BUREAU OF SUGAR EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA

FINAL REPORT – SRDC PROJECT BSS186
DEVELOPMENT OF A METHOD TO AID DECISION MAKING ON HERBICIDE USE FOR AUSTRALIAN CANEGROWERS

by T O'Grady* and T Murphy*

SD01005

Principal Investigators:	T.O'Grady*	T.Murphy*
	Research Officer	Research Officer
	BSES	BSES
	PMB 57	PMB 57
	MACKAY MC 4741	MACKAY MC 4741
	Phone (07) 49545100	Phone (07) 49545100

*** Both now employed by Aventis, Mackay**

The Sugar Research and Development Corporation funded this project during the 1997/98, 1998/99, 1999/2000 and 2000/2001 financial years. The Research Organisation is not a partner, joint venture, employee or agent of SRDC and has no authority legally to bind SRDC in any publication of substantive details or results of this project.

BSES Publication **July 2001**

SRDC Final Report SD01005

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

SUMMARY

This project successfully met its objectives. It demonstrated the strong competition effect weed growth has on the yield of sugarcane, developed a robust protocol for the rapid assessment of cane variety reaction to herbicides, and produced a decision aid for growers in the form of a herbicide manual.

The importance of controlling weeds in the early crop growth stage of sugarcane was highlighted in all regions from Innisfail to Bundaberg. In trials, it was shown that weed growth early in the crop establishment phase causes significant loss in cane yield of the order of 13% to 50% depending on the period of competition, the weed population and the climatic conditions. Of particular note was the potential crop loss due to weed growth in the first four weeks following emergence of the cane plant. Losses from weed competition were similar over the 1997/98 and 1998/99 seasons.

The concept of approaching weed control in young plant cane from the stance of accepting an economic threshold of weed infestation was not achieved. As rainfall has a major influence on windows of opportunity for spraying activity, and therefore the potential for uncontrolled weed growth to influence cane yield, growers are unprepared to accept the potential risk. Growers' attitudes to weed control were assessed through focus groups. They expressed a good qualified, but not quantified, knowledge of weed competition effects. Project results will overcome this deficiency. Growers expressed valid reasons for embracing a zero tolerance to weeds in young plant cane (see section 4.3.1) and why a quadrat would be unsuitable as a decision aid tool (section 3.3.2.2.).

A robust technique to evaluate rapidly the phytotoxic effect of herbicides on sugarcane varieties was developed. The technique is valuable because previous methods (large-scale field trials) were resource intensive, subject to a large number of uncontrollable variables, costly and took up to 15 months to complete. The technique was tested over two seasons of trials and is now being used from Tully to Bundaberg as a standard component of the BSES process to develop new sugarcane cultivars. It involves spraying sugarcane setts growing in pots at the 3-4 leaf stage with the candidate herbicides and measuring tillering, shoot elongation and biomass. The completion of trials by 10 weeks allows for the rapid assessment of new herbicides and varieties in a much shorter time frame.

The success of the weed competition trials in plant cane resulted in the production of a 'slide-rule' to provide growers with an indication of potential crop and income losses resulting from weed competition. The slide-rule gives a crop yield and income loss for a range of sugar prices and weed-free periods. This brings to growers' attention the magnitude of potential loss due to weeds and has assisted growers with decisions on weed control.

A comprehensive manual, intended as the main decision aid tool for canegrowers when making decisions on weed control, was developed, printed and provided to the canegrowing community. It is durable, in a format that allows regular updates, and covers herbicide selection at various stages of growth of the crop, herbicide information and application techniques.

1.0 INTRODUCTION

Canegrowers spend in excess of A$14 million on herbicides annually. Crop loss attributed to weed competition exceeds A$57 annually (McLeod pers. comm.).

These losses occur through excessive weed seed buildup, subsequently providing strong competition with the cane plant for light, nutrients and moisture; poor timing of spraying, eg weeds too large or cane too small to compete; and poor herbicide application resulting in a sub-visual level of phytotoxicity to the cane plant. Much of this herbicide usage is dictated by a 'scorched earth attitude' rather than an economic threshold control approach. Little consideration is given to an integrated weed management approach such as reducing the weed seed population during the fallow period.

The present philosophy is to apply a herbicide to any weed problem without consideration of either alternative control methods or economic threshold levels of the practice. A basic understanding is held of the competition and phytotoxic effects of weeds and herbicide usage. However, a more comprehensive quantitative understanding of the interaction of weed incidence x phytotoxicity x sugar yield was required before an overall assessment of the need for herbicide use could be made rationally.

Experimental work by *McMahon et al (1989)* demonstrated that a small weed population present at the early growth stage of the cane plant could have a significant competition effect, resulting in yield loss. The relationship between growth stage of the cane plant and weed density and the critical time for herbicide application required quantification. Initial experimentation by Linedale (BSES, pers. comm.) demonstrated that presently used herbicide x application techniques can cause severe yield loss in the cane crop through phytotoxicity to the cane plant. The extent of this loss and methods to overcome it required definition. The assessment of sugarcane cultivar reaction to herbicides is presently undertaken on a visual basis. Recent experimentation has shown a poor relationship to exist between the visual and measured reaction to phytotoxicity caused by herbicides (up to 45% yield loss measured but not assessed visually in the early growth stages). As field experimentation to assess herbicide x cane cultivar interaction is a costly and lengthy process, a simple pot-based experimental technique using measured rather than visual responses was required.

There is a strong need to reassess herbicide usage within the sugar industry in light of environmental and sustainability issues. Both Ham (1997) and Bauld *et al* (1995), working in the Burdekin, have shown that higher than acceptable levels of commonly used herbicides may be carried offsite in irrigation runoff waters. An extension component of this project was to develop an understanding of grower attitudes to herbicide use using focus group and local consensus data techniques.

2.0 OBJECTIVES

The objectives were to:

- develop a rapid and simple assessment technique for herbicide use to be used as an aid to decision making by canegrowers;
- to introduce to the canegrowing community the concept of an economic and sustainable approach to weed control rather than a scorched earth one.

To achieve these objectives it was necessary to:

- assess the competition effect of weed growth on sugar yield at a range of growth stages of the sugarcane crop and weed densities;
- assess the phytotoxic effect of presently used application technology x herbicide type on yield of sugar;
- develop economic thresholds for weed control through the combination of competition and phytotoxic effects;
- develop a support aid to assist grower decision making on weed control measures. The type of aid developed was dependent on the outcome of the above trial work;
- undertake an extension campaign, based on a participative approach, to introduce the concept of integrated weed management and economic thresholds for weed control to canegrowers.

3.0 METHODS

3.1 Weed competition

It has been recognised that the competition effect of weeds on cane growth is greatest at the early establishment stage of the sugarcane plant. To evaluate this effect, plant cane on commercial farms, with no artificial seeding of weeds, was provided with a weed-free environment for periods ranging from no control to full control. Trials were established to determine critical periods during which weeds must be controlled to prevent yield loss.

Seven trials were established in recently planted canefields at Innisfail, Ayr, Mackay and Bundaberg to cover any climatic or regional variation in competition effect that weeds may have on cane growth. Four trials were established in 1997/98, and three in 1998/99. Five weed control treatments were imposed from complete weed control, weed control after 4, 8 and 12 weeks, and no weed control in the 1997/98 trials. In the 1998/99 trials, treatment times were changed to 3, 5, 8 and 12 weeks to gain more information on weed effects. The weed-free environment was achieved through hand weeding to avoid any phytotoxic effect from the use of herbicides. An assessment of weed density, size, species, and biomass was made and cane and sugar yields were determined at harvest of the cane crop using the BSES weigh truck technique.

A factorial block design incorporating six treatments x four replications was used in all trials. Stalk (shoot) elongation was measured for selected stalks at the time of each weeding.

3.2 Herbicide x variety interaction

3.2.1 Herbicide screening for phytotoxicity (pot trials)

A technique to test rapidly for sugarcane variety reaction to herbicide application has been developed. A protocol for this technique is shown as Appendix 1. One-eye setts of sugarcane were pre-germinated then planted at the spike stage (before true leaves appear) into 21-litre pots containing a potting medium. Spraying using a precision compressed air sprayer was made at the 5-6 leaf stage of growth. The height of the primary tiller (ground to top visible dewlap), and the number of tillers emerging were recorded on a weekly basis for 7-8 weeks. Biomass was determined at 7-8 weeks through removal of both roots and above ground material. Initially two trials were established in 1998 in this series - one each at Mackay and the Burdekin. These were followed by four trials in 1999, and two in 2000. Details of treatments and varieties in each trial are shown in Appendix 10. Over the three-year period (1998 to 2000) the technique was shown to produce consistently reliable results. The technique is presently being used in a further four trials at Ingham, Mackay and the Burdekin to evaluate new varieties approaching release.

3.2.2 Field trials

3.2.2.1 Phytotoxicity trials

Two series of field trials were established. The first was to test for variety x herbicide interaction using the same varieties and herbicide treatments as used in the pot trials. The aim was to test the correlation between the field and pot trial results. Four replicated trials were established at Bundaberg, the Burdekin, Mackay and Innisfail using varieties Q124, Q135 and Q138 treated with Velpar K4, paraquat and Gesapax Combi. Treatments were applied at label rates as pre-emergent, early post-emergent, late post-emergent and unsprayed control. A further trial was established at Bundaberg in 1999 using the same varieties but an expanded range of herbicide treatments.

3.2.2.2 Demonstration trials

To emphasise first hand to growers some of the principles being developed through this project several demonstration sites were established and used during field days and bus trips. Nut grass (*Cyperus rotundus*) is a major weed of canefields in the Burdekin and Central districts. Two demonstration trials were established at Mackay and the Burdekin in 1999 to illustrate cost-effectiveness for nut grass control using all registered herbicides. They were based on improving timing of herbicide applications and the correct selection of herbicides to reduce overall herbicide usage and cost. Both demonstration trials successfully aided canegrowers in decision making for control of nut grass.

In Mackay, a trial was established to demonstrate the period of critical weed competition in plant cane. The trial assessed weed control efficacy and cost of post-plant pre-emergent herbicides Flame/Atrazine, Gesapax Combi, Trifluralin/Atrazine, and Stomp/Atrazine for weed control on autumn planted Q190[A]. The trial successfully demonstrated the economic benefit of early weed control.

3.3 Technology transfer

3.3.1 Focus groups

To assess grower attitudes to weed control, integrated weed management and herbicide use, focus groups were conducted at Innisfail, Ayr, Sarina and Bundaberg. They were structured on the effect of weed competition on plant cane, weed control in both plant and ratoon crops, and herbicide phytotoxicity. The questions used are shown in Appendices 2 to 5.

3.3.2 Decision aid tools

3.3.2.1 Slide-rule

A slide-rule indicating monetary losses from weeds was developed based on the weed competition trial results at Bundaberg as an example. The aim of the slide-rule was to create an awareness of potential crop and financial losses resulting from weed infestation at different times of growth of the cane plant. The slide-rule is a simple reference guide, which details the yield and income loss from weeds with varying sugar prices and periods of weed competition. An example of the slide-rule accompanies this report.

3.3.2.2 Manual

Information extrapolated from the participatory grower groups has aided development of a decision aid tool. The original concept of a physical tool (eg quadrat) for assisting the spray decision was disregarded for several reasons.

- Timing of weed control in sugarcane is primarily based on when weeds first appear, provided spraying is possible. Often there is limited time available for weed control and maintaining a weed-free threshold is necessary, because wet weather may prevent later effective control and cause significant yield loss. Therefore, because weed density is less important, a quadrat would not prove useful.
- The growers' opinion is that optimum timing of weed control is often limited by rainfall, and therefore a zero threshold approach to weed control during early growth of the crop is best practice.
- A large variation in climatic conditions in sugar producing regions results in a complex diversity of weed populations making an economic threshold determination impractical.
- The focus group outcomes suggest that growers require information on safe and economic herbicide selection based on the crop stage of growth, variety x herbicide tolerance, and correct herbicide application techniques
- Weed species is important in making the spray decision. The presence of problem weeds (vines and perennial grasses) in any part of a field influences growers' spray decision, irrespective of the weed density. Also, with large variation in weed composition in sugarcane fields, a simple-to-use quadrat covering many species would be impractical.

The decision aid tool, which was developed as a manual, took the form of a set of ‘guidelines for the best practice in weed control’. These guidelines provide information on critical stages for weed competition and the damage caused by different herbicides on different varieties, based around the practical aspects of spraying. The manual covers herbicide selection, timing of herbicide application, herbicide phytotoxicity, safety, correct application and weed identification. The format was tested to panels of growers at Mackay, Sarina and New South Wales with positive input. Manufacturing companies and distributors were also involved in discussions on the manual format. An example of the manual, which was released in February 2001, is attached.

4.0 RESULTS AND DISCUSSION

The original intention with this trial series was to evaluate the correlation between results from pot and field trials following spraying herbicides on sugarcane to see whether pot trials could replace resource expensive field trials. Parameters measured in the pot trials included shoot elongation rate, leaf numbers, tiller numbers and biomass of above ground and root sections. Final yields (tonnes cane and ccs) were measured in the field trials where appropriate. Due to the variable results obtained from the field trials, no determination of the correlation could be undertaken.

4.1 Weed competition

Three trials were harvested in the 1997/98 series while the Mackay trial was abandoned due to lack of weed growth. The Innisfail and Burdekin trials were not assessed beyond the 12-week stage, and therefore the unchecked treatment and the 12-week treatment are essentially the same in those trials.

The harvest results and statistical analysis of the six trials are included in detail in Appendix 6. Graphs of the results of the six trials are shown in Figure 1 and of the 1997/98 series in Figure 2. While there is considerable variation in magnitude of response to weed competition between trials this can be explained by variation in weed density, weed species, cane variety and climatic variation. The overall trend for a reduction in cane yield the longer the exposure to weed infestation is evident in all trials.

