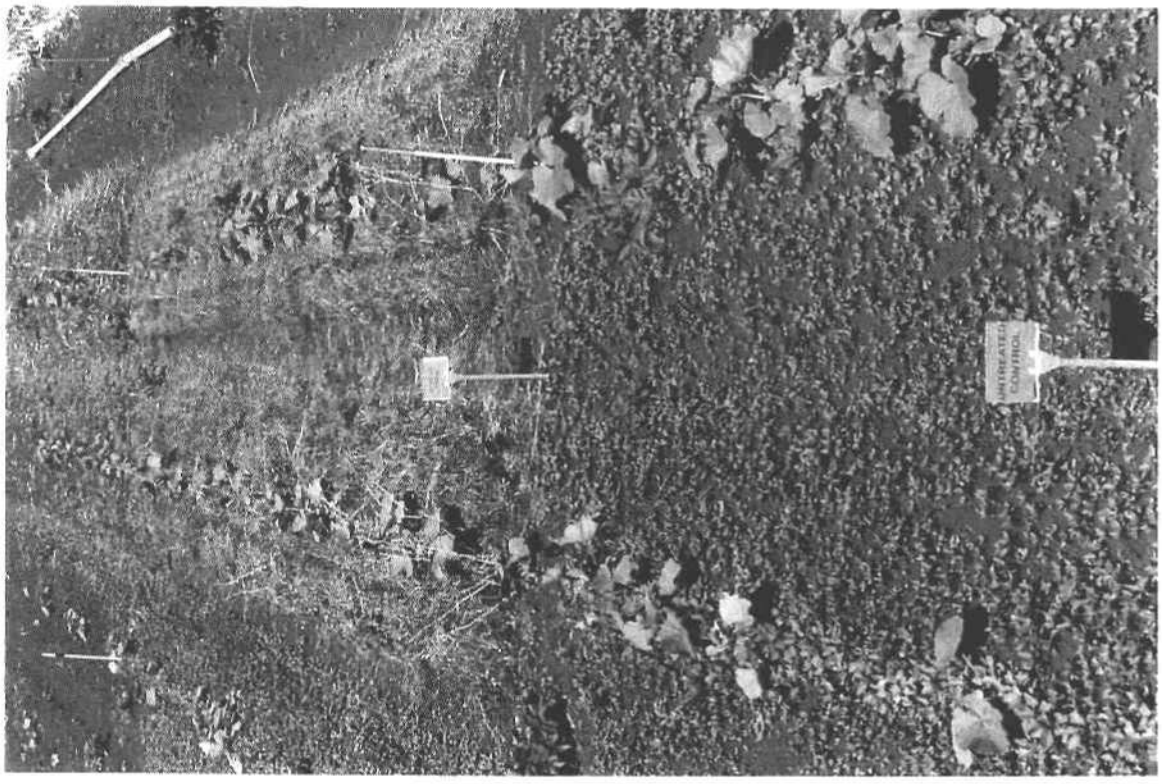
Crop Part	Site	Product	Rate/Ha	Sampling Date	Total Samples
Fruit	Kindred	Frontier	2L	16/3/00	2
Fruit	Kindred	Frontier	4L	16/3/00	2
Fruit	Kindred	Authority	500g	16/3/00	2
Fruit	Kindred	Authority	1kg	16/3/00	2
Fruit	Kindred	Untreated	0	16/3/00	4

Photograph 1 - Commercial kabocha crop at Wesley Vale, Inter-row cultivation has not controlled weeds between the plants.

Photograph 2 - Inter-row cultivation of a pumpkin crop for the control of weeds

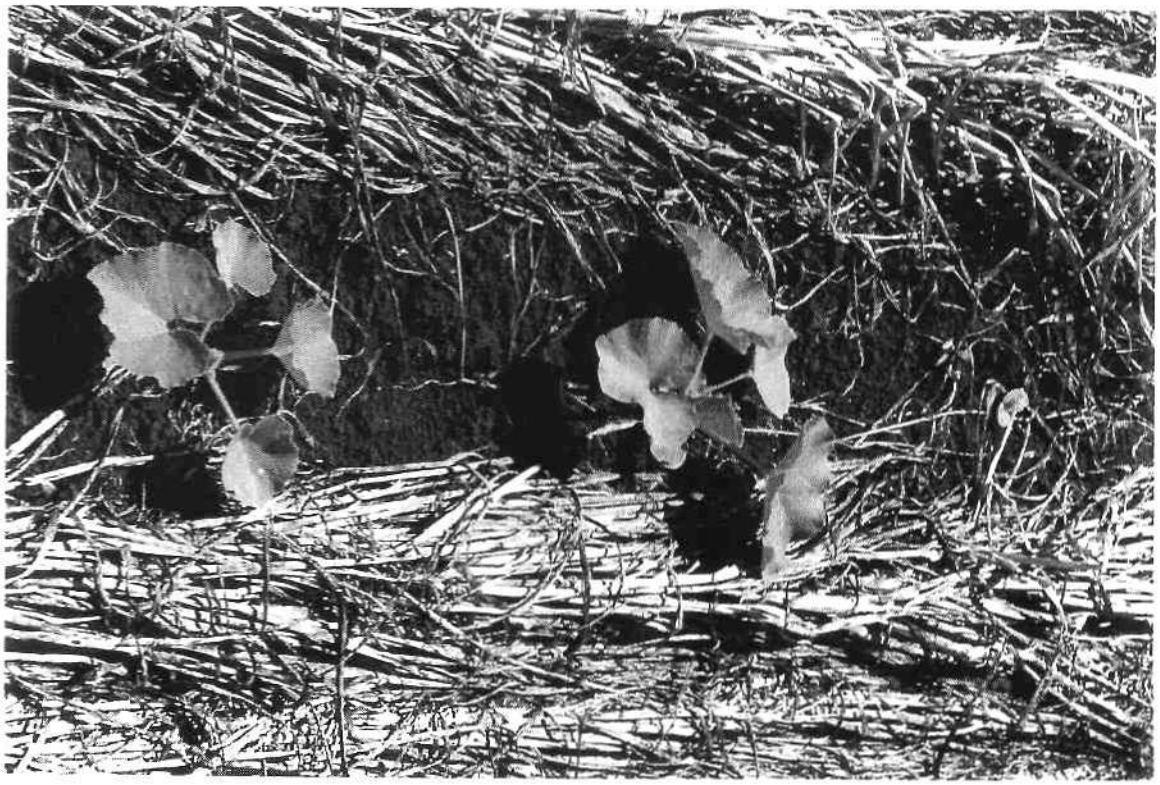


Photograph 3 - Command 500ml + Authority 500g (Left), Weedcheck Mulch 20kg/ha (Right)



Photograph 4 - Untreated Control (Foreground), Wheat Mulch 200kg/ha (Background)

Photograph 5 - Kabocha growing in oat mulch (note weeds between the plants)



Photograph 6 - Kabocha growing in oat mulch, banded application of Command 633ml and Frontier 1.9L