BSES Limited

NSW Farming Systems Group Inc.

FINAL REPORT – SRDC PROJECT NFS002

AN INTEGRATED APPROACH TO NUTGRASS CONTROL

by

R.L. AITKEN, A.J. MUNRO AND P.J. MCGUIRE

SD11002

Contacts:

Robert Aitken
Senior Extension Officer
BSES Limited
c/- Harwood Sugar Mill
Harwood Island NSW 2465
Telephone: 02 66400479
E-mail: raitken@bses.com.au

Alan Munro
Member, NSW Farming Systems Group Inc.
c/- 273 Woodford Dale Road
Woodford Island NSW 2463
Telephone: 0427476491

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SUMMARY

This project aimed to formulate and promote an integrated approach to nutgrass control in sugarcane cropping systems. The project was a Grower Group Research Project undertaken from July 2007 to June 2010 by the NSW Farming Systems Group Inc. and BSES Limited extension officers in NSW.

Trials evaluating the effect of nutgrass on plant-cane yield, ratoon biomass and soybean biomass were undertaken. These trials showed cane yield losses of around 30% in both plant and ratoon cane where nutgrass was allowed to grow without any control. Even allowing nutgrass to grow for 4-8 weeks after planting or ratooning resulted in a reduction in cane growth. Quantification of nutrient uptake and removal of soil moisture by nutgrass provided reasons for the large effect of nutgrass on cane yield. In moderate to heavy infestations, nutgrass tops took up 25-45 kg N/ha that would otherwise be available to the cane crop. Similarly, nutgrass tops took up 45-50 kg K/ha (equivalent to the K applied in many planting mixes). A thick sward of nutgrass removed the equivalent of 11-12 mm rain from the plough layer in 4-8 days.

The key to long-term control of nutgrass is to reduce the number of viable tubers and the literature clearly shows the effect of gylphosate in reducing the number of viable tubers. However, the effect of other nutgrass-specific herbicides registered for cane on tuber viability had not been evaluated. A large-plot, replicated trial assessed Hero®, Krismat®, Sempra®, and 'double-knock' treatments of 2,4-D followed 2-4 weeks later by one of the former nutgrass-specific herbicides for their effect on nutgrass tuber viability. All herbicide treatments improved cane growth by reducing nutgrass density and all significantly decreased tuber viability.

Trials were established to evaluate some 'best-bet' options for nutgrass control. These trials aimed to assess 'packages' of successive treatments all aimed at reducing the viability of nutgrass tubers. Results from these trials were used to extend options for long-term nutgrass control to cane producers.

The trial work undertaken and associated economic analysis showed that it is highly economic to control nutgrass in cane. Total control of nutgrass resulted in large dollar benefits ($350-450/ha) and trials evaluating 'one-off' herbicide treatments for nutgrass also showed net benefits of $200-400/ha. This indicates that, even where nutgrass is patchy, growers could outlay $60-100/ha for nutgrass control and still obtain a substantial net benefit.

A factsheet/decision support package titled 'Managing nutgrass in cane' was produced and circulated throughout the Australian sugarcane industry. This factsheet emphasises that nutgrass can only be managed using a long-term integrated approach aimed at reducing the number of viable tubers. No single 'one off' treatment will control nutgrass and repeated treatments are the only sure way of controlling nutgrass. A single 'one off' treatment will reduce nutgrass competition in the short term but, because of its ability to rapidly propagate under suitable conditions, repeated treatments are imperative. The factsheet provides options for nutgrass control at various stages in the cane crop cycle.

1.0 BACKGROUND

Nutgrass (*Cyperus rotundus* and *Cyperus esculentus*) is a significant weed problem in many cane-growing areas and is a particular problem for the NSW industry. Following widespread adoption of minimum tillage practices in the 1990s there has been a perceived increase in nutgrass infestations in cane-growing areas. Nutgrass is a strongly competitive, perennial weed that grows from underground tubers. In ideal conditions a single tuber can produce a further 100 tubers in 90 days and about 2000 tubers in a growing season. Nutgrass competes with newly planted cane causing reduced germination, and reduced growth of young plants and ratoon crops. The sugarcane industry has not had a structured, strategic approach for improved nutgrass control and no decision-support package for growers for nutgrass control. There is a paucity of information on nutgrass control in controlled traffic soybean/sugarcane cropping systems, but the literature for other crops suggests that an integrated approach will be the most successful. Experience in other cropping systems (eg cotton) indicates that this perennial weed will not be controlled with any single treatment.

A literature review indicated that nutgrass could cause marked yield reductions in a range of crops. Although sugarcane yield reductions of up to 45% as a result of high nutgrass densities had been reported from the Indian subcontinent and South Africa, there appeared to have been no work quantifying yield losses in Australian sugarcane systems. The literature review at the start of the project (2007) suggested that there was a lack of good data to guide decisions on the economics of controlling nutgrass for the Australian situation.

Control of nutgrass would mean significant productivity and economic gains for the sugarcane industry and, as a widespread weed, long-term control of nutgrass has applicability to the entire sugar industry. NSW mill areas were considered ideal locations for developing strategies for nutgrass control because of the extent of the problem. A strategic, structured approach to nutgrass control also aimed to reduce the number of non-effective spray applications with benefits for both growers and the environment.

Successful nutgrass management is likely to incorporate a range of management tools and a central aim of the project was to develop and extend management options and packages.

2.0 PROJECT OBJECTIVES

Nutgrass (*Cyperus rotundus* and *Cyperus esculentus*) is a significant weed problem in many cane-growing areas and is a particular problem for the NSW industry.

The project aimed to:

- Provide a structured, strategic approach for improved nutgrass control,
- Develop and extend a package incorporating a decision-support chart for growers for nutgrass control,
- Achieve significant productivity and economic gains for the sugar industry by improved nutgrass control,
- Reduce/eliminate the number of non-effective spray applications,
- Enhance the capacity of NSW Farming Systems Group members to undertake research projects, and
- Increase adoption of improved cropping systems (eg soybean fallow) as they offer better opportunity for nutgrass control.

The project met each of these objectives as detailed below.

3.0 PROJECT ACTIVITIES

3.1 Pre-project survey

3.1.1 Methods

A survey (Appendix 1) was sent out to all NSW growers in early September 2007. The analysis below is based on 137 survey returns representing 26%, 17% and 27% of Condong, Broadwater and Harwood growers, respectively.

3.1.2 Results and Discussion

Cropping systems used

The majority of growers practiced either soybean fallow or a combination of ploughout/replant and soybean fallow cropping systems (Table 1). The high percentage of growers using soybean fallow in the Broadwater and Harwood mill areas provides an opportunity for an integrated approach to nutgrass control using glyphosate pre- and post-soybean crop.

Table 1 - Cropping systems used by NSW growers

Cropping system	Mill area		
	Condong	Broadwater	Harwood
Ploughout/replant only	22%	11%	20%
Soybean fallow only	11%	57%	30%
Both ploughout/replant and soybean fallow	53%	30%	42%
Other (eg grass fallow or combination of PO/RP, soybean and grass fallow)	14%	2%	8%

Perception of nutgrass as a problem

Most growers considered nutgrass a problem on their farm (Table 2). The majority thought it was a problem in both plant and ratoon cane, with fewer growers thinking it was a problem in soybean crops.

Table 2 - Grower perception of nutgrass as a problem

Severity of nutgrass problem	Mill area		
	Condong	Broadwater	Harwood
Not a problem	13%	14%	11%
Small problem	62%	59%	59%
Significant problem	25%	27%	30%

Perception of nutgrass effects on cane yield

Less than 15% of growers thought that nutgrass had no effect on cane yield. Across all three mill areas, 58% of growers considered that nutgrass affected both plant and ratoon cane yields – there was little variation amongst the mill areas (50% at Condong, 54% at Broadwater, 64% at Harwood).

Products/methods for nutgrass control and their effectiveness

It was interesting to see a clear difference amongst mill areas in terms of the effectiveness of mechanical cultivation as a means of controlling nutgrass. As expected, a high proportion of growers in all mill areas had used cultivation as a method to control nutgrass. In the Condong and Broadwater areas growers rated mechanical cultivation as generally average (45%) or poor (45%) as a means of nutgrass control. However, at Harwood growers thought cultivation was either good (27%) or average (50%) at controlling nutgrass. These different views may reflect soil type and rainfall differences amongst mill areas or locally accepted practices.

