Evaluation of alternative herbicide systems for the sweetpotato crop

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Summary The proliferation of herbicide-resistant weeds is a global issue that now affects the New Zealand sweetpotato industry. For about 40 years the industry has used the herbicide paraquat to control weeds emerging within the established crop. As paraquat-resistant biotypes of black (*Solanum nigrum* L.) and small-flowered (*S. americanum* Mill.) nightshade have become prevalent, local sweetpotato growers have begun reviewing their weed management practices. In this study, alternative herbicide systems were examined in a field trial conducted at a commercial site known to have a high population of paraquat-resistant black nightshade. The residual herbicides acetochlor, dimethenamid and alachlor were all useful for weed control, but acetochlor was the most effective, particularly against black nightshade. Oxyfluorfen was effective against seedling black nightshade, but great care was required to avoid a crop phytotoxic response. As weed competition was relatively low, none of the weed control measures applied in this trial could be justified by improved economic returns within the evaluation season. Sweetpotato is a minor crop and growers must adapt the usage of generally available herbicides to meet the requirements of the production system, through modified application rates, application techniques and crop management. Further work is required to develop herbicide systems that are optimised for weed control, while minimising phytotoxic effects within the crop and producing residue levels that are environmentally sustainable and acceptable for human consumption.

Keywords *Ipomoea batatas*, kumara, weed management, yield.

INTRODUCTION

Crop production takes place in a dynamic, synthetic ecosystem and weed control strategies need to be continually modified to remain effective. The New Zealand sweetpotato (*Ipomoea batatas* (L.) Lam.) industry is well established in the Dargaville–Ruawai district, where it has been reliant on the herbicide paraquat for about 40 years. Low rates of the contact herbicide are applied repeatedly over the crop while the weeds are in the cotyledon or early growth stages, until the crop forms sufficient ground cover to be competitive. While the critical weed-free period varies with cultivar and seasonal conditions, it is generally 6–8 weeks. The industry has previously investigated other herbicide options (Lewthwaite and Triggs 2000), but paraquat remains the predominant herbicide. In recent years paraquat-resistant biotypes of black nightshade (*Solanum nigrum* L.) and small-flowered nightshade (*S. americanum* Mill.) have become increasingly widespread (Lewthwaite and Triggs 2009). Herbicide-resistant weeds are a problem on a global scale, causing concern for economically sustainable crop production. Through repeated cycles of plant germination, followed by herbicide selection and subsequent seed production, high levels of herbicide resistance may be found throughout an entire local population. Replacement herbicides can be difficult to identify for minor crops, as growers must adapt their usage of generally available herbicides to meet the requirements of their specific production system, through modified application rates, application techniques and crop management.

This research project was undertaken to investigate alternative weed control strategies for use within the New Zealand sweetpotato cropping system.

MATERIALS AND METHODS

The trial was conducted on a commercial property situated near Dargaville, in a field with an established history of paraquat-resistant black nightshade. The trial was laid out in a modified alpha row-column design, four columns wide by 16 rows long. The 16 treatments were replicated four times. Each plot was four rows wide by 3 m long, with a 1 m gap between plots along columns. Transplants were inserted 30 cm apart along each row, with an inter-row spacing of 75 cm. Each plot therefore contained a total of four rows with 10 plants in each row, the two outer rows serving as guard rows. The sweetpotato cultivar used throughout the trial was 'Owairaka Red'.

Herbicide combinations were selected for evaluation after a review of international approaches to weed control in sweetpotato and with local grower input. The products and associated active ingredients applied in the trial were: Frontier® (dimethenamid), Gramoxone® (paraquat dichloride), Lasso® (alachlor), Afalon®

(linuron), Organic Interceptor® (pine oil), Oxy*250® (oxyfluorfen), Sylon® (acetochlor) and Tough® (pyridate). The application rates (active ingredient, kg ha^{-1}:water rate, L ha^{-1}) were: dimethenamid (1.8:300), paraquat dichloride (0.10:300), alachlor (2.40:300), linuron (0.90:300), pine oil (i) (18.00:300), pine oil (ii) (9.00:300), oxyfluorfen (i) (0.10:481), oxyfluorfen (ii) (0.15:608), acetochlor (2.10:300), pyridate (i) (0.45:300) and pyridate (ii) (0.225:300). For herbicide treatment combinations refer to Table 1.