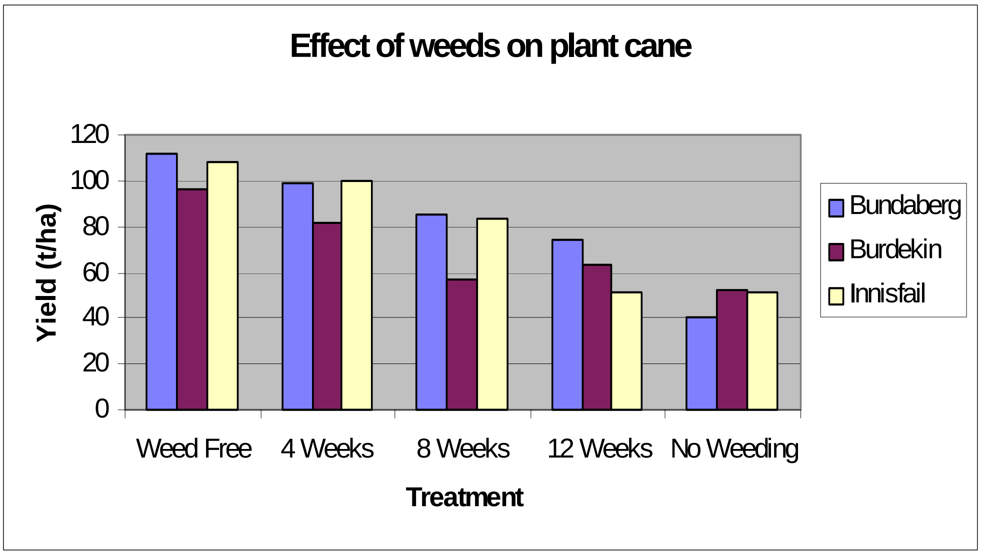


Figure 1. **Effect of weed competition on cane yield – all trials 1997/98 and 1998/99**

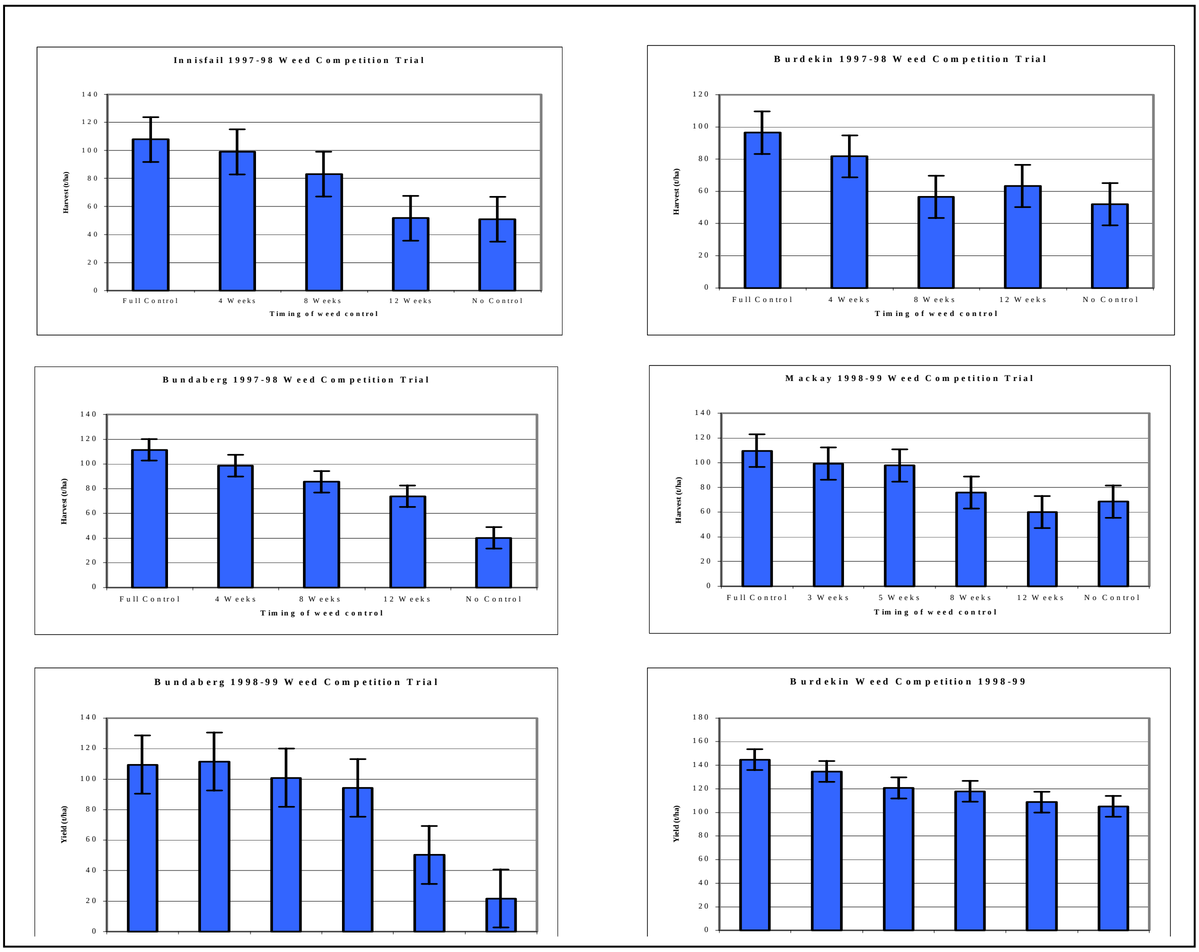


Figure 2. **Weed competition effect on cane growth – 1997/98 trials**

One of the components of the presence of weeds in canefields is that of the loss of crop and therefore income. This effect is illustrated in Figure 3 where the loss of income from weeds is shown for the Bundaberg trial at a raw sugar price of $250 per tonne. Losses are greater than the higher the price for raw sugar. The crop and financial loss associated with exposure to weeds in the first four weeks of cane establishment is particularly important (Bundaberg trial 1998 - $440/ha).

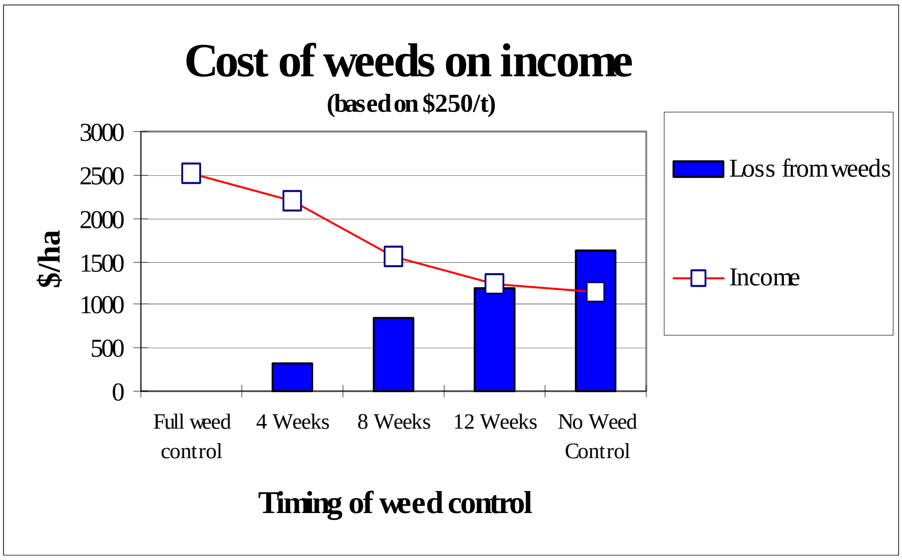


Figure 3. Cost of weeds on income – Bundaberg 1999

Although weed species, infestation intensity and biomass were not consistent across trials, and from district to district, a similar overall trend for the effect of weeds on young cane growth was experienced in all trials. An example using the 1997/98 trials is shown in Table 1.

Table 1. Weed biomass, cane height and cane yield for three weed-free periods in 1997/98 trial series

			4 weeks	8 weeks	12 weeks
Bundaberg					
Weed Biomass (g/m2)			203	518	-
Cane Height (TVD cm)		Full weed control	-	-	-
		Treatment	-	-	-
Yield Loss	(tc/ha)		13.2	26.4	38.1
	(% loss)		12	24	34
Innisfail					
Weed Biomass (g/m2)			22	308	-
Cane Height (TVD cm)		Full weed control	9.5	27.9	-
		Treatment	12.36	16.4	-
Yield Loss	(tc/ha)		8.5	24.8	57
	(% loss)		8	23	53
Burdekin					
Weed Biomass (g/m2)			175	274	-
Cane Height (TVD cm)		Full weed control	12.3	22.9	39.2
		Treatment	13.5	14.8	18.6
Yield Loss	(tc/ha)		14.7	39.7	33.2
	(% loss)		15	41	34

An example of the weed population and density experienced in this trial series is shown for the 1997/98 trials in Appendices 7 to 9.

4.2 Herbicide x variety phytotoxicity

4.2.1 Pot trials

The overall results from the pot trials have been variable from year to year, as expected, due to differing growing conditions in each district. The order of magnitude of response to herbicide treatment by varieties has varied but the trend demonstrating the phytotoxic effect of herbicides on cane varieties has been shown. There was sufficient statistical significance in the results to enable the technique as developed to be used with confidence in the commercial testing for herbicide x cane variety interaction.

4.2.1.1 1998 trials

Q135 proved significantly more susceptible to herbicide damage than either Q124 or Q138 (Table 2). Paraquat gave a significant reduction in stalk elongation rate compared to control, while Velpar K4 demonstrated a trend for reduction but was not significant. Both Velpar K4 and paraquat caused a significant reduction in fresh tops weight compared to the control with Gesapax Combi trending the same way but not significantly (Table 3). Results are shown in Figure 4.

Table 2. Shoot elongation and biomass - variety means 1998 pot trial Mackay

Variety	Elongation (mm)	Dry weight tops (g)	Fresh weight tops (g)
Q124	244.38 a	99.453 a	459.71 a
Q135	145.83 b	79.619 b	386.76 b
Q138	200.80 a	93.564 a	434.00 a
Lsd p=0.05	46.135	8.022	26.662

Means followed by same letter not significantly diff. (P=0.05)

Table 3. Shoot elongation and biomass - treatment means 1998 pot trial Mackay

Treatment	Elongation (mm)	Dry weight tops (g)	Fresh weight tops (g)
Gesapax Combi	226.2 a	86.21 bc	439.47 ab
Control	214.17 a	106.53 a	493.08 a
Velpar K4	208.06 a	98.82 ab	428.5 b
Paraquat	139.58 c	71.95 c	346.28 c
Lsd p=0.05	48.205	16.045	58.278

Means followed by same letter not significantly diff. (P=0.05)

In the Burdekin trial Gesapax Combi was significantly more damaging to cane than the other herbicide treatments with paraquat showing a similar, but not significant trend (Table 4).

Table 4. Biomass - treatment means 1998 pot trial - Burdekin

Treatment	Dry weight tops (g)	Fresh weight tops (g)
Control	26.44 a	386.55 a
Paraquat	25.166 ab	342.29 a
Agtreyne + Ametryn	26.59 a	340.65 a
Gesapax Combi	23.165 b	274.33 b
Lsd p=0.05	2.366	4.9539

Means followed by same letter not significantly diff. (P=0.05)

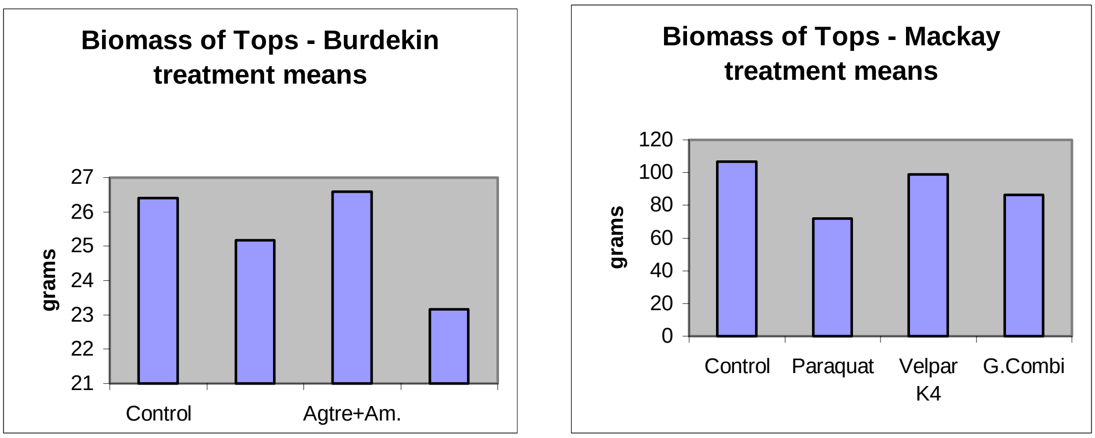


Figure 4. Biomass of dry tops - 1998 pot trials

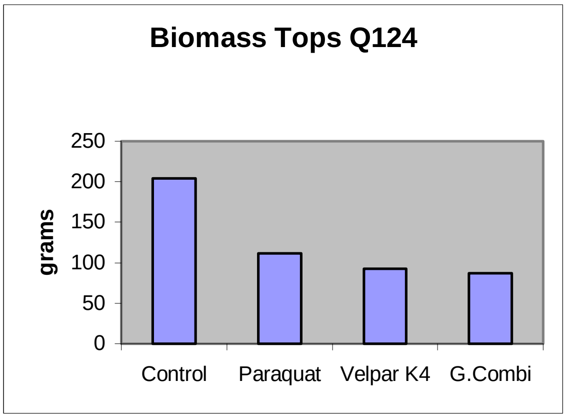
4.2.1.2 1999 trials

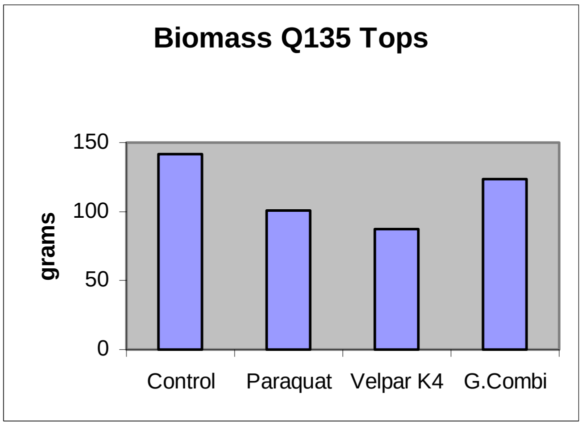
The 1999 series trials confirmed the pot trial technique as sufficiently robust to be used on a commercial basis for herbicide x variety evaluation. The results of the four trials in the 1999 series are attached as Appendices 11 to 14 to this report.

4.2.1.2.1 Mackay trials

In the 1999(1) Mackay trial, Q135 was shown to be significantly more susceptible to herbicide damage than Q138 with Q124 trending that way but not significantly. All herbicide treatments adversely affected Q124 and Q135 but not Q138 (see Appendix 11). Although there was no significant difference on tillering by any herbicide treatment on any variety, the Gesapax Combi treatment trended towards a reduction in tillering in all three varieties. The 1999(2) Mackay trials confirmed the significantly damaging effect of the Gramoxone/diuron treatment ($Q190^A$ the exception) and the relative phytotoxic effect of the other herbicide treatments (see Appendix 12). Dry biomass of the tops would appear the most consistent parameter to be used as the major indicator of phytotoxic effects rather than tiller numbers, elongation rate or root biomass (possibility of root binding in pots). Dry biomass of tops for the Mackay 1999 trials is shown in Figures 5 and 6.