The majority of growers had used paraquat and/or 2,4-D to control nutgrass but generally rated their effectiveness as average to poor. Those who had used glyphosate rated its effectiveness as either good or average.

There were differences amongst mill areas in the use of some products. For example, there had been relatively little use of Flame® to control nutgrass in the Harwood and Broadwater mill areas, whereas about a quarter of Condong growers had used this product with the majority rating it average in effectiveness.

Use of glyphosate during fallow for nutgrass control

Of the growers fallowing, a significant proportion of growers were not using glyphosate during the fallow (28% at Condong, 36% at Broadwater, 46% at Harwood). This probably reflects the nature of the fallow and the limited opportunity for glyphosate in conventional tillage systems.

Willingness to adopt inter-row application of glyphosate

In excess of 80% of growers indicated that they would use glyphosate to control nutgrass in the inter-row if suitable technology (eg shielded sprayers) was available.

Overall

A reasonable response by growers to the pre-project survey provided a good baseline of their current attitudes which subsequently enabled the project group to judge the project's effectiveness in changing grower management methods for nutgrass in cane and soybean fallow. Results of an end-of-project survey are presented in Section 3.8.

3.2 Baseline measurements- nutgrass densities and tuber depth

3.2.1 Methods

Nutgrass density in commercial cane blocks

To obtain some baseline data and to compare nutgrass densities in NSW cane lands with the published literature, sample counts of above-ground nutgrass shoots were undertaken in selected paddocks (no herbicide applied prior to sampling) in the Harwood mill area in mid-September 2007 (Plate 1). The total number of nutgrass shoots and other weeds were recorded in 200 mm x 200 mm quadrates (Turner 1984) along a transect from the cane row to the middle of the inter-row (see Figure 1). These transects were replicated within each field.

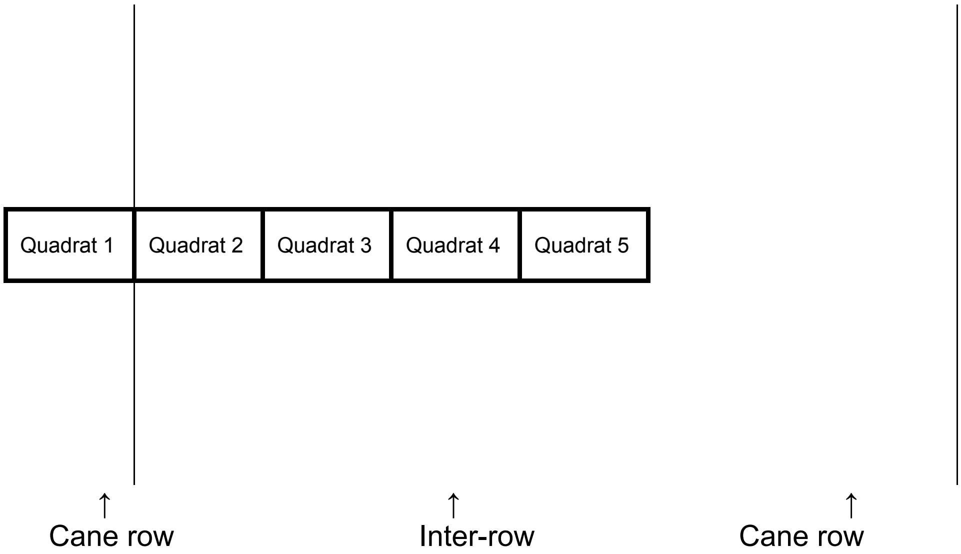

Figure 1 - Location of sampling quadrats in relation to cane rows (each quadrat was 200 mm x 200 mm)

Farm 1277, Block 1800 Farm 1278, Block 3210 Farm 1274, Block 600

Plate 1 - Fields used to assess densities of nutgrass

Tuber depth

A small sampling-depth study was undertaken to determine the depth of nutgrass tubers and an appropriate sampling depth for the tuber viability study (see Section 3.4 below). Tuber numbers for sampling depths of 0-15 cm and 0-30 cm were compared. At each of 8 sites, core samples (diameter = 78 mm) were taken to depths of 0-15 cm and 0-30 cm in the row (between dual rows; ratoon Empire variety) and at 0-15 cm depth in the inter-row (trafficked area). The tubers were manually washed out of the soil from each core and counted with part tubers counted as whole tubers.

3.2.2 Results and Discussion

Nutgrass density in commercial cane blocks

The average shoot densities of nutgrass and other weeds are presented in Table 3 and are expressed as above-ground shoots per m^2. These nutgrass populations are equivalent to, or exceed, nutgrass shoot densities at which cane growth was decreased in a South African study (Turner, 1984). Two of the three ratoon blocks showed a trend for nutgrass shoot density to be higher in the row area and lower in the more compacted interspace (Table 3).

Table 3 - Densities of shoots of nutgrass and other weeds (shoots per m^2) in each of four paddocks in the Harwood mill area in mid September 2007 (refer to Figure 1 for quadrat location)

Quadrat location	Farm and paddock							
	Farm 1274 Block 600 1st ratoon		Farm 1277 Block 1800 Fallow		Farm 1278 Block 3210 Old ratoons		Farm 1278 Block 3240 2nd ratoon	
	Nutgrass	Other	Nutgrass	Other	Nutgrass	Other	Nutgrass	Other
1	575	25	550	25	800	100	1625	275
2	750	25	500	25	600	100	1525	275
3	825	75	675	0	1150	150	1275	475
4	700	75	325	25	1000	100	1125	250
5	300	0	475	25	975	25	475	50

Tuber depth

A summary of the statistics for the number of tubers in soil cores is presented in Table 4 with data for each sampling site given in Table 5.

Of the tuber density obtained from a 0-30 cm sampling depth (Table 4), 92% of the tubers were in the 0-15 cm soil depth. These results suggested that a sampling depth of 0-15 cm would be adequate for the tuber viability study (Section 3.4). Over all 8 sites there was a significant linear regression (R^2=0.58) between tuber numbers in 0-15 cm and 0-30 cm depths. When site 3 (see table above) is omitted from the data, there is a highly significant linear relationship (R^2=0.87) between tuber numbers in the 0-15 and 0-30 cm depths with a slope close to 1.

Table 4 - Statistics on numbers of tubers for sampling depths of 0-15 and 0-30 cm

Statistic	Number of tubers in core		
	Sampling depth in row (between dual rows)		Inter-row
	0-15 cm	0-30 cm	0-15 cm
Average	12	13	11
Median	12	12	10
Range	4 - 21	7 - 24	5 - 21
Density (tubers/m^2)	2511	2720	2302

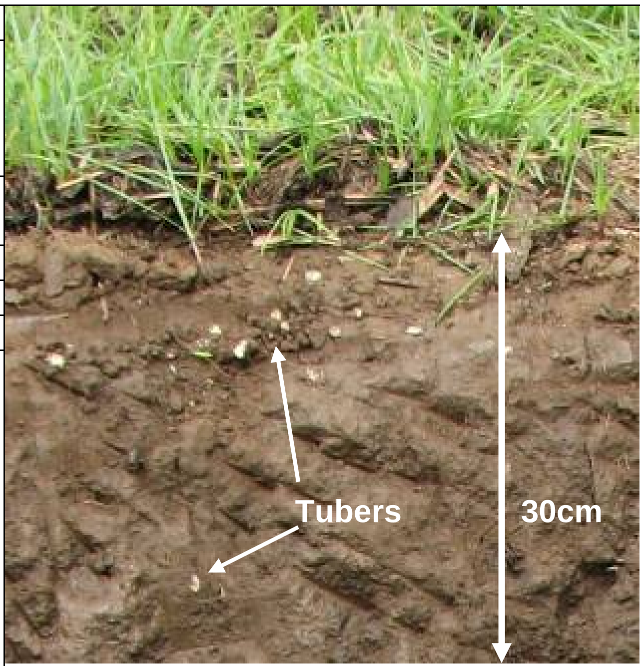

Table 5 - Numbers of tubers in soil cores at each sampling site

Sampling location	Number of tubers in core		
	Sampling depth in row (between dual rows)		Inter-row
	0-15 cm	0-30 cm	0-15 cm
1	15	15	11
2	11	11	9
3	4	12	21
4	21	24	9
5	15	11	5
6	11	10	5
7	7	7	16
8	13	12	14

If mechanical cultivation is to be used as a means of nutgrass control, then the soil should be cultivated to at least 15 cm depth and cultivation to 30 cm is likely to be required to effectively control nutgrass. It is unlikely that growers using mechanical cultivation for nutgrass are working the soil to this depth.