Residual herbicides (linuron**,** dimethenamid**,** alachlor, oxyfluorfen and acetochlor) were applied immediately after planting and the initial transplant watering were completed, on 29 December 2005. Treatments were applied at various chemical-specific water rates. For the linuron treatment, the herbicide was washed from the transplants' leaves immediately after application (Allemann 2004). The oxyfluorfen treatment plots were initially sprayed with water (608 L ha^{-1}) to simulate dew, prior to herbicide application. The weather was calm and dry during the application of residual herbicides, but over 20 mm of rainfall within the subsequent 10 days ensured herbicide activation. Analysis of a composite soil sample taken during the trial period (10 February) gave a pH of 5.6 and an organic matter level of 8.7%.

The first application of contact herbicides (paraquat dichloride**,** pine oil and oxyfluorfen) was made under calm, dry conditions on 11 January 2005. Oxyfluorfen treatment plots were again sprayed with water (608 L ha^{-1}) to simulate early morning dew, prior to herbicide application. Weed growth was light but relatively even throughout the trial, with the most advanced nightshade seedlings showing two to three true leaves. The second application of contact herbicides (paraquat dichloride, pine oil, oxyfluorfen and pyridate) was made under calm conditions in the early morning of 6 February 2005. The oxyfluorfen treatment plots were sprayed with herbicide while leaves were still naturally covered with morning dew.

On 3 March, weed samples were collected from four 40 × 40 cm quadrats per plot (two on ridges and two in the valleys) and the control plots were carefully hand-weeded. The season was generally dry, so weed germination was relatively light. The weed samples were used to evaluate weed numbers, species and biomass (oven dry weight at 80°C) under the different herbicide regimes. At harvest, on 10 April 2006, root total yield, marketable yield (roots greater than 2.5 cm in diameter) and marketable root numbers were recorded per plot. Roots were cut open to check for internal defects and root sub-samples were oven-dried

Table 1. Herbicides applied in 16 treatment combinations within a sweetpotato field trial conducted at Dargaville.

Treatment	Residual application[A]	First contact application	Second contact application
A	linuron	paraquat dichloride	paraquat dichloride
B	linuron	oxyfluorfen (i)	oxyfluorfen (i)
C	dimethenamid	paraquat dichloride	paraquat dichloride
D	dimethenamid	oxyfluorfen (i)	oxyfluorfen (i)
E	nil	paraquat dichloride	paraquat dichloride
F	nil	paraquat dichloride	pyridate (i)
G	nil	paraquat dichloride	pyridate (ii)
H	nil	nil	Hand-weeded[B]
I	alachlor	oxyfluorfen (i)	oxyfluorfen (i)
J	nil	pine oil (i)	pine oil (i)
K	nil	pine oil (ii)	pine oil (ii)
L	nil	oxyfluorfen (i)	oxyfluorfen (i)
M	nil	oxyfluorfen (ii)	oxyfluorfen (ii)
N	oxyfluorfen (ii)	oxyfluorfen (ii)	oxyfluorfen (ii)
O	acetochlor	paraquat dichloride	paraquat dichloride
P	acetochlor	oxyfluorfen (i)	oxyfluorfen (i)

[A] Applied on the day of crop transplanting and prior to weed emergence.
[B] Hand-weeding took place 25 days after second contact application.

at 80°C to assess the ratio of dry matter to water content. Data were analysed using the ANOVA procedure of the statistical software GENSTAT®.

RESULTS AND DISCUSSION

Examining the trial results for evidence of crop damage, show that the herbicide regimes evaluated had a significant effect (Table 2) on total root yield ($P < 0.001$), marketable yield ($P < 0.001$), root dry matter content ($P < 0.001$) and root number ($P = 0.020$), but not on marketable percentage ($P = 0.24$). On average, marketable yield increased by 0.95 t ha^{-1} (SE = 0.062) for every 1 t ha^{-1} increase in total yield ($P < 0.001$, R^2 = 94.7%). Herbicide applications had a significant effect (Table 3) on weed growth, as measured by weed dry weight ($P < 0.001$) and number ($P < 0.001$).