Figure 5. Dry biomass of tops in 1999 (1) Mackay pot trials





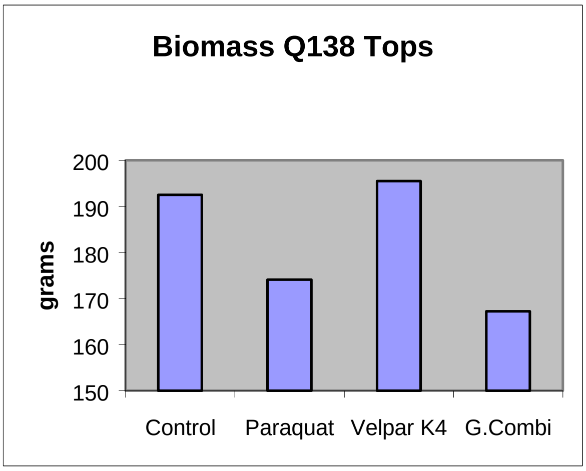
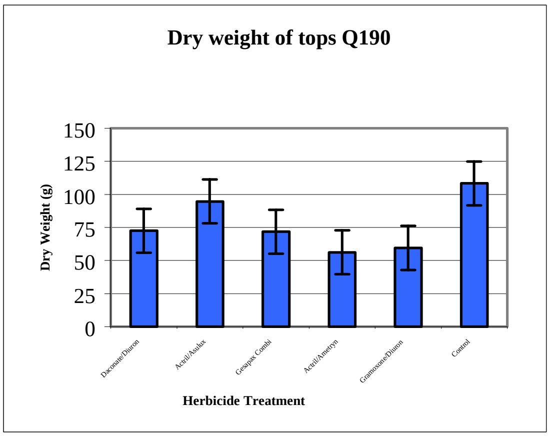
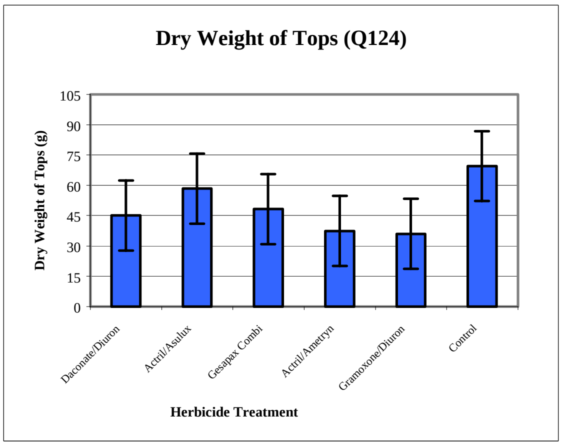
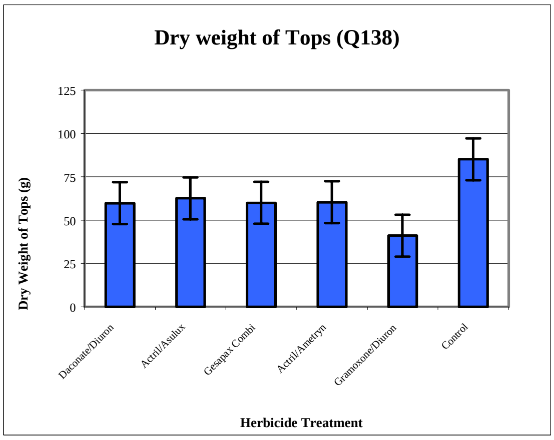
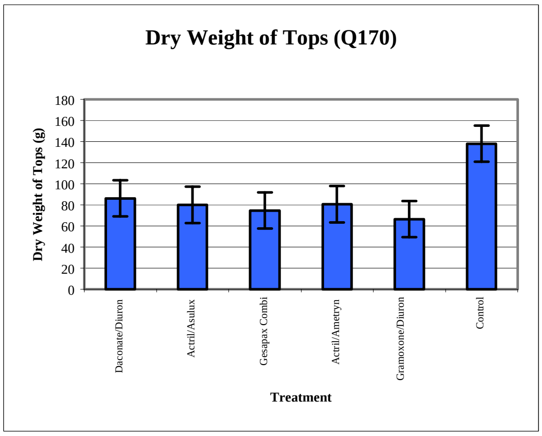


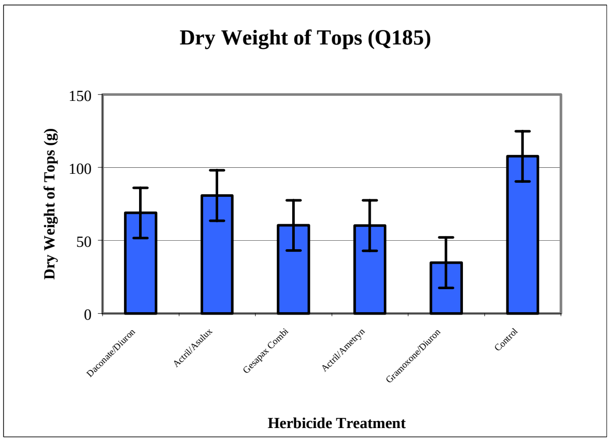
Figure 6. Dry biomass of tops in 1999 (2) Mackay pot trials











Summary sheets showing the reaction of the varieties tested in the Mackay trials, on a susceptible to tolerant scale, are attached to this report as Appendix 16 (broadcast rescue application) and Appendix 17 (directed spray).

4.2.1.2.2 Burdekin trials

Two trials in this series demonstrated the relative phytotoxic effects of different herbicide treatments. In trial 'A', variety means for both tillering and shoot elongation, while showing a significant difference between varieties (Table 5), were results inconsistent with other trials in this series. The Gramoxone treatment caused a significant reduction in both dry biomass of the tops and in shoot elongation (Table 6 and Figure 7) while in trial 'B' a significant yield reduction resulted from the MSMA treatment (Table 8).

Table 5. Tillering and shoot elongation - variety means pot trial 1999 (A) Burdekin

Variety	Tiller number	Shoot Elongation (mm)
Q135	16.958 a	364.67 a
Q138	14.500 b	306.25 b
Q124	11.625 c	169.58 c
Lsd	1.279	21.868

Means followed by same letter not significantly diff. (P=0.05)

Table 6. Tillering and shoot elongation - treatment means pot trial 1999 (A) Burdekin

Herbicide treatment	Tiller number	Shoot elongation (mm)
Gramoxone	15.778 a	231.11 b
Gesapax Combi	14.333 ab	279.72 a
Control	14.056 b	303.33 a
Velpar K4	13.278 b	282.50 a
Lsd	1.477	25.251

Means followed by same letter not significantly diff. (P=0.05)

Table 7. Tillering, shoot elongation and biomass - variety means pot trial 1999 (B) Burdekin

Variety	Tiller number	Shoot elongation (mm)	Biomass (g)
Q135	17.00 a	162.08 b	127.24 b
Q138	14.13 b	292.29 a	126.66 b
Q124	11.58 c	316.88 a	146.56 a
Lsd	1.053	28.85	13.36

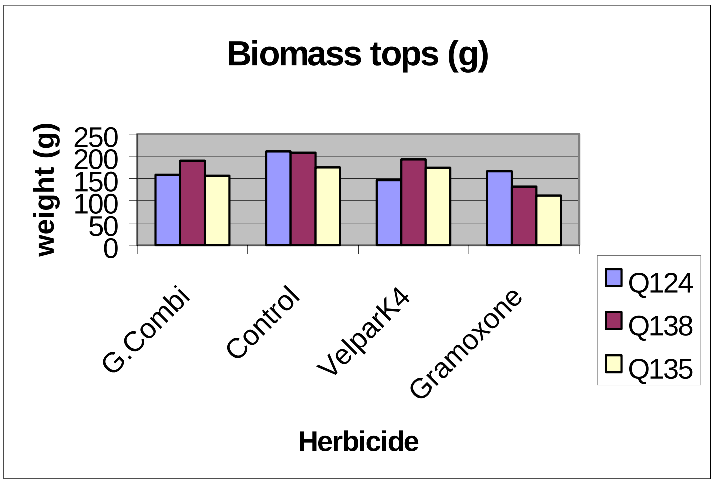
Means followed by same letter not significantly diff. (P=0.05)

Table 8. Tillering, shoot elongation and biomass - treatment means pot trial 1999 (B) Burdekin

Herbicide treatment	Tiller number	Shoot elongation (mm)	Biomass (g)
MSMA	15.055 a	212.22 b	111.70 b
Asulox+Actril directed	14.889 a	238.06 b	139.60 a
Control	14.444 a	284.72 a	142.19 a
Asulox+Actril boom	12.556 b	293.33 a	140.45 a
Lsd	1.216	28.69	15.427

Means followed by same letter not significantly diff. (P=0.05)

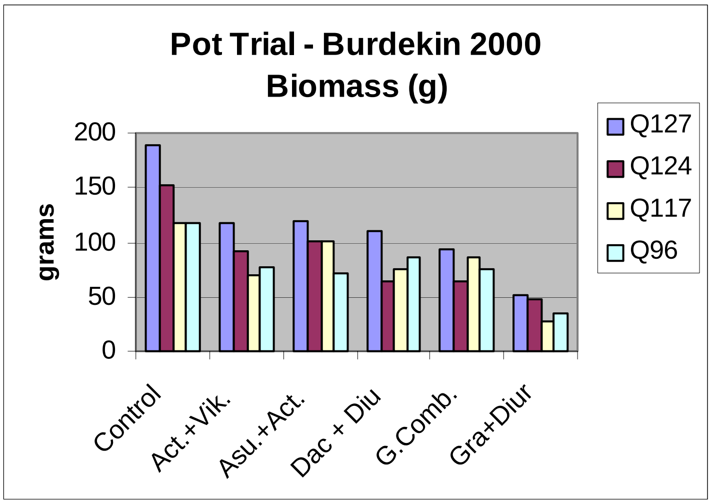
Figure 7. 1999 Burdekin 'A' pot trial - biomass of dry tops Herbicide x variety



4.2.1.3 2000 trials

In the Burdekin trial, stalk elongation and dry biomass both proved reliable indicators of variety response to herbicide treatment with tillering proving less reliable. Results are tabulated in Appendix 15. The treatment of Gramoxone + Diuron again caused a significant reduction in dry biomass in all varieties compared to the other treatments (Figure 8). While the Gesapax Combi and Daconate + Diuron treatments caused a significant biomass reduction compared to the unsprayed control they also trended towards a greater reduction than the other herbicide treatments, but not at a significant level.

Figure 8. 2000 Burdekin pot trial - biomass of dry tops - variety x herbicide



4.2.2 Field trials

Overall this series of trials failed to achieve the objective of permitting testing for a correlation between the field and pot trial series. This was due to several factors including poor CVs in the field trials due to weather conditions and pest damage. The trial series was of value in demonstrating differences in variety reaction to herbicide treatments and to the differences between herbicide treatments.

4.2.2.1 1998 series

The results of this series of field phytotoxicity trials proved highly variable and failed to provide sufficient data to permit a correlation between the field and pot trial series to be tested. Application of the paraquat treatment in the Innisfail trial was delayed due to wet weather and was not applied until the cane had reached the 6-leaf stage. Following the application of this treatment, the cane went through a period of moisture stress resulting in poor growth for the paraquat sprayed treatments and this was reflected as significant differences in final yields. Also at Innisfail, the controls were subjected to weed competition for a short period, which reduced their yield significantly below the Velpar K4 treatment.

Harvest of the Mackay trial was delayed and as a result the cane was very heavily lodged and suffered rat damage, causing considerable yield variation within treatments. In neither the Bundaberg nor the Mackay trial were treatments significantly different. Trial results are shown in Table 9.

Table 9. Harvest results of 1998 field trials - Innisfail, Mackay and Bundaberg

Treatment means
(Tonnes cane/ha)

Treatment	Bundaberg	Mackay	Innisfail
Control	129.7 a	134.2 a	55.9 b
Velpar K4	132.0 a	131.7 a	71.4 a
Paraquat	130.6 a	144.5 a	39.2 c

Means followed by same letter not significantly diff. (P=0.05)

Variety means
(Tonnes cane/ha)

Variety	Bundaberg	Mackay	Innisfail
Q138	137.8 a	153.2 a	61.2 a
Q124	135.2 a	128.6 b	49.5 b
Q135	121.4 b	128.4 b	50.4 b

Means followed by same letter not significantly diff. (P=0.05)

A significant difference in yield was recorded in a second trial in Bundaberg where an expanded range of herbicides was tested against the same varieties as the earlier trials (Table 10). The relatively poor yield of the control (unsprayed) plots was unexplained.

Table 10. Harvest results of 1998 (2) field trial - Bundaberg

Herbicide treatment	Yield (tcph)
Test herbicide 1	110.45
Test herbicide 2	103.58 b
Test herbicide 3	104.46 b
Test herbicide 4	120.90 a
Test herbicide 5	102.90 b
Test herbicide 6	103.73 b
Control	106.25 b
Diuron 14	111.33
Diuron 30	110.67
Diuron 60	109.94 b
Paraquat	108.26 b
Velpar K4	113.74

Means followed by the same letter are not significantly different (P=0.05)

4.2.2.2 1999 series

The Bundaberg trial tested an expanded range of herbicides against the same varieties as in previous trials but failed to show any significant differences between herbicide treatments (Table 11).

Table 11. Harvest results - Bundaberg 1999 field trial

Herbicide treatment	Yield (tcph)
Gesapax Combi	179.75
Control	162.35
Diuron	162.79
DP300	162.81
DP600	179.24
Paraquat	165.13
Velpar K4	168.78

4.3 Technology transfer

4.3.1 Focus groups

Overall growers displayed a good knowledge of standard weed control techniques at the focus group sessions. In north Queensland, weather conditions, in particular rainfall, played a greater role in the decision on when to spray weeds rather than did crop or weed size compared to south or central Queensland. In plant cane, a scorched earth approach to weed control appears the norm because the unpredictability of rainfall often prevents weed control at the appropriate time. Growers generally recognise that some herbicides cause damage to the cane crop; however, they consider this minimal compared to yield loss from weeds and spray when the window of opportunity presents.

In the Burdekin, soil type influences the strategy used for weed control eg on heavier soils growers will elect to spray rather than cultivate.

Grower attitudes are summarised in the following sections.

4.3.1.1 Weed size and control cost

- Weeds should be controlled at the 2-3 leaf stage permitting the use of cheap effective herbicides, eg paraquat ~ $10/ha
- Larger weeds are more difficult to control requiring the use of more expensive and selective sprays
- Cost of herbicide treatment rather than expected crop loss is the stronger motivator for early weed control

4.3.1.2 Weed species

The main weed species varies between districts, as does the effect on cane yield.
- Northern - mainly vines, guinea grass (*Panicum spp)* and some annual species
- Central - mainly vines, some broadleaf, annual and perennial grasses
- Burdekin - grass and broadleaf weeds
- Southern - mainly grasses

The approach is to control vines at an early growth stage because they can entangle in the crop at any growth stage.

4.3.1.3 Rainfall

- Often there is limited opportunity to control weeds due to rainfall events (Central and Northern regions) so control is effected at the first opportunity

4.3.1.4 Crop stage

- Spraying before 3-4 leaf stage allows rapid recovery of crop and less cane damage
- Spraying at the spiking stage of growth allows flexibility of application with boom spraying (non-directed) using non-selective herbicides such as Gesapax Combi, Diuron and Flame
- Spraying is often based around irrigation events (Burdekin) rather than crop/weed size

4.3.1.5 Neighbouring crops

- These have a strong influence on the application method (aerial) and herbicide choice (eg 2,4-D). Bundaberg (small crops), Innisfail (bananas) are the major areas where this is of concern.

4.3.1.6 Weed distribution/density

- Weed control is performed on entire blocks rather than selected sections with a weed problem
- Growers have no concept of a threshold of weed problems

These two factors were not considered important in the weed control decision.

4.3.2 Slide-rule

A slide-rule indicating losses from weeds was developed using the weed competition trial results at Bundaberg (Phase 1) as an example. The aim of the slide-rule is to create an awareness of potential cane yield losses from weeds for different periods of weed competition. The slide-rule is a simple reference guide, which details the yield and income loss from weeds with varying sugar prices for a range of weed-free growth periods (Figure 9).

Commercial company sponsorship was sought for printing and distribution of the slide-rule. Approximately 10,000 copies were printed with no profit generated. Distribution was on the front cover of the Oct-Nov 1999 issue of *Australian Sugarcane Magazine* with a follow up article. This extension exercise provided a large majority of canegrowers with information on potential losses from weed infestation.

4.3.3 Manual

The decision aid tool, to be presented as a manual, was successfully developed following broad consultation with agribusiness, end users and service providers. The objective of the herbicide manual is to improve current herbicide use by canegrowers. The manual covers all aspects of current herbicide use and aims at minimising herbicide costs, yield loss from herbicide phytotoxicity and weed competition, and off-site impacts. It has been given the ISBN number 094967804X. A summary of the manual is shown below.