3.3 Yield-effect trials

A series of trials was undertaken to clearly establish the effect of nutgrass on plant cane yield, ratoon cane biomass, and soybean biomass. Quantifying the effect of nutgrass on yield allowed an economic analysis providing information regarding costs and returns for various nutgrass control options. In conjunction with these trials, nutrient uptake and soil moisture removal by nutgrass was quantified.

3.3.1 Methods

Plant cane

Two trials were established in the Harwood mill area at Mororo and Woodford Island. Each trial was a randomized block design with five treatments. There were four replicates of each treatment plot at the Mororo site and five replicates at the Woodford Island site. Individual plots were 4 rows wide (1.5 m single rows at Mororo and 1.8 m dual row beds at Woodford Island) and 20 m long.

Treatments were:

- T1. No nutgrass
- T2. Nutgrass for 4 weeks & then controlled
- T3. Nutgrass for 8 weeks & then controlled
- T4. Nutgrass for 12 weeks & then controlled
- T5. Nutgrass not controlled

The Mororo site had a low to medium nutgrass density (see below) and was located on a riverbank alluvial soil (Brown Dermosol; alluvium overlying Holocene marine sediments). The previous cane crop was ploughed out and the block rotary hoed prior to cane planting. Cane (Empire variety) was billet planted on 14 October 2007 with Dual Gold® (1.5 L/ha) and atrazine (3.3 kg/ha) applied as a boom spray on 1 November.

Spraying of T1 treatments commenced on 6 November 2007. Nutgrass was controlled by spot spraying using a backpack. In general, ethoxysulfuron (equivalent to 150 g ai/ha) was used to control nutgrass. On one occasion (first spraying for T4) halosulfuron-methyl (equivalent to 90 g ai/ha) was applied. A shielded spray nozzle was used to ensure that no herbicide was applied to cane leaves. Weeds other than nutgrass at this site were controlled by hand weeding as the site had a low seed bank of weeds other than nutgrass. Effectively the only weed present at this site was nutgrass. Dates of initial sprayings for nutgrass control for individual treatments at the Mororo site are shown in Table 6. Subsequent spot sprayings occurred as required but were generally undertaken every 10-14 days. Spraying continued until late April/early May 2008.

Table 6 - Dates of initial sprays for nutgrass control in each treatment at the Mororo trial

Treatment	Date of initial spraying	Days after planting
T1. No nutgrass	6/11/07	23
T2. Nutgrass for 4 weeks & then controlled	7/12/07	54
T3. Nutgrass for 8 weeks & then controlled	8/1/08	86
T4. Nutgrass for 12 weeks & then controlled	6/2/08	115

The Woodford Island site was fallow prior to planting the cane and the site was heavily infested with nutgrass (Plate 2). Before planting, the plots were pegged out and glyphosate (3 L/ha Roundup® CT*)* applied to the T1 plots designated for no nutgrass on 7 November 2007 (see Plate 2). The site was then ripped, rotary hoed and beds formed (21 November) and dual-row cane (variety Q205[Φ]) billet planted on 23 November 2007.


Plate 2 - Plots (T1. no nutgrass) sprayed out with glyphosate prior to cultivation and establishing cane at the Woodford Island trial

At this site nutgrass control in the appropriate treatments was achieved by ethoxysulfuron (Hero®, equivalent to 150 g ai/ha) application from a backpack. Control of weeds other than nutgrass was achieved by a combination of regular hand weeding, two applications of very low rates of 2,4-D (250 mL/ha) to control very small broadleaf weeds without affecting the nutgrass, and application of Stomp Xtra® (2.2 L/ha) and atrazine (2 kg/ha). Dates of initial sprayings for nutgrass control for individual treatments are shown in Table 7. Subsequent spot sprayings (ethoxysulfuron) to control nutgrass occurred as required, generally every 10-14 days.

Table 7 - Dates of initial sprays for nutgrass control in each treatment at the Woodford Island trial

Treatment	Date of initial spraying	Days after planting
T1. No nutgrass	7/12/07	14
T2. Nutgrass for 4 weeks & then controlled	8/1/08	46
T3. Nutgrass for 8 weeks & then controlled	7/2/08	76
T4. Nutgrass for 12 weeks & then controlled	7/3/08	105

Soil cores (0-15 cm depth, 7.8cm diameter) were collected from each replicate plot of treatments T1, T2 and T5 on 30 January 2008. Twenty cores were collected from each plot and separately bagged. The tubers were recovered from these cores for counts and viability assessment.

Numbers of cane shoots were recorded at approximately monthly intervals (shoots per 10 m of row or dual-row bed) in permanently pegged subplots. Counts of nutgrass shoots in selected treatments were recorded in January 2008. In July 2008, numbers of millable cane stalks (number per 10 m row) were recorded in all plots at each site.

The yield of plant cane was determined in October 2008 using a weigh bin to record the weight of each row in a plot.

Ratoon cane biomass

The effect of nutgrass on ratoon cane was evaluated by:

(a) selecting ratoon blocks with patchy nutgrass and measuring cane biomass in replicated plots in areas with and without nutgrass, and

(b) monitoring first-ratoon cane after the harvest of plant cane at the Mororo and Woodford Island 'Yield Effect' sites (see above). This involved recording ratoon-cane shoot emergence and using a weigh bin to record year-old first-ratoon yield in 2009.

Three blocks of ratoon cane (9-10 months old) with patchy nutgrass and a general absence of other weed problems were selected. In areas with nutgrass, four replicate 10 m lengths of row (or dual row bed) were marked out at each site. Similarly, in adjacent areas without any nutgrass (or very little nutgrass), four replicate 10 m lengths of row were marked out. In each 10 m section, the total number of cane shoots and millable stalks was recorded. The method of Hogarth and Skinner (1967) was used to determine cane biomass (tops + stalks). Nutgrass shoot density was recorded in a 200 mm square quadrat in the middle of the row in the centre of each 10 m section.

Soybean biomass

The effect of nutgrass on soybean biomass was determined at two sites in the Harwood mill area. At each site, adjacent areas with and without nutgrass were sampled in established soybean crops in early February 2009. Soybean plant densities were recorded in each area. All of the above-ground soybean biomass from 1 m^2 quadrats was sampled, dried at 60°C and weighed. The samplings for these data were from unreplicated plots and, therefore, no statistical analysis was possible.

Nutrient uptake and soil moisture extraction by nutgrass

It is intuitively known that nutgrass (and weeds in general) takes nutrients and soil moisture from the cane crop, but there is little data as to the magnitude of the amounts removed. In this study we documented nutrient removal by nutgrass by replicated sampling of nutgrass swards at two sites.

The sites used for this study were the yield-effect trial sites in the Harwood mill area. The Mororo trial consisted of single cane rows at 1.5 m spacing, whereas the Woodford Island site was dual-cane rows at 1.8 m spacing. The above-ground portion of nutgrass was sampled from replicated quadrats in plots (four replicates) where there had been no control of nutgrass. Quadrats (0.2 m x 0.2 m) were located in the inter-row space with the quadrat centered 0.3 m from the cane row. The quadrats were centered about 0.3 m and 0.5 m from the fertilizer band at the Mororo and Woodford Island sites, respectively. Sampling was undertaken on 2 February 2009. The nutgrass density was recorded and the nutgrass was then cut at ground level, dried at 60°C and weighed. Plant tissue analysis (N, P, K, S, Ca, Mg, Mn, Fe, Cu, Zn, B) was then undertaken on the dried material. Nutrient uptake by nutgrass tops was then calculated.

The effect of nutgrass on soil moisture was measured by collecting soil samples at intervals after a rainfall event at the Mororo 'yield-effect' trial. It had been hoped to set up soil moisture data loggers at these sites to monitor soil moisture over extended periods. However, cost and time constraints prevented us from getting the loggers working. Soil samples (0-25 cm depth) were taken from 3 replicate plots in each of 'no nutgrass' and 'nutgrass not controlled' treatments at 1, 4, 8 and 12 days after 24 mm rain on 23 February 2009. A rain period 10-12 March precluded any further sampling. The gravimetric soil-moisture content was determined after drying the soil at 105°C.