As the season was dry, weed competition was relatively low and marketable root yield was not related to weed density as assessed by weed canopy dry weight. Any crop effects were indicative of herbicide phytotoxicity, rather than a response via modifying weed competition. Based on these results, none of the weed control measures applied in this trial could be justified by improved economic returns within the evaluation season. However, failure to restrain weed growth and subsequent seed set would cause major problems in seasons with more optimal conditions for weed growth.

A comparison of three residual herbicide treatment groups based on linuron, dimethenamid or acetochlor showed quite dissimilar responses in total weed dry weight, with the use of acetochlor allowing minimal weed growth. Paraquat dichloride was not as effective as oxyfluorfen for removing surviving black nightshade plants, owing to the resistant nightshade component. The acetochlor-oxyfluorfen combination provided the greatest control over paraquat-resistant nightshade germination and growth.

Although paraquat remains a useful tool in controlling weeds of the sweetpotato crop, the application of herbicide combinations will become increasingly important. Residual herbicides tend to require rain or soil incorporation to increase their effectiveness and are not as efficient on soils with high levels of organic matter. However, alachlor is sometimes applied through watering systems, at crop transplanting. Of the residual herbicides, acetochlor was particularly effective, but there is a manufacturer's warning to avoid prolonged cold wet post-planting conditions and soils with very low organic matter, conditions which can occur in the Dargaville region. Oxyfluorfen was effective against germinated paraquat-resistant nightshade, but requires careful application at high water rates under very low pressure, preferably to wet sweetpotato leaves, to prevent a crop phytotoxic response.

Table 2. Effects of various herbicide treatment combinations on the root yield of sweetpotato cultivar 'Owairaka Red' at Dargaville.

Treatment[A]	Total yield (t ha^{-1})	Marketable yield (t ha^{-1})	Marketable (%)	Root dry matter (%)	Number of roots (m^{-2})
N	11.9	10.1	81.9	31.0	6.2
A	12.8	9.6	73.1	28.7	6.4
M	13.6	10.5	76.1	29.8	7.1
C	14.0	10.9	76.9	27.2	7.3
B	15.1	12.0	77.1	28.5	7.6
F	15.1	11.7	76.7	30.2	7.6
P	15.3	13.1	85.6	31.1	7.6
D	15.8	13.3	83.4	31.5	8.2
L	15.8	12.5	80.1	29.0	8.2
G	16.0	13.0	81.7	29.9	7.4
O	16.1	13.0	79.0	28.5	8.4
I	16.2	13.3	83.0	31.1	7.8
E	16.7	13.8	79.5	28.6	8.6
K	17.1	13.9	78.8	29.4	8.3
J	18.0	14.6	79.3	30.2	9.8
H	18.5	14.9	80.0	30.7	9.7
$LSD_{0.95}$ (df = 30)	2.9	2.9	8.4	2.0	2.2
P-value	<0.001	<0.001	0.24	<0.001	0.020

[A] Refer to Materials and Methods section for treatment details.

Table 3. Effects of various herbicide treatment combinations on the weed population within a sweetpotato trial at Dargaville.

Treatment[A]	Weed dry weight (g m^{-2})	Weed number (m^{-2})	Nightshade number (m^{-2})	Nightshade[B] (%)
P	0.0	0.4	0.0	0.0
O	0.0	1.2	0.4	12.5
C	1.4	2.3	1.6	58.3
L	2.5	7.8	2.7	29.5
F	3.1	16.8	7.4	49.6
G	3.5	18.4	6.3	36.6
M	4.1	7.8	1.2	18.7
E	4.2	10.2	6.6	75.6
N	4.5	11.7	2.3	22.5
I	4.8	5.5	1.6	20.0
D	5.0	3.1	1.2	25.0
B	6.0	13.3	4.7	30.6
A	7.1	9.4	6.3	69.2
J	10.3	23.1	15.2	73.5
K	18.8	28.1	14.1	49.1
H	41.3	30.9	17.6	55.4
$LSD_{0.95}$ (df = 30)	15.1	10.08	5.61	
P-value	<0.001	<0.001	<0.001	

[A] Refer to Materials and Methods section for treatment details.
[B] Nightshade plants as a percentage of total weed numbers within treatments.

This study does not provide an enduring solution to the industry's needs. Herbicides are constantly challenged by the development of weed resistance and a changing weed spectrum. There is a need for continual investment into evaluation of new herbicides and novel techniques for weed control.

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