The manual covers all aspects of current herbicide use and aims at minimising herbicide cost, yield loss from herbicide phytotoxicity and weed competition, and off-site impacts.

Figure 9. Slide-rule loss calculator based on Bundaberg weed competition trial results

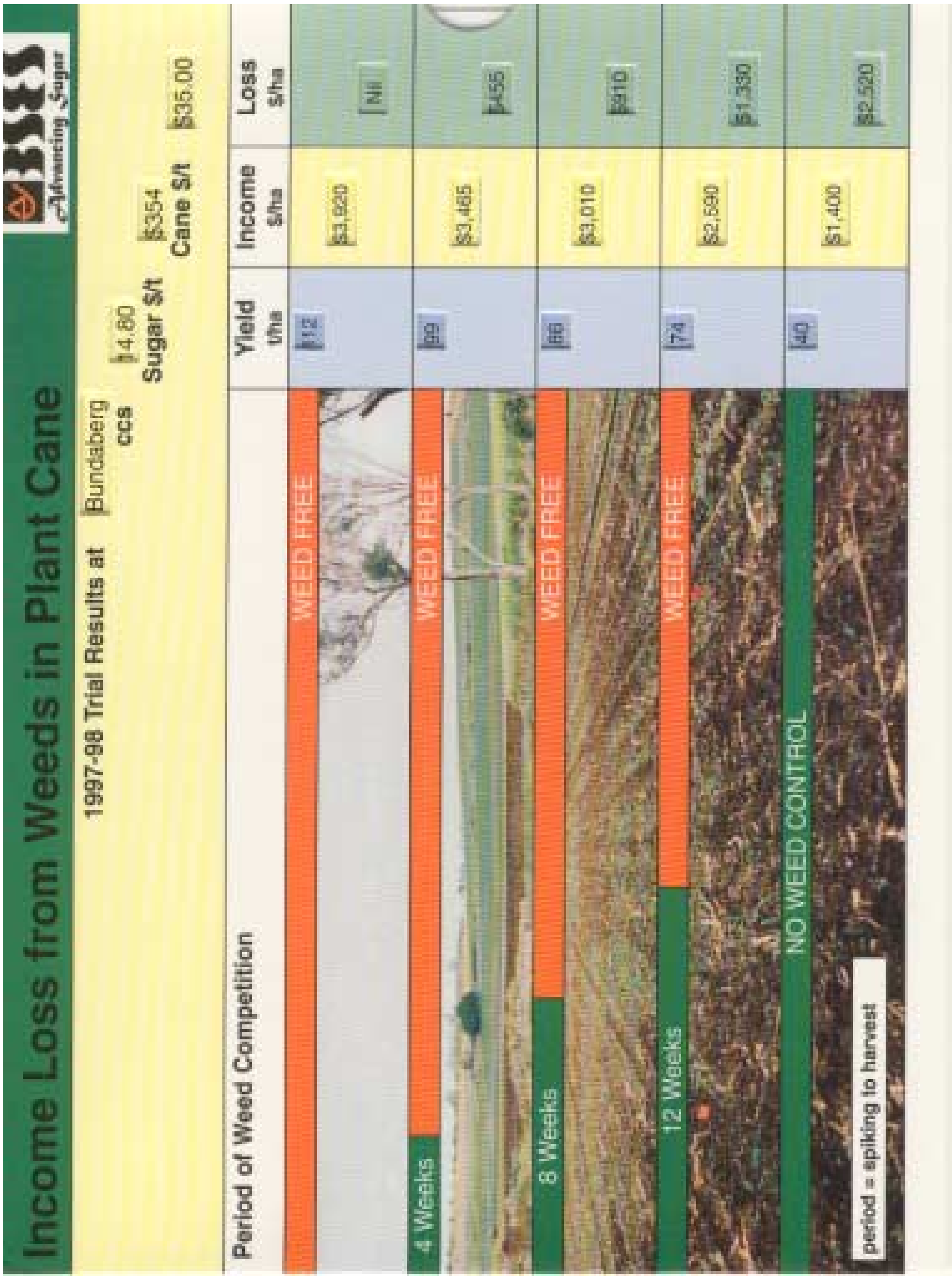
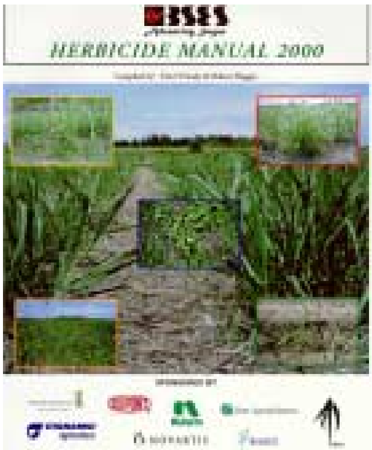


Plate 1. BSES Herbicide Manual - Front cover

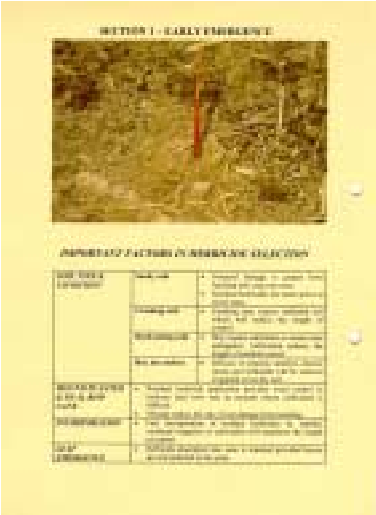


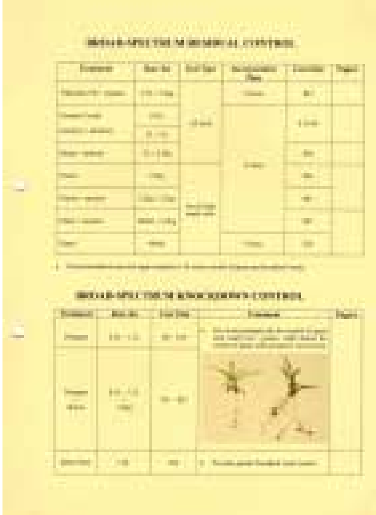
The BSES herbicide manual is a durable clip-folder for practical use in farm vehicles and chemical sheds. The four major sections in the herbicide manual include a selection guide, herbicide information sheets, and herbicide application and weed identification.

1. **Selection guide** - This is a guide to herbicide selection based on cost-effectiveness at different crop stages. The aim of this section is to provide an economic analysis of herbicide cost at different growth stages.

Plate 2. Includes all critical stages of weed control in sugarcane

Plate 3. Cost-effective herbicide recommendations at crop stage

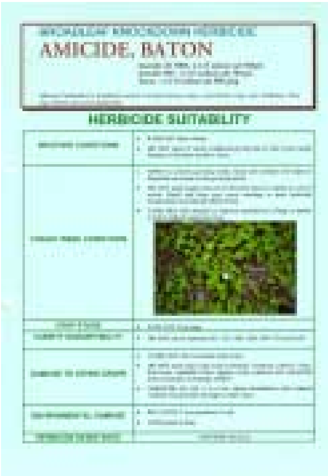




2. **Herbicide information –** Detailed technical information is provided on all registered herbicides in sugarcane. The herbicide information pages provide growers with the important factors to consider in selecting a herbicide based on suitability. These suitability factors include crop stage, soil type, target weed conditions, weather conditions, risk to other crops, risk to environment and risk of herbicide resistance.

   Over the page are important factors for correct herbicide application. These application factors include user safety and equipment, herbicide compatibility, effect of water quality, application equipment and detailed product rates based on the target sprayed.

Plate 4. Information sheets on key aspects of herbicide suitability and application



3. **Herbicide application –** This section provides information specific for herbicide application in sugarcane. It includes equipment calibration, nozzle selection charts, water rate selection charts and equipment set-up for minimising herbicide drift.

Plate 5. Application chapter aims at maximising efficacy and minimising drift

4. **Weed identification –** An identification guide to weed seedling identification is provided for the economic weeds of sugarcane.

The BSES herbicide manual will be updated annually, by posting update sheets to canegrowers for addition in the clip folder. Update sheets will include information on any variety herbicide tolerance information, newly registered herbicides and changes to weed research. This will keep canegrowers current with information on the best practice for weed control in sugarcane.

4.3.4 Field Days, publications and groups

All media outlets were used for dissemination of information on the objectives, progress and results of the project. Examples (not definitive) included -

- Australian Sugarcane Magazine (May 1999) – Article presenting results of the 1997-98 weed competition trials.
- Bush Telegraph Newspaper (May 1999) – Supplement for Mackay Field Day outlining pot trials and weed competition trials.
- Channel 7 News (May 1999) – Television story on Mackay pot trial.
- Burdekin and Mackay Field Days (1999 & 2000) – Personal communication with growers on weed competition results and live demonstration of pot trials.
- Bus trips to inspect field-based nut grass trials at Mackay (150 growers attended)
- and Burdekin
- Commercial herbicide companies - results of weed competition trials are being used by companies Crop Care and Rhone-Poulenc.
- Agribusiness, CPPB and growers inspection and discussion of Mackay pot trials 1999.

5.0 RECOMMENDATIONS

- The pot trial technique developed to assess variety x herbicide interaction be adopted as an industry standard and used to evaluate all new varieties before release to growers. The information obtained should be included in Variety Fact Sheets provided by BSES for growers.
- The Herbicide Manual be updated when new herbicides are registered for use in the sugar industry or when new technology is developed for weed control.
- A further extension exercise be undertaken to bring to the attention of growers the outcomes of the project, in particular the effect of weed growth on cane at the early establishment stage.

6.0 ACKNOWLEDGMENTS

The staff involved in the conduct of the project offer their sincere thanks to the many growers, staff of agribusiness, CPPB and BSES who offered critical and constructive comment on the conduct and progress of the project.

7.0 REFERENCES

Bauld, J, Leach, LL and Sandstrom, MW. (1995). Abstract: Impact of land use on groundwater quality in the Burdekin River Delta and the Burdekin River Irrigation Area. In *"Downstream Effects of Land Use"*. Eds. H M Hunter, A G Eyles and G E Rayment. pp. 195-6. (DNR, Brisbane).

Ham, GJ. (1997). Nutrients and pesticides in surface drainage water and soil under irrigated sugarcane. *Progress Report Project BS122. Sugar Research and Development Corporation Annual Report 1996-97. p.180* (Sugar Research and Development Corporation: Brisbane).

McMahon G.G., McGuire P.J., Williams, R.C., 1989. The effects of weed competition on ratoon sugar cane yield. Proc Aust. Soc. Sugar Cane Tech. pp. 88-92.

APPENDIX 1

APPENDIX 1

POT TRIAL HERBICIDE SCREENING PROTOCOL

1. GERMINATING ONE-EYE SETTS (one week)

- Germinate around twice the number of plants required.
- Cut one-eye setts the same length (drop saw easiest method, and gives the cleanest cut. Set the length of the cut based on the width of the jiffy pot)
- Dip cut billets in Cane Strike or Shirtan (mercury-based fungicide).
- Weigh the total weight of billets per variety, and divide by number of billets. This will give the average billet weight (g) in the jiffy pot.
- Fill jiffy pots with vermiculite and place in one-eye sett (eye facing up)
- Place in germination room and keep well watered (once a day at least).
- Aim to get a consistent size of plant among varieties. Different varieties will vary in their speed of germination. Vary the time each variety is in the germination room for consistency.
- After the cane has spiked (but before true leaves appear) – pot up.

Comments – Varieties such as Q124 require around 2-3 days extra in the germination room, to be around the same size as fast germinating canes such as Q170^{A} , 86C451 and Q185^{A}. Getting the size of plants uniform is very important, to prevent bias in results by having large variation in crop size at the time of spraying. Try to manipulate the size of plants by time in the germination room.

2. POTTING UP

- Fill pots (305 mm black plastic Yates, 21 L volume, pots) to close to the same level with potting medium (around 5 cm from top lip).
- Put each pot on scales to determine the weight of the soil and potting medium.
- Carefully select plants and pot up plants that are of similar size. Do not spill any soil from the pot in this process.
- Number each pot with a plastic tag - for simplification use the pot number.
- Keep a good record of the pot number, variety and treatment.

3. HERBICIDE APPLICATION (USE PRECISION SPRAYER)

- Weigh each pot prior to application. From the weight subtract the initial pot and soil weight and average billet weight to give an estimate of the plant weight. This is important and the easiest means in determining the plant weight at the time of application. It can then be determined if the plants were significantly different or not at the time of spraying.
- The height (TVD mm) and number of tillers is also recorded just prior to spraying.
- Precision compressed air sprayer used.
- Sprayed as broadcast or directed spray depending on stage of application to be simulated.
- After herbicide application, turn off dripper irrigation for 48 hours.

4. DATA COLLECTION (7-8 weeks)

- Tie a ribbon around the primary shoot.
- Measure the height of the primary shoot (TVD mm) and count the number of tillers at weekly intervals for a period of 7-8 weeks.
- The experiment should be stopped after this, because the root mass is limited.

5. HARVEST (DRY MATTER)

- Cut plants at soil level and put into large numbered paper bags .
- Harvest all tops material (tiller and primary shoot).
- Place bags in drying oven (60^{o}C) until constant weight.
- Determine the dry weight of tops.

MATERIALS & METHODS

WATER AND FERTILISER

- Water with pressure-compensating drippers (6 or 8 l/hr flow).
- Set up a ½ inch soft-wall poly system, of micro-irrigation drippers (DON'T USE OVERHEAD SYSTEMS).
- Each pot must receive the same water or the trial is biased.
- Plants should not be water stressed at any time.
- Nutrient must be added to potting medium (FLOWFEED EX7).
- Make a stock solution and decant exactly the same volume into each pot (must be accurate).

EXPERIMENTAL DESIGN

- Use six replicates (each pot is a rep).
- For example, if testing 5 varieties, and 5 herbicide treatments:
  Require – 5*5*6 = 150 pots.
- No need to randomise treatments within each variety.

POTS USED

- Yates black plastic pots (305mm, volume around 21 L).
- Contact: Arthur Yates & Co (Sydney).

POTTING MEDIUM

- 50% coarse, clean river sand.
- 50 % KIWIPEAT (compressed sterilised peat).
- Calmag 0.5 kg/cubic meter).
- Superphosphate (4 kg/cubic meter).
- Aglime (2 kg/cubic meter).

COMMENTS

- KIWIPEAT contains around 100 L of compressed peat.
- 10 KIWIPEAT bags will make around 1 cubic meter of peat.
- For example, for 200 pots, you need 20 bles KIWPEAT, 2 cubic meters of sand.
- KIWIPEAT is available from Growforce (around $30/bale).
- Mackay and the Burdekin Stations use a commercial cement mixer to mix the large volume of medium required. This is the faster way and provides uniform consistency.

APPENDIX 2

APPENDIX 2

INNISFAIL FOCUS GROUP REPORT

REPORT SUMMARY

This report details current grower attitudes to and practices for weed control in Innisfail. Vines and annual grasses have the greatest effect on cane yield. Grasses affect plant cane early in crop growth (at the spike stage) whereas vines affect cane throughout crop growth.

Weed control is performed when weeds first appear, rather than at a critical stage. The bare-earth policy is preferable because wet weather can prevent weed control when required and result in excessive weed growth. The size and species of weeds are important factors in the control decision.

The methods of weed control in plant cane are evenly divided between growers primarily cultivating, and those using a combination of early spraying and later cultivation. There was little use of pre-emergent herbicides in plant cane. In ratoon cane there is greater reliance on herbicides, with vine control the major problem.