3.3.2 Results and Discussion

Plant cane
Cane establishment was excellent at the Mororo trial. However, despite using good quality billets, there was a less than perfect establishment at the Woodford Island trial. Examination of the establishment gaps suggested that some were due to the absence of billets but that some billets had struck short roots, but failed to develop further or produce a viable shoot. Given the short time between incorporation of a vigorous sward of nutgrass and cane planting, it is possible that an allelopathic effect may partially explain the gappy establishment of the cane. Evidence for an allelopathic effect of nutgrass on soybean in a nearby field is presented in Appendix 2.

Cane growth in three treatments at the Mororo site is shown in Plate 3. The effect of the same treatments on cane growth at the Woodford Island site is shown in Plate 4.

At the Woodford Island trial (Plate 4) the T2 treatment had been sprayed for the first time only 12 days prior to the photograph being taken and chlorotic nutgrass is still evident.

Nutgrass not controlled	Nutgrass allowed to grow for 4 weeks then controlled	Nutgrass controlled since cane planting

Plate 3 - Effect of different levels of nutgrass control on cane growth 100 days after planting at the Mororo trial

Nutgrass not controlled | Nutgrass allowed to grow for 4 weeks then controlled | Nutgrass controlled since cane planting

Plate 4 - Effect of different levels of nutgrass control on cane growth 60 days after planting at the Woodford Island trial

In addition to the effect on cane growth (Plates 3 and 4), there was a pronounced effect of the period of nutgrass control on numbers of cane shoots (Table 8). There was about a 40% reduction in numbers of cane shoots in plots where nutgrass had not been controlled compared to no-nutgrass plots. These reductions in growth (Plates 3 and 4) and cane-shoot numbers were associated with what are medium nutgrass densities of about 600-800 nutgrass shoots m^{-2} (Table 8). Nutgrass shoot densities of about 1600 shoots m^{-2} were recorded in preliminary surveys (Table 3) and other studies (Charles, 2002) have recorded densities of up to 2200 shoots per m^{-2}.

The effect on cane-shoot numbers was also evident in the February shoot counts (Table 9). The slight reduction in cane-shoot density for the ‘No nutgrass’ treatment at the Mororo trial (22 to 19 shoots m^{-1}; Tables 8 and 9) is attributed to ‘crowd out’, as only live shoots were counted. In the less-advanced crop at Woodford Island, there was a 154% increase in cane-shoot numbers in the ‘No nutgrass’ plots from 10 January to 27 February (11 to 28 shoots m^{-1}), whereas in the ‘nutgrass not controlled’ plots there was only a 40% increase (7 to 10 shoots m^{-1}).

Table 8 - Effect of nutgrass on cane-shoot numbers (10 January 2008)

Treatment	**Trial**	
	Mororo (cane shoots / m of row)	**Woodford Island (cane shoots / m of dual-row bed)**
No nutgrass	22	11
Nutgrass for 4 weeks & then controlled	15	6
Nutgrass not controlled	13 (600 nutgrass shoots m^{-2})	7 (825 nutgrass shoots m^{-2})
	Cane planted 14/10/2007	Cane planted 23/11/2007

Table 9 - Effect of nutgrass on cane-shoot numbers (27 February 2008)

Treatment	Trial	
	Mororo (cane shoots / m of row)	**Woodford Island (cane shoots / m of dual row bed)**
No nutgrass	19	28
Nutgrass for 4 weeks & then controlled	15	20
Nutgrass for 8 weeks & then controlled	13	11
Nutgrass for 12 weeks & then controlled	12	10
Nutgrass not controlled	12	10
	Cane planted 14/10/2007	Cane planted 23/11/2007

There was a significant (P=0.01) treatment effect on millable stalk numbers at each site, with more millable stalks in treatments with no nutgrass (Table 10).

Table 10 - Effect of nutgrass on millable-stalk numbers of plant cane (July 2008)

Treatment	Trial	
	Mororo (stalks / m of row)	**Woodford Island (stalks / m of dual row bed)**
No nutgrass	12^{A}	17^{A}
Nutgrass for 4 weeks & then controlled	12^{A}	14^{A}
Nutgrass for 8 weeks & then controlled	11^{A}	11^{B}
Nutgrass for 12 weeks & then controlled	10^{B}	10^{B}
Nutgrass not controlled	10^{B}	9^{B}
	P=0.0076 LSD=1.4	P=0.002 LSD=2.9
	Cane planted 14/10/2007	Cane planted 23/11/2007

For a given trial, values with the same superscript letter are not significantly different (P=0.05).

The effect of different levels of nutgrass control on cane yield is shown in Table 11. At the Mororo trial, there was a significant (P=0.01) reduction in cane yield when nutgrass was left uncontrolled for periods of 8 weeks or more following planting. Even a period of 4 weeks after planting without nutgrass control resulted in a trend for reduced yield (Table 11). Similarly, at the Woodford Island site nutgrass reduced cane yield. The magnitude of the yield reductions recorded were similar at both sites with a 27% yield loss in plots where nutgrass was allowed to grow uncontrolled compared to nutgrass-free plots (Table 11 and Plate 5).

Table 11 - Effect of nutgrass on plant-cane yield (October 2008)

Treatment	Trial*	
	Mororo (tonnes cane / ha)	**Woodford Island (tonnes cane / ha)**
No nutgrass	96.7^{A}	103.9^{A}
Nutgrass for 4 weeks & then controlled	85.6^{AB}	103.0^{A}
Nutgrass for 8 weeks & then controlled	79.2^{BC}	94.7^{AB}
Nutgrass for 12 weeks & then controlled	72.1^{BC}	84.2^{BC}
Nutgrass not controlled	70.6^{C}	75.7^{C}
	P = 0.0004 LSD = 11.6	P=0.0004 LSD=11.9
	Cane planted 14/10/2007 Harvested 27/10/2008 Empire variety	Cane planted 23/11/2007 Harvested 28/10/2008 Q205$^{\phi}$ variety

* For a given trial, values with the same superscript letter are not significantly different (P=0.05).

Plate 5 - Harvesting Mororo trial using a weigh bin (insets). Main picture shows 'nutgrass not controlled' plot (left) and 'no nutgrass' plot (right)

These yield reductions were associated with moderate nutgrass levels in untreated plots at the Mororo trial (600 nutgrass shoots m^{-2}) and somewhat heavier nutgrass levels at the Woodford Island trial (825 nutgrass shoots m^{-2}) recorded in late January 2008. Higher nutgrass shoot densities (> 1600 shoots m^{-2}) have been recorded in cane blocks as part of this project (Table 3).

At the Woodford Island yield-effect trial, tuber viability was markedly affected by treatment. Soil cores were obtained from three treatments: 'no nutgrass', 'nutgrass for 4 weeks & then controlled' and 'nutgrass not controlled', with densities of 50, 140 and 980 viable tubers/m^2, respectively, for samples collected 30 January 2008. These data show that repeated spot spraying with ethoxysulfuron (Hero®) had a significant effect on viability of nutgrass tubers. The effect of nutgrass-specific herbicides on tuber viability is discussed further in Section 3.4.

The large yield reductions (Table 11) were recorded in a season in which the rainfall for the December-May growing period was in excess of the long-term average rainfall (Table 12). During January-May the soil moisture profile was full and moisture was generally non-limiting for cane growth. It is probable that even larger yield reductions would have been recorded had soil moisture regimes been drier leading to a bigger competition effect from the nutgrass.

Table 12 - Rainfall (mm) for the December 2007 to May 2008 cane-growth period

Site	Dec '07	Jan '08	Feb '08	Mar '08	Apr '08	May'08	Total
Woodford Island	41.5	202.5	368.5	33.0	87.0	31.0	763.5
Harwood	44.2	313.2	283.7	27.7	237.4	43.0	949.2
Long-term average (Harwood 126 years)	107.0	140.6	158.7	168.2	129.2	126.7	830.4

At the Woodford Island trial, selected treatments were sampled for laboratory determination of sugar content. Cane juice was extracted using a small mill and POL measured (Table 13). Nutgrass decreased POL, even when present for only 4 weeks (Table 13). Cane-shoot counts showed that in February-May there was a significant number of small, recent cane shoots in all treatments except the 'no nutgrass' plots. Between February and May, the nutgrass senesced, allowing late cane shoot development. However, these shoots remained immature. This resulted in a higher proportion of millable, mature stalks in the 'no nutgrass' plots, explaining the markedly higher sugar levels in this treatment. Similarly, shoot and millable stalk counts in ratoon cane (see below) have shown generally higher millable stalk to total shoot ratios in areas without nutgrass compared to areas with nutgrass.

Table 13 - Effect of treatment on POL and sugar yield (October 2008) for selected treatments at the Woodford Island trial

Treatment	Cane yield (tonnes cane / ha)	Pol in cane (PIC)	Sugar yield (tonnes PIC/ha)
No nutgrass	103.9^{A}	14.7^{A}	15.3
Nutgrass for 4 weeks & then controlled	103.0^{A}	11.7^{B}	12.1
Nutgrass not controlled	75.7^{C}	10.6^{B}	8.0
	P=0.0004 LSD=11.9	P=0.0016 LSD=1.7	

Values with the same superscript letter are not significantly different (P=0.05).

Ratoon cane yield and biomass

At each of the three ratoon-cane sites there was a significant (P=0.05) effect of nutgrass on cane biomass (Table 14), with yield reductions of 30%, 32% and 37%. Although there was a trend for reduced millable stalk numbers in areas with nutgrass, the effect was significant at only one site (Table 14). There was no significant effect of nutgrass intensity on total cane-shoot number. These results confirm data from the plant-cane trials suggesting that the effect of nutgrass on cane yield arises from reduced millable stalk numbers and reduced stalk size.

Table 14 - Effect of nutgrass intensity on ratoon-cane shoot and millable stalk numbers and cane biomass

Site & crop	Nutgrass intensity (shoots/m^2)	Total shoot number (shoots/10 m)	Millable stalk number		Average cane biomass		Yield reduction (%)
			(stalks/10 m)	LSD	(t/ha)	LSD	
Farm 1277 Block 4100 Q124 4th ratoon 1.8m single rows	Moderate (575)	190	144	19	63.9	22.7	37%
	No nutgrass (0)	193	179		101.1		
Farm 1279 Block 4110 Q155 2nd ratoon 1.8m dual rows	Heavy (1100)	422	246	NS	101.0	7.9	32%
	Light (<25)	404	256		148.5		
Farm 1162 Block 2210 Empire 1st ratoon 1.5m single rows	Moderate (255)	159	131	NS	79.1	20.9	30%
	Light (40)	175	149		113.8		

When data from all three sites were combined for statistical analysis there was a significant effect of nutgrass on both biomass and millable stalk number (Table 15). The consistent, large yield loss due to nutgrass in ratoon cane highlights the importance of nutgrass control and the magnitude of these yield losses were a surprise to the grower group undertaking this project. This yield effect on ratoon cane contrasts with the perception of a significant proportion of growers who consider that nutgrass is mainly only a problem in plant cane. The pre-project survey (Section 3.1) indicated that 40% of growers across the three mill areas perceived nutgrass to be a problem mainly in plant cane and not in ratoons (Condong – 31%; Broadwater – 46%; Harwood – 42%).

Table 15 - Effect of nutgrass intensity on ratoon-cane shoot and millable stalk numbers and cane biomass - data from three ratoon sites combined

Nutgrass intensity	Total shoot number (shoots/10m)	Millable stalk number (stalks/10m)	Average cane biomass (t/ha)
Nutgrass	257	174	81.3
No or light nutgrass	257	195	121.1
	NS	P=0.0023	P<0.0001

At the two ‘yield-effect’ trials there was no control of nutgrass in the ratoon crop and other weeds were controlled by herbicides that had little or no effect on nutgrass. Although there was no statistically significant effect of treatments imposed during the plant crop on first-ratoon yields (Tables 16 and 17), there was a trend for reduced yield with increasing plant-cane nutgrass density, indicating residual effects from plant-cane treatments. These results suggest that a concerted effort at controlling nutgrasss during the plant crop will have benefits into the first ratoon, even if no nutgrass-specific control measures are used in the first ratoon. Total yield (plant plus first ratoon) data (Table 18) suggests that good control of nutgrass in the plant crop would result in yield benefits of around 15-20% over the plant and first-ratoon crops.

Despite the absence of nutgrass in ‘no nutgrass’ plots (Plate 6) and considerable nutgrass in ‘nutgrass not controlled’ plots, the yield response in first-ratoon cane was not as great as that recorded in the plant crop (Tables 16 and 17). Environmental/seasonal factors may have played a role in this, but it also indicates that the plant crop is more ‘sensitive’ to nutgrass – a not unexpected finding. A grower survey early in the project showed that many growers perceived nutgrass to be a bigger problem in the plant cane crop. In contrast to the results presented in Tables 16 and 17 for first-ratoon cane at the ‘yield-effect’ trials, biomass samplings of ratoon cane showed large and statistically significant effects of nutgrass on cane yield, with 30-37% yield reductions.

Measurements of nutgrass density at the Woodford trial highlight the benefit of early control of nutgrass in the plant-cane crop. In contrast, when nutgrass was left uncontrolled for 8 or 12 weeks, nutgrass densities were not significantly different from the ‘nutgrass not controlled’ treatment (Plate 6). These residual effects (Plate 6) suggest that ‘good’ nutgrass control over an extended period (October-April) will keep nutgrass densities low while ‘good’ control for a shorter period (January-April) is less effective due to regeneration of nutgrass.

At the Mororo trial there was a general trend (not significant P=0.05) for CCS to decrease with increasing nutgrass pressure (Table 16), but no consistent trend was recorded at the Woodford trial (Table 17). A CCS/POL effect for a limited sampling at the Woodford trial was previously presented in Table 13. While this CCS effect was not evident in the first ratoon (Table 17), data from other trials suggest trends for decreasing CCS/POL with increasing nutgrass density.

Table 16 - Effect of nutgrass on plant and ratoon cane yield at the Mororo trial (Empire variety)

Treatment (plant crop)	Crop class		
	Plant cane*	First ratoon	
	Cane yield** (t/ha)	Cane yield (t/ha)	CCS
No nutgrass	96.7^{A}	64.4	15.74
Nutgrass for 4 weeks & then controlled	85.6^{AB}	67.1	15.55
Nutgrass for 8 weeks & then controlled	79.2^{BC}	62.1	15.65
Nutgrass for 12 weeks & then controlled	72.1^{BC}	58.1	15.20
Nutgrass not controlled	70.6^{C}	57.3	15.29
	P = 0.0004 LSD = 11.6	NS P=0.06	NS P=0.16
	Cane planted 14/10/2007 Harvested 27/10/2008	Harvested 21/10/2009	

* CCS not measured on plant cane at this site.
**Values with the same superscript letter are not significantly different (P=0.05).

Table 17 - Effect of nutgrass on plant and ratoon cane yield at the Woodford trial ($Q205^{\Phi}$ variety)

Treatment (plant crop)	Crop class			
	Plant cane		First ratoon	
	Cane yield* (t/ha)	CCS*	Cane yield (t/ha)	CCS
No nutgrass	103.9^{A}	13.94^{A}	124.8	13.49
Nutgrass for 4 weeks & then controlled	103.0^{A}	10.63^{B}	122.9	14.69
Nutgrass for 8 weeks & then controlled	94.7^{AB}	-	118.7	14.19
Nutgrass for 12 weeks & then controlled	84.2^{BC}	-	120.7	14.28
Nutgrass not controlled	75.7^{C}	9.49^{B}	118.7	14.69
	P=0.0004 LSD=11.9	P=0.003 LSD=2.06	NS P=0.45	NS P=0.41
	Cane planted 23/11/2007 Harvested 28/10/2008		Harvested 22/10/2009	

* For a given site, values with the same superscript letter are not significantly different (P=0.05).