The species of weeds present, cane variety, and the neighbouring crops influence the choice of herbicide used. Growers accept a level of damage from herbicides, which is considered minimal compared to yield loss from weeds.

1.0 WEED COMPETITION IN SUGARCANE

How much do weeds affect plant cane?

Weeds have a significant effect on plant cane. The estimate of the yield loss is between 5-10% in small infestations, to greater than 50% in out of control weed growth. Longer duration of weed growth results in greater yield loss.

Weed species vary in their competitive effect on plant cane. Grasses and vines are considered to have the greatest effect on yield. Annual grasses (such as summer grass and crows foot) compete with the developing stool for nutrients, preventing good establishment. Vines reduce yield by tangling around cane and pulling it down.

The effect of weed competition in plant cane was considered to reduce yield of the ratoon crop. Establishing weed-free plant cane is important for ratoon crops.

When is plant cane most vulnerable to weeds?

Plant cane is most vulnerable to grasses at spiking, around three weeks after planting. Grasses have a competitive period for around 6-8 weeks from planting. Towards the out-of-hand stage, cane is less vulnerable to grasses. However, cane is vulnerable at all growth stages to vines and other problem perennial species such as guinea grass.

How is the decision made to control weeds?

Growers make the decision to control weeds based on when they first appear, provided it's possible to spray or cultivate. Frequent wet weather may prevent weed control when required, which results in a considerable duration of weed growth and yield loss. Therefore, the bare-earth policy is considered the best practice because weeds can get out of control if weather doesn't permit spraying or cultivation.

Weed size and species are important factors in the control decision. Annual grasses (such as, summer grass and crows foot) are controlled around the 2-3 leaf stage. These grasses are known to cause considerable yield loss, and are more effectively and cheaply controlled when small. Towards the out-of-hand stage annual grasses are not considered to reduce yield, because the cane is more competitive and the canopy closing will prevent further weed growth.

Problem vines (mile-a-minute, centro, calopo) and guinea grass are controlled when first observed because they cause yield loss throughout crop growth. Preventing establishment of vines is important due to difficulty of control.

The weed density is not important in the control decision. Weed control is performed if weeds are only present in some areas of the field.

2.0 METHODS OF WEED CONTROL IN SUGARCANE

What method of weed control is used in plant cane?

Half the growers relied mainly on cultivation as the method of weed control. This involved multiple passes with cotton king and multi-weeder cultivators. The crop was often filled-in earlier to smother weeds. Cultivation is used because it is cheaper, causes less cane damage and encourages stooling. These growers only spray if the ground it too wet to cultivate or to control problem vines, which are not effectively pulled by cultivation.

The other half used a combination of herbicides and cultivation. Gramoxone over the top early in crop growth is frequently used on small weeds. This is combined with multiple cultivation passes, with a directed residual spray at the out-of-hand stage. These growers generally did not use pre-emergent spray, even though they thought it an effective method. Previous phytotoxicity from pre-emergent herbicide may be the reason for their limited use.

What method of weed control is used in ratoon cane?

Vine control is the major problem in ratoon cane. Vines have become a greater problem than grasses since the practice of trash blanketing. There is heavy reliance on herbicides for vine control, which incurs large spray costs. The choice of herbicide in ratoon cane depends on the weed species present. The most commonly used herbicides are 2,4-D, Velpar K4, Atrazine, Diuron and Gramoxone.

Can spraying or cultivation alone control weeds?

Herbicides alone give effective weed control but incur increased costs and some phytotoxicity yield loss. Growers believed that nut grass control may be a problem if no cultivation was used. Cultivation alone was considered possible, but may be difficult to control some problem species such as vines and guinea grass.

What method would be used in High Density Planting (HDP)?

There will be greater use of pre-emergent herbicides in HDP. Growers indicated that weed control by cultivation or directed sprays would not be possible in the 700 mm row spacing. There was little understanding how equipment may be modified to suit this configuration. Possible suggestions for application of herbicides included spray droppers, over the top sprays of selective herbicides and blowers. A multi-weeder was a suggested cultivation method.

Weed competition may be less in HDP. Weed growth may be less, provided there is a good stool to prevent weeds growing in the row and there is fast canopy closure to shade the inter-row. However, vines would remain a major problem.

3.0 HERBICIDES IN SUGARCANE

Which herbicides are used in plant cane?

In early plant cane establishment the herbicides commonly sprayed over the top are Gramoxone, 2,4-D, Gesapax Combi and Atrazine. Some growers are using these at low rates to kill small emerged weeds. At the out-of-hand stage, directed sprays of Velpar K4 were common. Vines are commonly sprayed with 2,4-D, Atrazine and Oxytril.

The choice of herbicide sprayed depends on the weed species of present, the herbicide cost, the variety planted and the neighbouring crop compatibility to the herbicide. Crops such as bananas and pawpaws grow in close proximity to cane at Innisfail and are susceptible to drift. This influences what herbicide is sprayed and how it is applied. For example, there is no aerial application of 2,4-D near these crops.

How much damage do herbicides cause to cane?

Herbicides damage cane; however, growers are willing to accept some phytotoxicity yield loss as this is minimal compared to the loss from weed competition. Growers found it difficult to quantify the effect of herbicide damage on cane and have been accepting a certain level of damage for a period and have no comparison.

Determining which visual phytotoxic symptoms are causing yield loss is a problem for growers. There is limited knowledge of yield loss from herbicides, with only one grower suggesting that yield loss may occur from non-visual symptoms.

Which chemicals cause the most damage to cane?

The most damaging herbicides are Gesapax Combi, Diuron and Velpar K4. Growers believed that Gramoxone damage doesn’t have a considerable yield effect. It was generally believed the ratoon crop had greater herbicide tolerance than plant cane

Is variety important in the choice of herbicide?

Growers believed variety was important in the choice of herbicide and how it was applied. For example, some growers won't use Diuron on plant Q158. Growers use herbicides more carefully around varieties regarded as susceptible such as Q122, Q158 and Q152.

APPENDIX 3

APPENDIX 3

BURDEKIN FOCUS GROUP REPORT

1.0 WEED COMPETITION IN SUGARCANE

How much do weeds affect plant cane?

Weeds greatly reduce yield of plant cane and incur a major control cost. Growers have no estimate of yield loss from weeds, but regarded grasses as the major problem. Annual grasses (for example, summer grass) and problem perennial species (for example, guinea grass) cause large yield losses.

Weed competition in plant cane affects the yield and number of ratoon crops. Effective weed control in the plant crop is considered important in minimising weed populations for ratoons.

When is plant cane most vulnerable to weeds?

There is no defined critical time for weed competition in plant cane. Yield is reduced from weed competition from emergence to the out-of-hand stage.

How do you make a decision to control weeds?

Weeds are controlled when they first emerge, provided field conditions are suitable. Rainfall and irrigation often limit the time available for weed control through preventing field access. Therefore, maintaining weed-free establishment is important in preventing excessive weed infestation when control is not possible.

Weed size and species are important factors in the control decision. Annual grasses are controlled when small, because control is cheaper and more effective. Problem weeds (eg guinea grass) are controlled when they are first observed, because late control is difficult and expensive. Weed control is performed based on emergence of weeds even if only in one area of a field.

Weed control decisions are based on an individual field basis. Excessive weed growth in a crop may alter the decision on weed control. In this situation, growers may make the decision not to control weeds, because the yield loss has already occurred and controlling established weeds is expensive.

2.0 METHODS OF WEED CONTROL IN SUGARCANE

What method of weed control do you use in plant cane? Why?

A combination of cultivation and herbicides is used for weed control. Early cultivation (for example, with cut-away discs, strawberry harrows) removes small weeds and encourages stooling. Towards the out-of–hand stage, weeds are controlled with directed sprays or aerial application of knockdown and pre-emergent herbicides (eg Gramoxone, Atrazine, Gesapax Combi and Diuron).

Aerial application of residual herbicides is more common on larger size fields. Aerial application allows for faster weed control than ground spraying or cultivation. This is important when wet weather or irrigation events limit the time available for weed control.

How much damage do herbicides cause plant cane?

Yield loss from herbicides was not quantified, but was significantly less than the effect of weed competition. Herbicides causing the most damage to plant cane are Gramoxone, Diuron, Asulox and Actril (over the top) and trifluralin as a pre-emergent.

How are weeds controlled in ratoon crops?

A combination of cultivation and herbicides is used on ratoon cane. Cultivation occurs first to remove weeds and spraying is performed later. Spraying with Atrazine, Gesapax Combi and 2,4-D was common practice. Vine control is an increasing problem in ratoon crops. High clearance tractors and aerial application are used for vine control in the ratoon crop.

Is variety important in the choice of herbicide?

Growers agreed varieties were affected differently by herbicides. However, the varietal susceptibility or tolerance of current varieties was not really known by growers. Growers tended to plant the best performing variety irrespective of its herbicide susceptibility.

How would weed control be performed in High Density Planting?

This system would require much greater use of herbicides for weed control, especially pre-emergent herbicides because cultivation is difficult.

APPENDIX 4

APPENDIX 4

BUNDABERG FOCUS GROUP REPORT

SUMMARY

This report details weed control practices of a group of canegrowers in the Southern canegrowing region. All information was extrapolated from a focus group held with growers in the Bundaberg area.

Weed size and species present are the most important factor in timing of weed control. Weeds are controlled at the 2-3 leaf stage, because it is cost effective with knockdown herbicides. The neighbouring small crops also influence the timing and choice of herbicides.

Plant cane weed control is performed mostly by herbicides. Post-plant pre-emergent herbicides are used with later knockdown applications depending on weed emergence.

Ratoon cane is both trash blanketed and burnt depending on soil type. Grasses are more difficult to control than vines in ratoon cane as they can be controlled at any crop stage.

Herbicides are not causing a major yield loss. Any loss occurring from herbicides is minimal compared to yield loss from weeds.

1.0 WEED COMPETITION IN SUGARCANE

When do weeds reduce cane yield?

There was no critical time of weed competition in plant cane. Effective weed control is critical throughout the plant crop and first ratoon for good ratoon yields. Weed control is not a major problem provided that plant cane establishment is weed free.

How is the decision made to control weeds in plant cane?

Weed size is the major factor influencing the weed control decision. Weeds are controlled at 2-3 leaf stage due to cheap effective control with knockdown herbicides and less herbicide damage to cane.

The expected weather conditions affect the decision to control weeds. Control of small weeds is performed because rainfall can result in weed growth but prevent field access for weed control. Growers therefore control weeds in the time available.

Weed species is important in the control decision. Grasses have the greatest effect on yield and are controlled when small, as their population will increase in the ratoon. Establishment of the major problem grasses (green summer grass, crows foot, guinea grass and green panic) greatly reduces final yield. Broad-leaved weeds and vines are not considered a major problem due to easy control at any crop stage.

The neighbouring small crops can restrict the herbicide choice and timing of application. Prevailing southerly winds can cause a problem with herbicide drift onto susceptible small crops, which alter the herbicide used. The timing of spray application is often late afternoon or at night because there is lower drift and also greater weed control effectiveness.

2.0 METHODS OF WEED CONTROL IN SUGARCANE

What is the method of weed control used in plant cane?

Weed-free fallows are important for plant cane establishment. Fallow weed control relies mainly on cultivation with some herbicides. Herbicides are used where weed infestation is greater or where the same row centres are required for the plant crop over the line of the subsurface irrigation. Glyphosate is used to spray out the ratoon and control larger weeds, with Gramoxone used to control small emerged weeds.

Plant cane weed control is performed mostly using herbicides. Post-plant pre-emergent sprays are common at or before spike stage with Treflan, Atrazine and Stomp. At spiking boom application of Gramoxone/Diuron provides cheap control of small weeds. Residual herbicides at planting provide weed control to around the five-leaf stage, after which weeds are generally controlled by cultivation.

What method of weed control is used in dual-row plant cane?

Total herbicide control is performed on dual-row planted cane with cultivation limited between the rows. Post-plant pre-emergent application of herbicides such as Atrazine, Stomp and Flame provides residual weed control. Weed control is considered less of a problem due to greater competition with weeds and faster canopy closure.

Will reduced sugar prices impact on weed control methods?

There will be no change to the method of weed control or herbicides used. However, a higher weed threshold may be accepted, which may alter the timing and number of sprays.

What is the method of weed control in ratoon cane?

Varying soil type influences the decision to trash-blanket or burn ratoon cane. Burnt ratoon cane is sprayed with Treflan for grass control and mechanically incorporated. A late irvin leg spray of atrazine/diuron/2,4-D may be applied depending on species present. Vines and broad leaved weeds are not a problem and are easily controlled at any crop stage with 2,4-D.

In trash-blanketed ratoon cane weed control is not often a problem. Grasses emerging are sprayed with knockdown herbicides early and vines are not a major concern due to easy control with 2,4-D/atrazine.

Which herbicides cause the most damage to cane?

There are no herbicides recognised as causing severe yield loss. Correct use of application equipment at label rates causes no yield loss. Growers will accept some herbicide damage because yield reduction from weeds is significantly greater.

Is variety important in herbicide choice?

Varieties vary in their tolerance to herbicide damage. Q124 is the most susceptible variety is to all herbicides in general.

APPENDIX 5

APPENDIX 5

SARINA FOCUS GROUP REPORT

SUMMARY

This report details weed control practices of a group of canegrowers in the Central canegrowing region. All information was extrapolated from a focus group held with growers in the Plane Creek mill area.

Weed size is the most important factor in timing of weed control. Weeds are controlled at the 2-3 leaf stage, due to the cheap effective control with knockdown herbicides. Weed density is not an influencing factor because weed control is practised across entire blocks.

Plant cane weed control involves a combination of early knockdown sprays and cultivation to control small emerged weeds. Knockdown application may be required during crop establishment, with use of selective herbicides where weeds are out-of-control. Directed residual herbicides are applied prior to the out-of-hand stage.

Herbicides are used for weed control in ratoon cane over the trash-blanket. Multiple knockdown applications may be required depending on the species emerging. Vine control is the major problem in ratoon cane.

Herbicides are recognised to cause damage to cane, however, this is minimal compared to yield loss from weeds. Variety and soil type are important in phytotoxicity from herbicides.

1.0 WEED COMPETITION IN SUGARCANE

When do weeds reduce plant cane yield?

There is not a specific critical time of weed competition in plant cane. The effect of weed competition varies depending on cane, the weed species and size.

Small emerged grasses in early plant cane establishment cause no yield loss, provided there is adequate soil moisture for the crop. However, when not controlled, grasses such as nut grass, barnyard grass, green summer grass and guinea grass cause significant crop loss when established in the crop.

The critical time for vine competition with plant cane is when vines first emerge. Vines reduce yield through entangling and pulling down the crop, which may occur at any stage of crop growth. Numerous vine species cause yield loss in plant cane.

How is the decision made to control weeds in plant cane?

The size of weeds is the most important factor influencing the timing of weed control. Weeds are controlled soon after they first emerge, around the two to three leaf stage. This decision is based on the cheap effective control of small weeds with knockdown herbicides, rather than any expected yield loss from small weeds.

Weed density has no influence on timing of weed control. Weed control is practised on entire blocks, even if weed distribution is localised, because untreated areas will have later weed infestation.

2.0 METHODS OF WEED CONTROL IN SUGARCANE

What is the method of weed control used in plant cane?

Fallow weed control is practised prior to plant cane establishment. After harvest the trash is incorporated by offset discs. Weed control is then performed by boom applications of glyphosate and Actril, depending on species present. Multiple glyphosate applications may be required where nut grass is underlying annual grasses. Fallow weed control is important in reducing the weed seed bank in the plant crop.