Table 18 - Effect of nutgrass control in the plant crop on total yields (Plant + First Ratoon) at the Mororo and Woodford trials

Treatment (plant crop)	Total cane yield (t/ha)		Relative yield (%)	
	Mororo	Woodford	Mororo	Woodford
No nutgrass	161.1	228.7	100	100
Nutgrass for 4 weeks & then controlled	152.7	225.9	94.8	98.8
Nutgrass for 8 weeks & then controlled	141.3	213.4	87.7	93.3
Nutgrass for 12 weeks & then controlled	130.2	204.9	80.8	89.6
Nutgrass not controlled	127.9	194.4	79.4	85.0

Treatment (plant crop)	Nutgrass density (shoots/m^2)
No nutgrass	0
Nutgrass for 4 weeks & then controlled	242
Nutgrass for 8 weeks & then controlled	433
Nutgrass for 12 weeks & then controlled	483
Nutgrass not controlled	542
	P=0.008 LSD=262

Plate 6 - Nutgrass densities November 2009 (one month after first-ratoon harvest) at the Woodford 'yield effect' trial. Photo shows 'no nutgrass' plot (centre/right) and 'nutgrass not controlled' (left).

Relationship between nutgrass shoot density and cane yield

Data from both plant-cane yield-effect trials and ratoon-cane yield-effect assessments were combined to investigate the relationship between nutgrass density and cane yield. Relative cane yields were calculated for individual replicate treatments and plotted against the corresponding nutgrass shoot densities. The relationship (Figure 2) should be regarded as indicative only, as cane yield response to the presence of nutgrass is an integration of the weeds present over the 12 month growing period and the nutgrass shoot densities (Figure 2) represent only one point in time (late January for the plant cane trials and June/July for ratoon trials). Moreover, the nutgrass shoot densities for the ratoon trials were obtained by counting shoots of senesced nutgrass and probably underestimate the peak nutgrass densities in those plots. It is not suggested that the relationship shown in Figure 2 be used for predictive purposes and the low coefficient of determination (R^2=0.50) supports this contention. However, the relationship suggests that nutgrass shoot densities of 1600 shoots m^{-2} (recorded in some ratoon cane blocks) could result in yield reductions of around 50%.

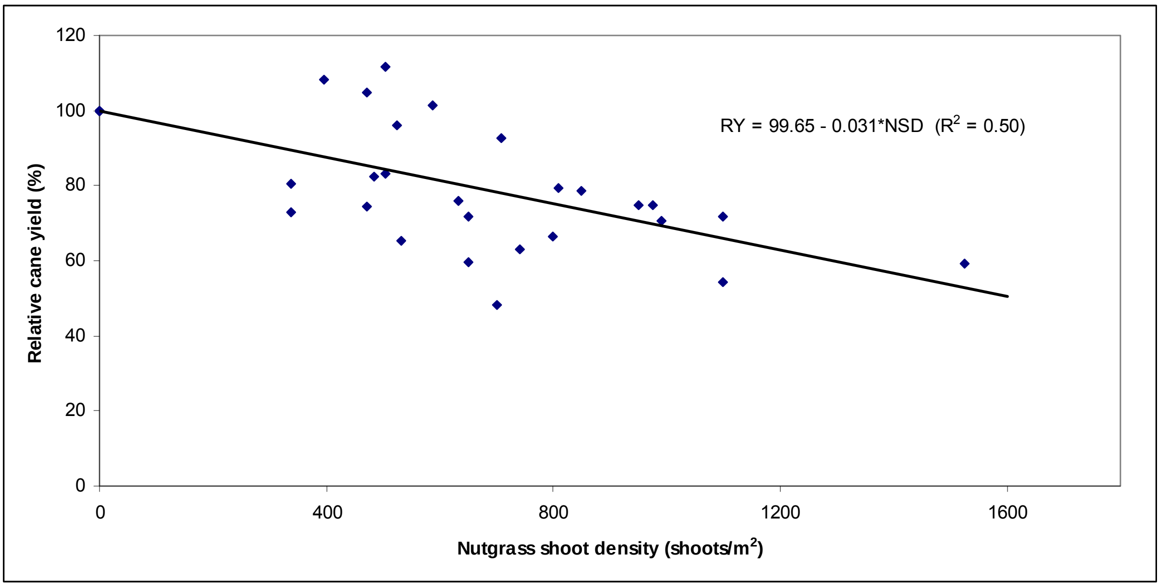

Figure 2 - Relationship between relative cane yield and nutgrass shoot density

Soybean biomass

There was a clear trend for soybean density and biomass to be lower in the areas with higher nutgrass density (Table 19, Plates 7 and 8). At these two sites, the relative soybean densities and biomass reductions were not proportional to the relative nutgrass densities. It is possible that nutgrass had an allelopathic effect on soybean and affected germination. Evidence for such an effect on soybean is presented in Appendix 2.

Table 19 - Effect of nutgrass on soybean biomass

Site	Nutgrass (shoots/m^2)	Soybean density (plants/m^2)	Soybean biomass (kg/ha)
Farm 1016 Block 720	0	50	556
	141	18	166
Farm 1159 Block 800	9	39	1669
	450	21	802

Plate 7 - Soybean growth in the presence (left) and absence (right) of nutgrass (Farm 1016)

Plate 8 - Soybean growth with moderate (left) and very low (right) nutgrass densities (Farm 1159)

Nutrient uptake and soil moisture extraction by nutgrass

The uptake of nutrients by nutgrass at two sites, together with nutgrass density and biomass, is presented in Table 20. The higher average nutgrass biomass at the Mororo site is attributed to a higher nutgrass density, higher rainfall environment and closer proximity to the applied fertilizer.

At the Mororo site the nutgrass tops had taken up 47 kg N/ha from the soil (Table 20). This is the equivalent of 1 bag urea/acre or about one-quarter of the nitrogen applied to a 2-year cane crop in NSW.

At the Woodford Island site the nutgrass tops removed 23 kg N/ha – a lower value probably attributed to lower nutgrass biomass and the nutgrass sampled being a greater distance from the applied fertilizer band.

The nitrogen uptake measured represents only a portion of total uptake as the nitrogen in roots and tubers was not measured.

Table 20 - Average nutgrass density, biomass and uptake of nutrients by nutgrass at two sites

Measurement	Site	
	Mororo	Woodford Island
Nutgrass density (shoots/m^2)	1456	1125
Nutgrass biomass (kg dry wt/ha)	2800	1731
N uptake (kg/ha)	47	23
P uptake (kg/ha)	3	2
K uptake (kg/ha)	49	46
S uptake (kg/ha)	5	8
Ca uptake (kg/ha)	23	11
Mg uptake (kg/ha)	12	5
Mn uptake (kg/ha)	1.25	1.03
Fe uptake (kg/ha)	0.66	0.98
Cu uptake (kg/ha)	0.01	0.01
Zn uptake (kg/ha)	0.07	0.12
B uptake (kg/ha)	0.06	0.04

The uptake of phosphorus by nutgrass tops was around one-eighth to one-tenth of the phosphorus removed by a well-grown cane crop. Uptake of potassium was high, with 46-49 kg K/ha in the tops (Table 20). This is the equivalent of about two 40 kg bags CK44 per acre and is approximately the amount of potassium many growers would be applying at planting. Sulfur uptake was about half of that applied to low-sulfur soils in the Harwood mill area. In a USA study, Holm *et al.* (1977) measured nutrients in nutgrass tops, roots and tubers and recorded values of 160 kgN/ha, 160 kgK/ha and 67kgP/ha. The uptake of significant amounts of nitrogen and potassium by nutgrass begs the question as to how much nutrients are taken up by weeds in general.

The effect of nutgrass on soil moisture is shown in Figure 3. Four days after rainfall there was a gravimetric moisture difference of 3.3% (Figure 3). This difference is equivalent to 11.5 mm of rainfall assuming the rain was evenly distributed through the 0-25 cm depth and a soil bulk density of 1.4 g/cm^3.

This moisture difference remained relatively constant over the following 8 days. However, it should be remembered that this is not an absolute measure of the effect of nutgrass on soil moisture as the results are confounded by the presence of cane in the plots sampled. The 'no nutgrass' plots had large cane plants whereas the 'nutgrass' plots had markedly smaller cane.

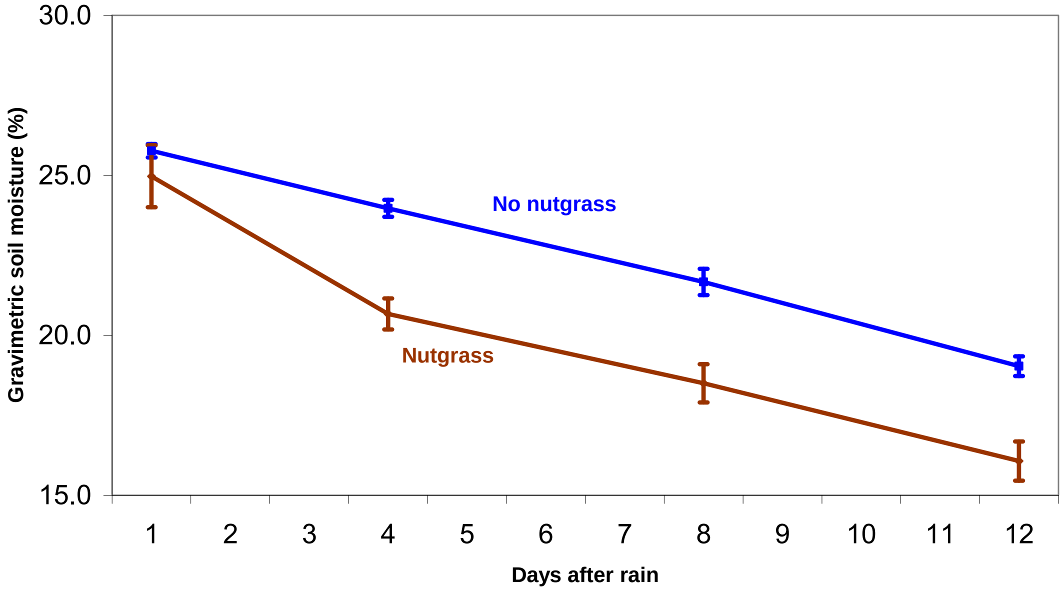

Figure 3 - Effect of nutgrass on gravimetric soil moisture at various times after a rainfall event. Vertical bars are one standard deviation of the mean

3.4 Tuber-viability trial

The literature clearly documents the effect of glyphosate on nutgrass tuber viability and the trials reported here did not include a gylphosate treatment. However, a review of literature suggested that some of the newer products for nutgrass control, such as Krismat® (ametryn/trifloxysulfuron sodium) and Hero® (ethoxysulfuron), had the potential to affect tuber viability. A trial to assess the effect of some available herbicides on tuber density, viability and crop growth was therefore established on Woodford Island (Harwood mill area) in late December 2007.

3.4.1 Methods

The trial was a randomized block design with six treatments and two replicate strips of each treatment. Individual plots were four rows wide and 75 m long. The treatments were:

1. Check (no nutgrass control)
2. Hero® (250 g/ha)
3. Sempra® (140 g/ha)
4. Krismat® (2 kg/ha)
5. Krismat® (2 kg/ha) & Actril® DS (400 mL/ha)
6. 2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D.

Treatments were applied on 20-21 December 2007, using a boom spray capable of spraying the 4-row plots (Plate 9). All spray treatments were applied using Hardi Injet 04 nozzles operated at 5 bar and applying 350 L/ha. Initially, it was intended that the Krismat® application for Treatment 6 be applied 2-3 weeks after the 2,4-D application but very wet weather precluded its application until 20 January 2008.

Plate 9 - Boom-spray application of Krismat® (20 December 2007)

Treatment effects were visually assessed at weekly intervals (see Plates 10-12) and soil cores were collected on 30 January 2008 (40 days after treatment application). We took 28 cores (0-15 cm depth) from each plot and separately bagged them. The tubers were washed from the soil cores, counted and then all tubers from an individual plot were bulked and assessed for viability. Tuber viability was determined by placing the tubers into moistened potting mix in shallow trays in a glasshouse and counting germinated tubers at weekly intervals for 3 months. Cane yield from each plot was obtained on 28 October 2008 using a weigh bin to weigh each row in the plot.

Following the harvest of the plant crop (October 2008), we measured nutgrass density and cane shoot numbers in early December 2008 to gauge the residual effects from herbicide application in Dec/Jan 2007/08. The six treatments (see above) were then reapplied during Dec/Jan 2008/09 except that:

- treatment 5 was changed to two Actril® DS applications 4 weeks apart;
- inadvertently, treatment 4 received two applications of Krismat® (2 kg/ha) 4 weeks apart.

Nutgrass density and cane shoot numbers in the first-ratoon crop were recorded in January 2009, but the viability of tubers was not assessed in that crop. The first-ratoon crop was harvested at 1-year old in November 2009 and the yield was recorded using a weigh bin. During the harvest of the ratoon crop, a sample of millable stalks was obtained from each plot for small-mill CCS.

3.4.2 Results and discussion

As expected, all herbicide treatments affected the nutgrass (Plate 10). The most pronounced immediate effect was observed in the Krismat®/Actril® DS treatment and we attribute this to the Actril® DS component (Plate 11). However, subsequent observation indicated that the nutgrass in this treatment recovered relatively quickly, suggesting that the

Actril® DS inhibited the capacity for the plant to translocate the Krismat®. Treatments 2, 3 and 4 gave approximately similar lengths of nutgrass control (Plate 12).

Plate 10 - Hero® treated plot (front) and untreated plot (back) 14 DAA

Plate 11 - Krismat®/Actril® DS treatment 14 DAA

In terms of longevity of control, visual observations suggested that the best treatment was Treatment 6 (2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks later). The initial 2,4-D application gave the usual 2-3 weeks control of nutgrass. However, 4 weeks after 2,4-D application the nutgrass was again green and actively growing. Application of Krismat® at this stage was then effective (Plate 12).

Although there was no significant (P=0.05) difference in nutgrass tuber density (0-15 cm depth) across the treatments with an average of 1620 tubers m^{-2}, the trial had a very high coefficient of variation (56%), indicating variable tuber density across the site (range 284-2586 tubers m^{-2} for individual plots). Therefore, the results of this trial need to be interpreted cautiously.



1. Control (no herbicide) **2. Hero®** **3. Krismat®**



4. Sempra® **5. Krismat®/Actril® DS** **6. 2,4-D & Krismat® later**

Plate 12 - Treatment plots (tuber viability trial) 49 DAA

All herbicide treatments resulted in a significant decrease in viable tuber density (Table 21), but there was no significant difference in viable tuber density across the commercial products. There was a trend (not significant P=0.05) for Sempra® to have fewer viable tubers than the other commercial products. The trends for increased cane yield and the reduction in tuber viability (Table 21) suggest that the use of herbicides specific for nutgrass would prove economical. The results suggest that nutgrass-specific herbicide application not only produces a yield benefit in the crop to which it is applied but also reduces viable tubers in the soil. The latter effect is an important strategy in achieving long-term nutgrass control.

Table 21 - Effect of commercial nutgrass herbicides on cane yield, nutgrass tuber viability

Treatment	Cane yield (t/ha)	Total tubers/m^2	Viable tubers/m^2 *	Tuber viability * (% relative to 'nutgrass not controlled')
Check (nutgrass not controlled)	51.6	1581	427	100
Hero® (250 g/ha)	79.7	1940	101	25
Sempra® (140 g/ha)	82.6	1738	4	1
Krismat® (2 kg/ha)	74.2	1525	97	19
Krismat® (2 kg/ha) & Actril® DS (400 mL/ha)	69.3	1091	75	21
2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D	83.8	1846	41	7
	NS	NS	LSD=281	

* Nutgrass tubers sampled 40 days after herbicide application and assessed for viability

The 'check' treatment had a generally low proportion of viable tubers at about 30%. Although this was somewhat lower than expected, it is not outside the range of values previously recorded for nutgrass (G. Charles, pers. comm.) and, despite the long period of viability assessment (approx. 3 months), it is likely that many tubers remained dormant during the autumn/winter viability assessment period. Dormancy percentages of up to 70% have been recorded for nutgrass (G. Charles pers. comm.). In our trial, the effectiveness of the commercial products (Sempra® in particular) was higher than that recorded in trials undertaken in the cotton industry (G. Charles pers. comm.). We suggest that this may in part be due to differences in climate and nutgrass growth rates on the coastal floodplains compared to the drier inland areas where cotton is grown. In the wetter coastal environment, herbicide may be more effective as nutgrass is likely to be more actively growing at application time.

Recognising that there was some variability in baseline nutgrass density across the site, the relationship between cane yield and viable tuber density in individual replicate plots was investigated (Figure 4). Cane yield decreased linearly (R^2=0.64) with increasing density of viable nutgrass tubers (recorded 40 days after herbicide application) highlighting the importance of a long-term strategy for reducing numbers of viable tubers in cane soils.