Plant cane weed control involves a combination of early knockdown sprays and cultivation. Cultivation with cut away discs is used to control weeds at the 1-2 leaf stage and to open the furrow to increase soil temperature and stooling. However, cultivation is ineffective in wet conditions and may stimulate weed germination by exposing moist soil.

Knockdown boom sprays of Gramoxone and 2,4-D are used for early control of small emerged weeds. This commonly used method provides cheap effective control of small weeds. This timing of application is based on weed size (2-3 leaf stage), rainfall and irrigation events. Residual herbicides atrazine and diuron may be sprayed early to prevent weed establishment. Timing sprays at spiking allows a greater choice of herbicides that can be sprayed over cane.

Large established grasses in the late post-emergent stage are controlled commonly with Asulux. The higher herbicide cost doesn't alter the control decision due to the importance of good plant cane establishment for future ratoons. Preventing large grass weed infestations at this stage is also important to minimise possible rat damage

Residual herbicides, Velpar K4 and Gesapax Combi, are applied as late directed sprays below the canopy prior to the out-of-hand stage. These may be combined with knockdown herbicides (for example, Gramoxone) depending on weeds present. Some weed control after the out-of-hand use stage is practiced with high clearance tractors and inter-row motorbike spraying.

What method of weed control is used in ratoon cane?

Ratoon cane is trash-blanketed without incorporation for weed control. Herbicides are used for weed control over the trash blanket. Two knockdown sprays are commonly used depending on the time of year and the species emerging.

Grass weeds may emerge first before cane, especially at the end of rows where the trash blanket is thinner. Small grasses are controlled when they first emerge with boom sprays of gramoxone and diuron. Vines often emerge more slowly at a similar time to the ratoon. A boom application of Actril and atrazine at the 3-4 leaf stage is required to prevent vine establishment and to provide some grass suppression.

Prior to the out-of-hand stage, a directed Gramoxone application is used when cane is tall enough to have minimal herbicide contact from the octopus head. Atrazine and diuron are used mainly for knockdown weed control as they have less residual activity over the trash blanket.

What method of weed control is used on mounded dual rows?

Total herbicide control is the method used in dual-row mound planted cane. Post-plant pre-emergent herbicide application with atrazine and diuron followed by later knockdown sprays are used for weed control. Cultivation is not desirable on mounds due to due to destruction of the mound profile and difficulty in cultivation between the rows. Also, growers assume that complete herbicide control would be necessary in higher density row planting.

Will reduced sugar prices impact on weed control methods?

Herbicide weed control is a cheaper and more effective method than cultivation. Lower sugar prices will not influence the method of weed control used.

3.0 HERBICIDES IN SUGARCANE

Which herbicides cause the most damage to cane?

Herbicides causing the most damage to cane were Velpar K4 and Ametryn, respectively. Velpar K4 (4 kg/ha) can cause yield loss in plant cane of 10-15 t/ha, especially when used on sandy soil around January and February. Lower than label rates of Velpar K4 are commonly used due to crop sensitivity.

Diuron over plant cane at spike stage has caused crop damage. No concerns on crop yield were expressed for Gramoxone, because cane recovers after initial damage.

Is variety tolerance important in the choice of herbicide?

Herbicides are used more carefully around varieties regarded as susceptible. Q135 is regarded as tolerant, compared to Q124 which was susceptible to herbicide damage. Overall, growers were unsure of variety tolerances to different herbicides.

What herbicide phytotoxicity occurs on cane?

Visual leaf discolouration and necrosis on cane leaves are the phytotoxicity symptoms of herbicide damage. Growers have difficulty in determining non-visual phytotoxicity because entire blocks are treated with the same herbicide making it difficult to recognise differences in cane yield.

APPENDIX 6

APPENDIX 6

WEED COMPETITION TRIALS - HARVEST RESULTS

1997/98 TRIALS

Innisfail

Treatment Means (Harvest)	t/ha		ccs-1.5	
Full Control	107.8	a	13.3	a
4 Weeks	99.0	ab	13.3	a
8 Weeks	83.1	b	12.8	a
12 Weeks	51.7	c	11.6	b
No Control	50.9	c	11.1	b
LSD p=0.05	**15.98**		**1.08**	

Burdekin

Treatment Means (Harvest)	t/ha		ccs-1.5	
Full Control	96.4	a	16.3	a
4 Weeks	81.7	b	16.1	a
8 Weeks	56.6	c	14.9	b
12 Weeks	63.2	c	14.7	b
No Control	51.9	c	16.0	a
LSD p=0.05	**13.13**		**0.9**	

Bundaberg

Treatment Means (Harvest)	t/ha		ccs-1.5	
Full Control	111.4	a	14.8	a
4 Weeks	98.8	b	14.8	a
8 Weeks	85.6	c	14.8	a
12 Weeks	73.9	d	14.3	a
No Control	40.3	e	10.9	b
LSD p=0.05	**8.73**		**1.19**	

1998/99 TRIALS

Mackay

Treatment Means (Harvest)	t/ha		ccs-1.5	
Full Control	109.6	a	14.2	a
3 Weeks	99.2	a	14.0	ab
5 Weeks	97.8	a	13.7	ab
8 Weeks	75.9	b	14.0	ab
12 Weeks	60.1	c	13.3	b
No Control	68.5	bc	13.8	ab
LSD p=0.05	**13.11**		**0.75**	

Bundaberg

Treatment Means (Harvest)	t/ha	ccs-1.5
Full Control	109.45 a	15.3 ab
3 Weeks	111.45 a	14.8 b
5 Weeks	100.9 a	15.3 ab
8 Weeks	94.2 a	15.17 b
12 Weeks	50.3 b	15.9 a
No Control	21.8 c	15.05 b
LSD p=0.05	**19.107**	**0.6744**

Burdekin

Treatment Means (Harvest)	t/ha	ccs-1.5
Full Control	144.78 a	17.07 a
3 Weeks	134.66 b	17.72 a
5 Weeks	120.76 c	17.8 a
8 Weeks	117.9 c	17.14 a
12 Weeks	108.8 d	17.03 a
No Control	105.2 d	17.3 a
LSD p=0.05	**8.83**	**1.33**

APPENDIX 7

APPENDIX 7

Bundaberg Weed Competition Trial (1997-98) - Summary Sheet							
		4 Weeks		*8 Weeks*		*12 Weeks*	
Weed density (m^2)		**Number**	**Total**	**Number**	**Total**	**Number**	**Total**
Pig Weed	2-4 Leaf Stage	1		0		0	
	Stalling <100mm	0		0		0	
	Well developed <250mm	0		0		0	
	>250mm (not flowering)	0		0		0	
	Flowering (any size)	0	**1**	0	**0**	0	**0**
Ipomoea Sp.	2-4 Leaf Stage	3		1		2	
	Stalling <100mm	13		5		0	
	Well developed <250mm	3		5		0	
	>250mm (not flowering)	0		4		5	
	Flowering (any size)	0	**19**	1	**15**	0	**7**
Nut Grass	2-4 Leaf Stage	1		0		0	
	Stalling <100mm	3		1		2	
	Well developed <250mm	0		14		26	
	>250mm (not flowering)	0		11		6	
	Flowering (any size)	0	**4**	0	**27**	0	**34**
Stagger Weed	2-4 Leaf Stage	15		0		0	
	Stalling <100mm	1		5		1	
	Well developed <250mm	0		8		9	
	>250mm (not flowering)	0		2		4	
	Flowering (any size)	0	**16**	1	**16**	4	**18**
Green Summer Grass	2-4 Leaf Stage	0		1		0	
	Stalling <100mm	0		1		0	
	Well developed <250mm	0		4		0	
	>250mm (not flowering)	0		2		2	
	Flowering (any size)	0	**0**	2	**10**	12	**12**
Chinese Gooseberry	2-4 Leaf Stage	0		0		0	
	Stalling <100mm	0		1		0	
	Well developed <250mm	0		4		0	
	>250mm (not flowering)	0		4		1	
	Flowering (any size)	0	**0**	1	**10**	5	**6**
Weed Biomass (g/m2)		203		518		-	
Cane Height (TVD cm)	Full weed control treatment		-		-		-
Yield loss (t/ha)		**13.2**		**26.4**		**38.1**	
(% loss)		**12**		**24**		**34**	

APPENDIX 8

APPENDIX 8

Burdekin Weed Competition Trial (1997-98) - Summary Sheet							
		4 Weeks		***8 Weeks***		***12 Weeks***	
Weed Density (m2)		**Number**	**Total**	**Number**	**Total**	**Number**	**Total**
Pig Weed	2-4 Leaf Stage	47		2		14	
	Stalling <100mm	22		16		27	
	Well developed <250mm	19		14		8	
	>250mm (not flowering)	0		4		4	
	Flowering (any size)	0	**88**	10	**46**	32	**85**
Ipomoea Sp.	2-4 Leaf Stage	2		0		3	
	Stalling <100mm	1		1		3	
	Well developed <250mm	5		2		2	
	>250mm (not flowering)	0		2		3	
	Flowering (any size)	0	**8**	4	**9**	4	**15**
Nut Grass	2-4 Leaf Stage	6		0		5	
	Stalling <100mm	16		14		30	
	Well developed <250mm	29		25		48	
	>250mm (not flowering)	7		31		65	
	Flowering (any size)	0	**58**	7	**77**	4	**152**
Sow Thistle	2-4 Leaf Stage	2		0		1	
	Stalling <100mm	0		0		0	
	Well developed <250mm	2		0		0	
	>250mm (not flowering)	0		0		0	
	Flowering (any size)	0	**5**	4	**4**	2	**3**
Green Summer Grass	2-4 Leaf Stage	0		0		0	
	Stalling <100mm	0		0		0	
	Well developed <250mm	0		0		0	
	>250mm (not flowering)	0		0		0	
	Flowering (any size)	0	**0**	0	**0**	0	**0**
Chinese Gooseberry	2-4 Leaf Stage	0		0		0	
	Stalling <100mm	1		0		0	
	Well developed <250mm	0		0		0	
	>250mm (not flowering)	0		0		0	
	Flowering (any size)	0	**1**	0	**0**	2	**2**
Weed Biomass (g/m2)		175		274		-	
Cane Height (TVD cm)	Full weed control	12.3		22.9		39.2	
	Treatment	13.5		14.8		18.6	
Yield Loss t/has		**14.7**		**39.7**		**33.2**	
(% loss)		**15**		**41**		**34**	

APPENDIX 9

APPENDIX 9

Innisfail Weed Competition Trial (1997-98) - Summary Sheet							
		4 Weeks		***8 Weeks***		***12 Weeks***	
Weed Density (m2)		**Number**	**Total**	**Number**	**Total**	**Number**	**Total**
Green Summer Grass	2-4 Leaf Stage	10		1		0	
	Stalling <100mm	10		6		0	
	Well developed <250mm	3		5		0	
	>250mm (not flowering)	5		9		1	
	Flowering (any size)	0	**28**	2	**22**	9	**10**
Wild Rose	2-4 Leaf Stage	8		0		0	
	Stalling <100mm	3		4		1	
	Well developed <250mm	1		2		0	
	>250mm (not flowering)	0		1		0	
	Flowering (any size)	0	**12**	4	**11**	7	**8**
Sensitive weed	2-4 Leaf Stage	1		0		0	
	Stalling <100mm	0		0		0	
	Well developed <250mm	0		0		0	
	>250mm (not flowering)	0		0		0	
	Flowering (any size)	0	**1**	0	**0**	0	**0**
Weed Biomass (g/m2)		22		308		-	
Cane Height (TVD cm)	Full weed control	9.5		27.9		-	
	Treatment	12.36		16.4		-	
Yield Loss t/ha		**8.5**		**24.8**		**57**	
(% loss)		**8**		**23**		**53**	

APPENDIX 10

APPENDIX 10

POT TRIAL TREATMENTS

1998 Burdekin

Varieties	Q124	Q165[A]	Q171[A]
Treatments	Gramoxone		1.5L/ha
	Agtreyne+ametryne		4 l + 3.7 L/ha
	Gesapax Combi		7L/ha
	Unsprayed control		

1998 Mackay

Varieties	Q124	Q135	Q138
Treatments	Gramoxone		1.5L/ha
	Velpar K4		4 kg/ha
	Gesapax Combi		7L/ha
	Unsprayed control		

1999 Burdekin

Varieties	Q124	Q135	Q138
Treatments	Gramoxone		1.5L/ha
	Velpar K4		4kg/ha
	Gesapax Combi		7L/ha
	MSMA		
	Asulox + Actril DS		8.5l + 1.5 L/ha (overspray)
	Asulox + Actril DS		8.5l + 1.5 L/ha (directed)
	Unsprayed control		

1999 Mackay No.1

Varieties	Q124	Q135	Q138
Treatments	Gramoxone		1.5L/ha
	Velpar K4		4kg/ha
	Gesapax Combi		7L/ha
	Unsprayed control		

2000 Burdekin

Varieties	Q96	Q117	Q124	Q127
Treatments	Asulox + Actril DS		8.5l + 1.5 L/ha	
	Actril DS + Viking		1.5l + 2 L/ha	
	Gramoxone + Diurex		1.5l + 2 kg/ha	
	Daconate + Diurex		3l + 2 kg/ha	
	Gesapax Combi		8 L/ha	
	Unsprayed control			

1999 Mackay No.2

Varieties	Q124	Q138	Q170[A]	Q185[A]	Q190[A]
Treatments	Asulox + Actril DS			8.5l + 1.5 L/ha	
	Actril DS + Viking			1.5l + 2 L/ha	
	Gramoxone + Diurex			1.5 l + 2 kg/ha	
	Daconate + Diurex			3l + 2 kg/ha	
	Gesapax Combi			8 L/ha	
	Unsprayed control				

APPENDIX 11

APPENDIX 11

POT TRIALS – Mackay 1999 (1)

Q124

	Shoot Height TVD (mm)				Tillering (No.)				Biomass - roots & tops			
Treatment	Application		Harvest		Application		Harvest		Dry Weight Tops (g)		Dry Weight Roots (g)	
Control	425	a	684	a	4.3	a	9.3	a	204.5	a	97.2	a
Paraquat	358	b	642	ab	3.0	ab	10.2	a	111.2	b	73.7	ab
Velpar K4	352	b	575	bc	3.1	ab	9.1	a	92.2	b	75.7	ab
Gesapax Combi	306	b	520	c	1.8	b	8.0	a	86.8	b	61.8	b
	LSD= 66.26		LSD=95.61		LSD=1.44		LSD=2.36		LSD=56.28		LSD=27.92	

Q135

	Shoot Height TVD (mm)				Tillering (No.)				Biomass - roots & tops			
Treatment	Application		Harvest		Application		Harvest		Dry Weight Tops (g)		Dry Weight Roots (g)	
Control	281.6	a	354.2	a	10.5	bc	19.2	a	141.5	a	140.8	a
Paraquat	291.6	a	340.8	a	13.2	ab	18.0	a	100.7	b	90.0	bc
Velpar K4	271.6	a	297.5	b	9.5	c	17.8	a	87.2	b	81.5	c
Gesapax Combi	290.0	a	343.3	a	13.5	ab	17.8	a	123.5	ab	122.0	ab
	LSD=34.46		LSD=41.86		LSD=2.67		LSD=3.48		LSD=39.13		LSD=35.34	

Q138

	Shoot Height TVD (mm)				Tillering (No.)				Biomass - roots & tops			
Treatment	Application		Harvest		Application		Harvest		Dry Weight Tops (g)		Dry Weight Roots (g)	
Control	316.7	b	523.3	ab	8.0	a	15.0	a	192.5	a	197.0	a
Paraquat	361.6	a	543.3	ab	6.6	a	13.7	a	174.1	a	140.5	a
Velpar K4	361.6	a	517.5	ab	8.0	a	13.8	a	195.5	a	144.3	a
Gesapax Combi	343.3	ab	460.0	b	7.6	a	13.6	a	167.2	a	146.2	a
	LSD=37.8		LSD=68.07		LSD=2.9		LSD=2.97		LSD=71.26		LSD=127.32	

APPENDIX 12

APPENDIX 12

POT TRIALS – Mackay 1999(2)

Q190[A]

Treatment	Shoot height TVD (mm)				Tiller numbers				Dry Weight (g)	
	Application		Harvest		Application		Harvest			
Daconate/Diuron	119	a	381	b	1.66	a	14.5	a	72.5	b
Actril/Asulux	129	a	436	ab	2.16	a	15	a	94.66	a
Gesapax Combi	141	a	321	b	1.6	a	13.5	ab	71.83	b
Actril/Ametryn	113	a	363	b	1.5	a	13.1	ab	56.16	b
Gramoxone/Diuron	142	a	346	b	1	a	10.8	b	59.5	b
Control	138	a	491	a	1.8	a	15.3	a	108.33	a

LSD 35.49 LSD=71.1 LSD=1.2 LSD=3.17 LSD=16.59

Q124

Treatment	Shoot height TVD (mm)				Tiller numbers				Dry Weight (g)	
	Application		Harvest		Application		Harvest			
Daconate/Diuron	99.6	a	381	bc	0	b	5.8	b	45	bc
Actril/Asulux	123	a	436	ab	0	b	7.8	ab	58.33	ab
Gesapax Combi	127.1	a	321.6	c	0.833	a	9.66	a	48.16	bc
Actril/Ametryn	125	a	363	c	0.16	ab	5.33	b	37.5	c
Gramoxone/Diuron	130	a	346	c	0	b	7.16	ab	36	c
Control	122.5	a	456.6	a	0	b	8.8	a	69.5	a

LSD 34.5 LSD 63.5 LSD= 0.68 LSD=2.55 LSD=17.29

Q170[A]

Treatment	Shoot height TVD (mm)				Tiller numbers				Dry Weight (g)	
	Application		Harvest		Application		Harvest			
Daconate/Diuron	144	a	406	bc	2.3	ab	21	ab	86.1	b
Actril/Asulux	145	a	436	b	1.6	a	18	b	80	bc
Gesapax Combi	142	a	400	bc	2.8	a	20.1	b	74.6	bc
Actril/Ametryn	151	a	373	c	2.3	ab	20.6	b	80.6	bc
Gramoxone/Diuron	156	a	391	bc	2.6	a	19.1	b	66.5	c
Control	155	a	498	a	2.8	a	24	a	138	a

LSD 16.7 LSD 51.3 LSD=0.8 LSD=3.2 LSD=17.16

Q185[A]

Treatment	Shoot height TVD (mm)				Tiller numbers				Dry Weight (g)	
	Application		Harvest		Application		Harvest			
Daconate/Diuron	120	a	285	b	1.1	ab	12.8	ab	68.8	bc
Actril/Asulux	103	bc	305	ab	0.8	abc	11.5	ab	80.66	b
Gesapax Combi	115	abc	298	ab	0.5	bc	10.3	bc	60.3	c
Actril/Ametryn	111	abc	285	b	1.3	a	10.6	bc	60.1	c
Gramoxone/Diuron	100	c	206	c	0.3	c	8.1	c	34.8	d
Control	117.5	ab	345	a	1.3	a	13.8	a	107.5	a

LSD 16 LSD 56 LSD 0.8 LSD 3.1 LSD 17.2

Q138

Treatment	Shoot height TVD (mm)				Tiller numbers				Dry Weight	
	Application		Harvest		Applicatio n		Harvest		(g)	
Daconate/Diuron	110	a	395	b	0.5	b	11.1	a	59.8	b
Actril/Asulux	101	ab	403	b	0.16	b	8	bc	62.6	b
Gesapax Combi	107	ab	403	b	0.3	a	9.8	ab	60	b
Actril/Ametryn	118.33	a	398	b	0.16	ab	6.8	c	60.33	b
Gramoxone/Diuron	92.5	b	311	c	0.3	b	8.8	bc	41.1	c
Control	115.8	a	485	a	0.16	b	9.3	ab	85.16	a
	LSD 17.5		LSD 51.2		LSD = 0.6		LSD = 2.2		LSD = 12.0	

APPENDIX 13

APPENDIX 13

POT TRIAL – BURDEKIN 1999 (A)

The SAS System 10:41 Friday, March 16, 2001 260

The ANOVA Procedure

Class Level Information

Class	Levels	Values
treat	4	Combi Control Gramoxon Velpar
variety	3	Q124 Q135 Q138
rep	6	1 2 3 4 5 6

Number of observations 72

The SAS System 10:41 Friday, March 16, 2001 261

The ANOVA Procedure

Dependent Variable: tiller

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	26	472.8611111	18.1869658	3.76	<.0001
Error	45	217.7500000	4.8388889		
Corrected Total	71	690.6111111			

R-Square	Coeff Var	Root MSE	tiller Mean
0.684700	15.31739	2.199747	14.36111

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	5	2.2777778	0.4555556	0.09	0.9927
variety	2	342.0277778	171.0138889	35.34	<.0001
variety*rep	10	31.3055556	3.1305556	0.65	0.7658
treat	3	58.9444444	19.6481481	4.06	0.0123
treat*variety	6	38.3055556	6.3842593	1.32	0.2683

Tests of Hypotheses Using the Anova MS for variety*rep as an Error Term

Source	DF	Anova SS	Mean Square	F Value	Pr > F
variety	2	342.0277778	171.0138889	54.63	<.0001

The SAS System 10:41 Friday, March 16, 2001 262

t Tests (LSD) for tiller

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	4.838889
Critical Value of t	2.01410
Least Significant Difference	1.4768

Means with the same letter are not significantly different.

t Grouping		Mean	N	treat
	A	15.7778	18	Gramoxon
B	A	14.3333	18	Combi
B		14.0556	18	Control
B		13.2778	18	Velpar

The SAS System 10:41 Friday, March 16, 2001 263

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for tiller

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	4.838889
Critical Value of Studentized Range	3.77270
Minimum Significant Difference	1.9561

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Treat
	A	15.7778	18	Gramoxon
B	A	14.3333	18	Combi
B	A	14.0556	18	Control
B		13.2778	18	Velpar

The SAS System 10:41 Friday, March 16, 2001 264

The ANOVA Procedure

t Tests (LSD) for tiller

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	4.838889
Critical Value of t	2.01410
Least Significant Difference	1.279

Means with the same letter are not significantly different.

t Grouping	Mean	N	variety
A	16.9583	24	Q135
B	14.5000	24	Q138
C	11.6250	24	Q124

The SAS System 10:41 Friday, March 16, 2001 265

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for tiller

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	4.838889
Critical Value of Studentized Range	3.42751
Minimum Significant Difference	1.539

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Variety
A	16.9583	24	Q135
B	14.5000	24	Q138
C	11.6250	24	Q124

The SAS System 10:41 Friday, March 16, 2001 266

The ANOVA Procedure

Class Level Information

Class	Levels	Values
treat	4	Combi Control Gramoxon Velpar
variety	3	Q124 Q135 Q138
rep	6	1 2 3 4 5 6

Number of observations 72

The ANOVA Procedure

Dependent Variable: tops

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	66692.3265	2565.0895	3.30	0.0002
Error	45	34944.8329	776.5518		
Corrected Total	71	101637.1594			

R-Square	Coeff Var	Root MSE	tops Mean
0.656181	16.52433	27.86668	168.6403

rep	5	1427.03316	285.40663	0.37	0.8681
variety	2	8696.46914	4348.23457	5.60	0.0067
variety*rep	10	5998.42430	599.84243	0.77	0.6541
treat	3	34403.23202	11467.74401	14.77	<.0001
treat*variety	6	16167.16791	2694.52798	3.47	0.0067

Tests of Hypotheses Using the Anova MS for variety*rep as an Error Term

Source	DF	Anova SS	Mean Square	F Value	Pr > F
variety	2	8696.469136	4348.234568	7.25	0.0113

The SAS System 10:41 Friday, March 16, 2001 268

The ANOVA Procedure

Level of treat	Level of variety	N	………tops……… Mean	Std Dev
Combi	Q124	6	158.803333	22.7340719
Combi	Q135	6	156.163333	26.2638205
Combi	Q138	6	189.888333	25.7371882
Control	Q124	6	211.228333	35.0674261
Control	Q135	6	175.113333	24.4666186
Control	Q138	6	208.553333	33.4640342
Gramoxon	Q124	6	166.645000	16.1206200
Gramoxon	Q135	6	111.431667	26.9403448
Gramoxon	Q138	6	131.831667	35.9200492
Velpar	Q124	6	146.958333	19.2086100
Velpar	Q135	6	174.051667	27.8879461
Velpar	Q138	6	193.015000	15.3046656

The SAS System 10:41 Friday, March 16, 2001 269

The ANOVA Procedure

Class Level Information

Class	Levels	Values
treat	4	Combi Control Gramoxon Velpar
variety	3	Q124 Q135 Q138
rep	6	1 2 3 4 5 6

Number of observations 72

The SAS System 10:41 Friday, March 16, 2001 270

The ANOVA Procedure

Dependent Variable: elong

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	507041.6667	19501.6026	13.79	<.0001
Error	45	63658.3333	1414.6296		
Corrected Total	71	570700.0000			
	0.888456	13.71850	37.61156	274.1667	

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	5	13645.8333	2729.1667	1.93	0.1082
variety	2	413358.3333	206679.1667	146.10	<.0001
variety*rep	10	17545.8333	1754.5833	1.24	0.2926
treat	3	50486.1111	16828.7037	11.90	<.0001
treat*variety	6	12005.5556	2000.9259	1.41	0.2301

Tests of Hypotheses Using the Anova MS for variety*rep as an Error Term

Source	DF	Anova SS	Mean Square	F Value	Pr > F
variety	2	413358.3333	206679.1667	117.79	<.0001

The SAS System 10:41 Friday, March 16, 2001 271

The ANOVA Procedure

t Tests (LSD) for elong

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1414.63
Critical Value of t	2.01410
Least Significant Difference	25.251

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	303.33	18	Control
A	282.50	18	Velpar
A	279.72	18	Combi
B	231.11	18	Gramoxon

The SAS System 10:41 Friday, March 16, 2001 272

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for elong

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1414.63
Critical Value of Studentized Range	3.77270
Minimum Significant Difference	33.445

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	303.33	18	Control
A	282.50	18	Velpar
A	279.72	18	Combi
B	231.11	18	Gramoxon

The SAS System 10:41 Friday, March 16, 2001 273

The ANOVA Procedure

t Tests (LSD) for elong

NOTE: This test controls the Type 1 comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1414.63
Critical Value of t	2.01410
Least Significant Difference	21.868

Means with the same letter are not significantly different.

t Grouping	Mean	N	variety
A	346.67	24	Q124
B	306.25	24	Q138
C	169.58	24	Q135

The SAS System 10:41 Friday, March 16, 2001 274

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for elong

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1414.63
Critical Value of Studentized Range	3.42751
Minimum Significant Difference	26.314

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	variety
A	346.67	24	Q124
B	306.25	24	Q138
C	169.58	24	Q135

APPENDIX 14

APPENDIX 14

Pot trials – Burdekin 1999 B full analysis

The SAS System 10:41 Friday, March 16, 2001 305
The ANOVA Procedure
Class Level Information

Class	Levels	Values
treat	4	AAdir Aaover Control MSMA
variety	3	Q124 Q135 Q138
rep	6	1 2 3 4 5 6

Number of observations 72

The SAS System 10:41 Friday, March 16, 2001 306
The ANOVA Procedure

Dependent Variable: tiller

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	523.3611111	20.1292735	6.14	<.0001
Error	45	147.6250000	3.2805556		
Corrected Total	71	670.9861111			

R-Square	Coeff Var	Root MSE	tiller Mean
0.779988	12.72279	1.811230	14.23611

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	5	20.0694444	4.0138889	1.22	0.3138
variety	2	352.5277778	176.2638889	53.73	<.0001
variety*rep	10	55.1388889	5.5138889	1.68	0.1151
treat	3	71.3750000	23.7916667	7.25	0.0005
treat*variety	6	24.2500000	4.0416667	1.23	0.3081

Tests of Hypotheses Using the Anova MS for variety*rep as an Error Term

Source	DF	Anova SS	Mean Square	F Value	Pr > F
variety	2	352.5277778	176.2638889	31.97	<.0001

The SAS System 10:41 Friday, March 16, 2001 307
The ANOVA Procedure
t Tests (LSD) for tiller

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	3.280556
Critical Value of t	2.01410

Least Significant Difference 1.216
Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	15.0556	18	MSMA
A	14.8889	18	Aadir
A	14.4444	18	Control
B	12.5556	18	Aaover

The SAS System 10:41 Friday, March 16, 2001 308

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for tiller

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	3.280556
Critical Value of Studentized Range	3.77270
Minimum Significant Difference	1.6106

Means with the same letter are not significantly different

Tukey Grouping	Mean	N	treat
A	15.0556	18	MSMA
A	14.8889	18	Aadir
A	14.4444	18	Control
B	12.5556	18	AAover

The SAS System 10:41 Friday, March 16, 2001 309

The ANOVA Procedure

t Tests (LSD) for tiller

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	3.280556
Critical Value of t	2.01410
Least Significant Difference	1.0531

Means with the same letter are not significantly different

t Grouping	Mean	N	variety
A	17.0000	24	Q135
B	14.1250	24	Q138
C	11.5833	24	Q124

The SAS System 10:41 Friday, March 16, 2001 310

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for tiller

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	3.280556
Critical Value of Studentized Range	3.42751
Minimum Significant Difference	1.2672

Means with the same letter are not significantly different

Tukey Grouping	Mean	N	variety
A	17.0000	24	Q135
B	14.1250	24	Q138
C	11.5833	24	Q124

The SAS System 10:41 Friday, March 16, 2001 311

The ANOVA Procedure

Class Level Information

Class	Levels	Values
treat	4	AAdir Aaover Control MSMA
variety	3	Q124 Q135 Q138
rep	6	1 2 3 4 5 6

Number of observations 72

The SAS System 10:41 Friday, March 16, 2001 312

The ANOVA Procedure

Dependent Variable: tops

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	30462.48092	1171.63388	2.22	0.0093
Error	45	23760.87911	528.01954		
Corrected Total	71	54223.36003			

R-Square	Coeff Var	Root MSE	tops Mean
0.561796	17.21423	22.97868	133.4865

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	5	6284.93379	1256.98676	2.38	0.0534
variety	2	6158.24770	3079.12385	5.83	0.0056
variety*rep	10	4412.28331	441.22833	0.84	0.5974
treat	3	11454.49183	3818.16394	7.23	0.0005
treat*variety	6	2152.52429	358.75405	0.68	0.6669

Tests of Hypotheses Using the Anova MS for variety*rep as an Error Term

Source	DF	Anova SS	Mean Square	F Value	Pr > F
variety	2	6158.247703	3079.123851	6.98	0.0127

The SAS System 10:41 Friday, March 16, 2001 313

The ANOVA Procedure

t Tests (LSD) for tops

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	528.0195
Critical Value of t	2.01410
Least Significant Difference	15.427

Means with the same letter are not significantly different

t Grouping	Mean	N	treat
A	142.193	18	Control
A	140.451	18	Aaover
A	139.602	18	Aadir
B	111.700	18	MSMA

The SAS System 10:41 Friday, March 16, 2001 314

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for tops

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	528.0195
Critical Value of Studentized Range	3.77270
Minimum Significant Difference	20.433

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	142.193	18	Control
A	140.451	18	Aaover
A	139.602	18	Aadir
B	111.700	18	MSMA

The SAS System 10:41 Friday, March 16, 2001 315

The ANOVA Procedure

t Tests (LSD) for tops

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	528.0195
Critical Value of t	2.01410
Least Significant Difference	13.36

Means with the same letter are not significantly different.

t Grouping	Mean	N	variety
A	146.561	24	Q124
B	127.242	24	Q135
B	126.657	24	Q138

The SAS System 10:41 Friday, March 16, 2001 316

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for tops

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	528.0195
Critical Value of Studentized Range	3.42751
Minimum Significant Difference	16.077

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	variety
A	146.561	24	Q124
B	127.242	24	Q135
B	126.657	24	Q138

The SAS System 10:41 Friday, March 16, 2001 317

The ANOVA Procedure

Class Level Information

Class	Levels	Values
treat	4	AAdir Aaover Control MSMA
variety	3	Q124 Q135 Q138
rep	6	1 2 3 4 5 6

Number of observations 72

The SAS System 10:41 Friday, March 16, 2001 318

The ANOVA Procedure

Dependent Variable: elong

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	429710.4167	16527.3237	9.05	<.0001
Error	45	82177.0833	1826.1574		
Corrected Total	71	511887.5000			
		0.839463	16.62246	42.73356	257.0833
rep	5	4883.3333	976.6667	0.53	0.7488
variety	2	332152.0833	166076.0417	90.94	<.0001
variety*rep	10	4364.5833	436.4583	0.24	0.9904
treat	3	80145.8333	26715.2778	14.63	<.0001
treat*variety	6	8164.5833	1360.7639	0.75	0.6163

Tests of Hypotheses Using the Anova MS for variety*rep as an Error Term

Source	DF	Anova SS	Mean Square	F Value	Pr > F
variety	2	332152.0833	166076.0417	380.51	<.0001

The SAS System 10:41 Friday, March 16, 2001 319

The ANOVA Procedure

t Tests (LSD) for elong

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1826.157
Critical Value of t	2.01410
Least Significant Difference	28.69

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	293.33	18	Aaover
A	284.72	18	Control
B	238.06	18	Aadir
B	212.22	18	MSMA

The SAS System 10:41 Friday, March 16, 2001 320

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for elong

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1826.157
Critical Value of Studentized Range	3.77270

Minimum Significant Difference 38

Means with the same letter are not significantly different.

Tukey Grouping	**Mean**	**N**	**treat**
A	293.33	18	AAover
A	284.72	18	Control
B	238.06	18	Aadir
B	212.22	18	MSMA

The SAS System 10:41 Friday, March 16, 2001 321

The ANOVA Procedure

t Tests (LSD) for elong

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1826.157
Critical Value of t	2.01410
Least Significant Difference	24.846

Means with the same letter are not significantly different.

t Grouping	**Mean**	**N**	**variety**
A	316.88	24	Q124
A	292.29	24	Q138
B	162.08	24	Q135

The SAS System 10:41 Friday, March 16, 2001 322

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for elong

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	45
Error Mean Square	1826.157
Critical Value of Studentized Range	3.42751
Minimum Significant Difference	29.898

Means with the same letter are not significantly different.

Tukey Grouping	**Mean**	**N**	**variety**
A	316.88	24	Q124
A	292.29	24	Q138
B	162.08	24	Q135

APPENDIX 15

APPENDIX 15

POT TRIAL – BURDEKIN 2000

	Q96		Q117	
Herbicide Treatment	**Tiller numbers**	**Dry Tops (g)**	**Tiller numbers**	**Dry Tops (g)**
Gesapax Combi	14.50 a	75.50 b	10.67 a	85.67 bc
Asulox+Actril DS	14.00 a	71.33 b	9.00 a	100.67 ab
Viking+ Actril DS	13.83 a	76.67 b	8.50 a	69.17 c
Daconate+Diurex	13.17 a	85.83 b	9.00 a	75.83 bc
Gramoxone+Diurex	13.00 a	34.00 c	5.17 b	28.00 d
Control	12.83 a	117.00 a	8.83 a	118.33 a

Means followed by same letter not significantly diff. (P=0.05)

	Q127		Q124	
Herbicide Treatment	**Tiller numbers**	**Dry Tops (g)**	**Tiller numbers**	**Dry Tops (g)**
Gesapax Combi	16.83 a	94.00 bc	10.67 ab	64.83 c
Asulox+Actril DS	15.50 ab	118.83 b	10.17 ab	100.67 b
Viking+ Actril DS	13.83 bc	117.83 b	9.33 b	91.17 b
Daconate+Diurex	15.50 ab	110.50 b	10.50 ab	64.50 c
Gramoxone+Diurex	12.50 c	50.50 c	11.50 a	47.83 c
Control	16.33 ab	189.67 a	10.67 ab	153.00 a

Means followed by same letter not significantly diff. (P=0.05)

APPENDIX 16

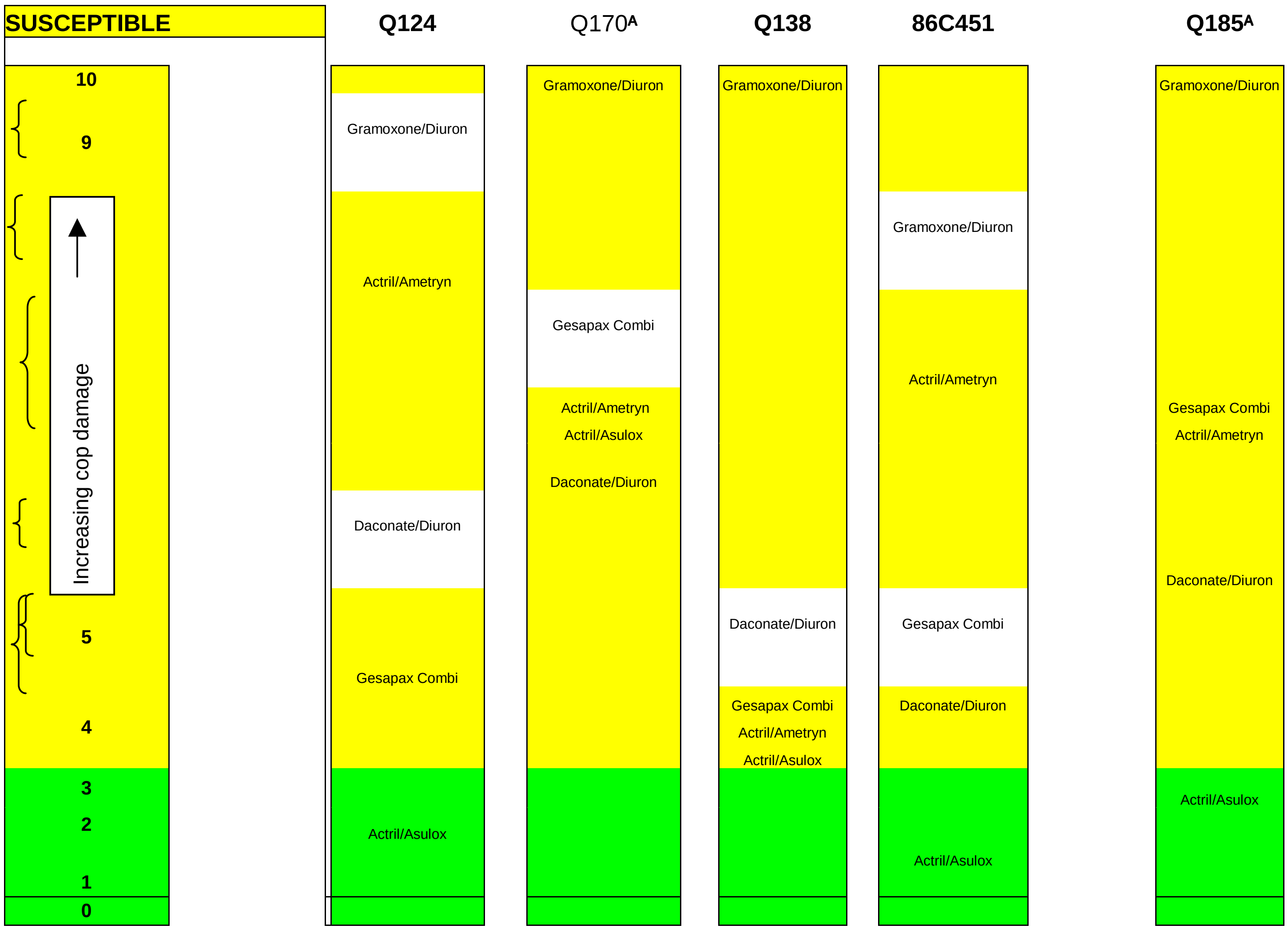
APPENDIX 16

CROP DAMAGE FROM HERBICIDES AT STOOLING

* Grass control options are limited at the stooling stage
* Unacceptable crop damage may result from broadcast application of daconate, diuron, ametryn and paraquat. Directed sprays are not possible.
* The graphs below indicate the relative crop damage from ' rescue sprays' for different varieties

NOTE: herbicides grouped are not different.

Rescue Treatments	***Rate/ha***
Daconate + Diuron	3 L + 0.5 kg
Actril + Asulox	1.5 L + 8.5 L
Gesapax Combi	6 L
Actril + Ametryn	1.5 L + 2 L
Gramoxone + Diuron	1.5 L + 0.5 kg

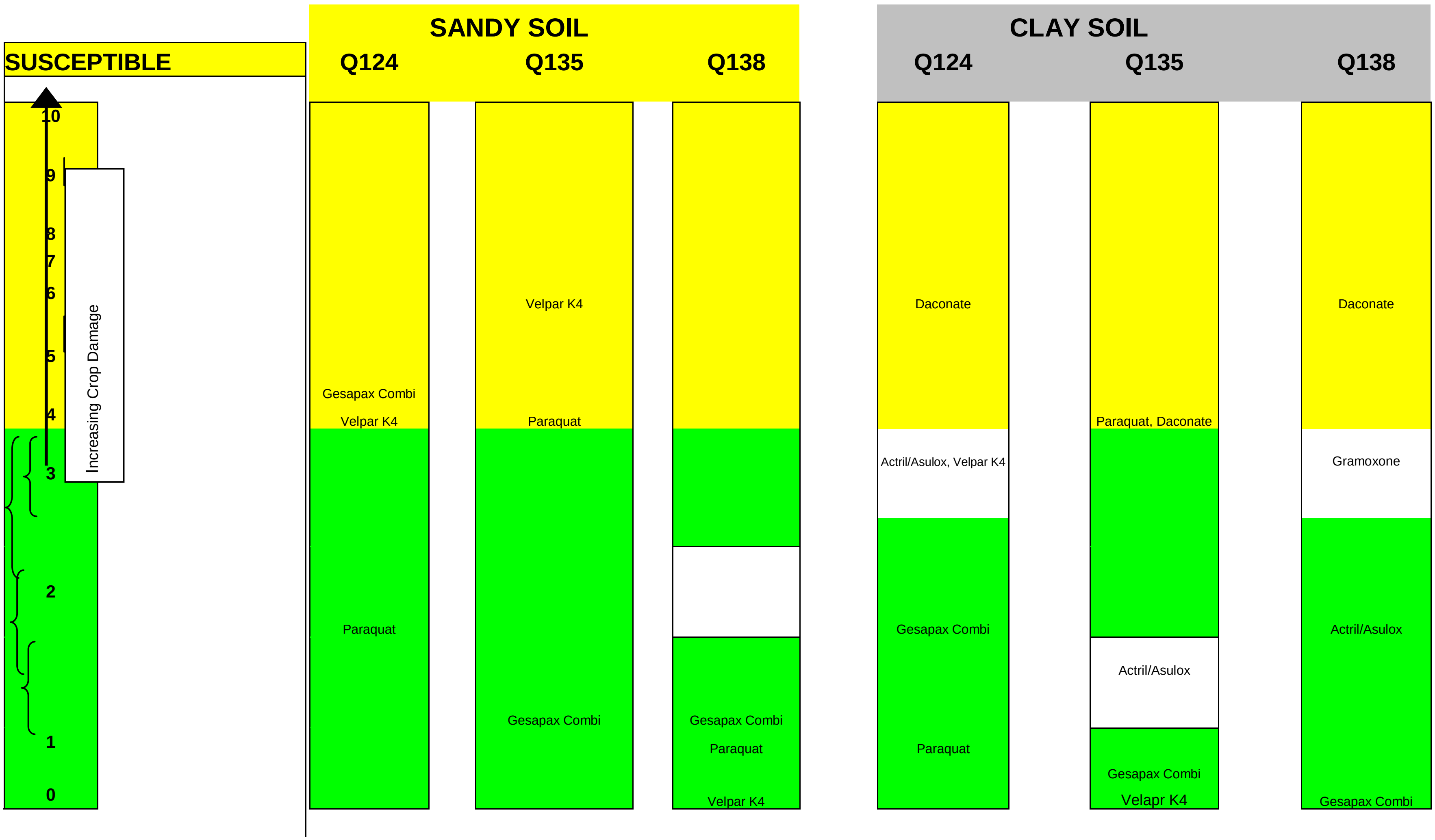

SUSCEPTIBLE
10
9
Increasing cop damage
5
4
3
2
1
0
Q124
Gramoxone/Diuron
Actril/Ametryn
Daconate/Diuron
Gesapax Combi
Actril/Asulox
Q170A
Gramoxone/Diuron
Gesapax Combi
Actril/Ametryn
Actril/Asulox
Daconate/Diuron
Q138
Gramoxone/Diuron
Daconate/Diuron
Gesapax Combi
Actril/Ametryn
Actril/Asulox
86C451
Gramoxone/Diuron
Actril/Ametryn
Gesapax Combi
Daconate/Diuron
Actril/Asulox
Q185A
Gramoxone/Diuron
Gesapax Combi
Actril/Ametryn
Daconate/Diuron
Actril/Asulox

APPENDIX 17

APPENDIX 17

CROP DAMAGE FROM DIRECTED HERBICIDE APPLICATION

HERBICIDES APPLIED AS A DIRECTED SPRAY:
Paraquat 1.5 L/ha
Gesapax Combi 6L/ha
Velpar K4 4 kg/ha
Daconate 6 L/ha
Actril + Asulox 8.5 + 1.5 L/ha


SANDY SOIL
CLAY SOIL
SUSCEPTIBLE
Q124
Q135
Q138
Q124
Q135
Q138
10
9
8
7
6
5
4
3
2
1
0
Increasing Crop Damage
Gesapax Combi
Velpar K4
Paraquat
Velpar K4
Paraquat
Gesapax Combi
Gesapax Combi
Paraquat
Velpar K4
Daconate
Actril/Asulox, Velpar K4
Gesapax Combi
Paraquat
Paraquat, Daconate
Actril/Asulox
Gesapax Combi
Velapr K4
Daconate
Gramoxone
Actril/Asulox
Gesapax Combi