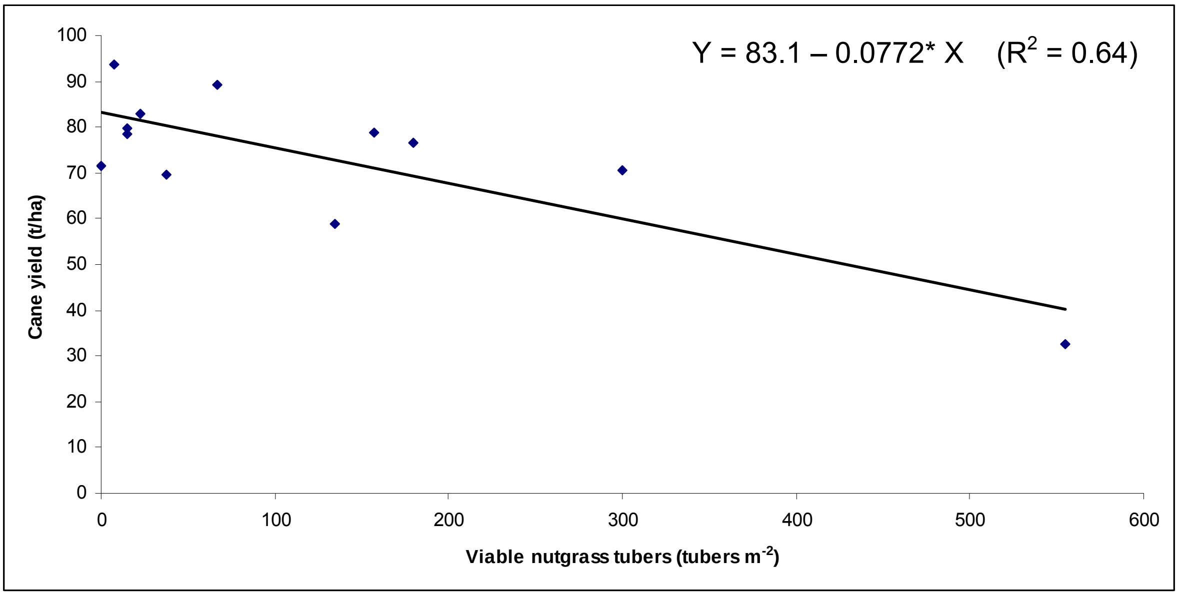

Figure 4 - Relationship between cane yield and viable nutgrass tuber density 40 days after treatment application

Inspection of this trial site in late November 2008 (after harvest in late October) showed that there were visual differences across the plots in ratoon-cane growth. These residual effects from treatments applied in 2007 are shown in Table 22.

Although there was no significant effect ($P<0.05$) of herbicide on cane shoot numbers there was a marked trend for fewer shoots in the treatment without any nutgrass control. Ratoon cane growth (visual assessment) was clearly retarded in plots without any nutgrass control. There was a significant effect of herbicide on nutgrass density recorded 12 months after herbicide application (Table 22) and these results support and confirm the tuber viability data (Table 21). There was a trend for treatments 2, 3 and 6 to have lower nutgrass densities than the other herbicide treatments but statistical analysis indicated no significant ($P<0.05$) differences between any of the herbicide treatments.

Table 22 - Effect of herbicides applied to plant cane on cane and nutgrass densities in the first-ratoon crop (December 2008)

Treatment (Dec/Jan 07/08)	Cane shoots/m of dual-row bed	Nutgrass density (shoots/m^2)
1. Check (nutgrass not controlled)	37	676
2. Hero® (250 g/ha)	49	94
3. Sempra® (130 g/ha)	55	31
4. Krismat® (2 kg/ha)	47	201
5. Krismat® (2 kg/ha) & Actril® DS (400 mL/ha)	44	163
6. 2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D	47	82
	NS	LSD=314 P=0.0224

Following reapplication of treatments during Dec/Jan 2008/09, all herbicides significantly reduced live and total nutgrass shoot density (Table 23). Again, there was no statistically significant difference amongst herbicide treatments, but there was a clear trend for treatments 2, 3, 4 and 6 to be more effective in lowering the density of live nutgrass shoots.

Table 23 - Effect of herbicides on cane and nutgrass densities in the first-ratoon crop (January 2009)

Treatment (Dec/Jan 08/09)	Cane shoots/m of dual-row bed	Nutgrass density (shoots/m^2)		
		Live	Dead	Total
1. Check (nutgrass not controlled)	37	615	160	775
2. Hero® (250 g/ha)	47	25	175	200
3. Sempra® (130 g/ha)	52	0	100	100
4. Krismat® (2 kg/ha) & then Krismat® (2kg/ha) 4 weeks later*	48	0	150	150
5. Actril® DS(1 L/ha) and then Actril® DS (1 L/ha) 4 weeks later	43	50	175	225
6. 2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D	49	0	13	13
	NS	LSD=73 P=0.001	NS	LSD=200 P=0.002

* Inadvertently received two applications of Krismat®.

There was no statistically significant effect of treatment on the yield of first-ratoon cane (only two replications of each treatment at this site), but herbicide application generally resulted in increased cane yield (Table 24). A 'double-knock' application of Actril® DS had minimal impact on improving cane yield, but other nutgrass-specific herbicides resulted in trends for higher cane yield (Table 4). There was also a general trend (not significant P=0.05) for CCS to be higher where nutgrass was controlled.

Table 24 - Effect of nutgrass-specific herbicides on plant and first-ratoon cane yields and nutgrass density (November 2009) in the tuber-viability trial

Treatment (plant crop)	Cane yield (t/ha)	Treatment (first ratoon)	First ratoon			Total yield P+1R (t/ha)
			Cane yield (t/ha)	CCS	Nutgrass density (shoots/m^2)	
Check (nutgrass not controlled)	51.6	Check (nutgrass not controlled)	115.0	14.46	950	166.6
Hero® (250 g/ha)	79.7	Hero® (250 g/ha)	132.6	14.55	138	212.3
Sempra® (130 g/ha)	82.6	Sempra® (130 g/ha)	137.8	14.82	25	220.4
Krismat® (2 kg/ha)	74.2	Krismat® (2 kg/ha) and Krismat® (2 kg/ha) 4 weeks later *	122.7	14.67	0	196.9
Krismat® (2 kg/ha) & Actril® DS (400 mL/ha)	69.3	Actril® (400 mL/ha) and Actril® (400 mL/ha) 4 weeks later	116.5	14.80	213	185.8
2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D	83.8	2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D	122.8	15.17	25	206.6

* inadvertently received two applications of Krismat (2 kg/ha) 4 weeks apart.

All herbicide treatments significantly (P=0.10) reduced nutgrass density (Table 24). However, there was no significant difference amongst herbicides on nutgrass density despite trends for the Sempra® and the 'double knock' treatments of 'Krismat® + Krismat®' and '2,4-D + Krismat®' to have lower nutgrass densities. A 'double knock' of Actril® DS in the first-ratoon was less effective in reducing nutgrass density than the other herbicide treatments.

3.5 Shielded sprayer and trials using a dual-delivery sprayer

A review of literature and discussion with project collaborator Graham Charles (NSWDPI with experience regarding nutgrass in cotton) had indicated that application of glyphosate to inter-row areas using shielded sprayers would play an important role in long-term nutgrass control. As part of this project a four-row dual-delivery spray rig was constructed (see Appendix 3) and tested.

3.5.1 Methods

A trial aimed at assessing the use of glyphosate application to the inter-row was established on 2 December 2008 in a block of third-ratoon Q193$^{\Phi}$. There were 5 treatments with 3 replicates in a randomized block design with each plot 4 rows wide x 280 m long. Treatment details are shown in Table 25. The entire block had been sprayed with paraquat/Balance®/atrazine on 10 November 2008 (cane at 3-leaf stage) after being harvested on 7 October 2008. Cane shoots (number per 10 m row) were counted in each plot and nutgrass densities were recorded on 29 January 2009, 58 days after herbicide application. In October 2009, a weigh bin was used to determine the yield of cane for each replicate plot (individual plot size was 0.2 ha).

Table 25 - Trial treatments applied to assess the dual-delivery sprayer

Treatment			Application method
#	Inter-row	Row	
1	Glyphosate	Hero®	Dual-delivery rig
2	Flame®	Hero®	Dual-delivery rig
3	Hero®	Hero®	Directed spray
4	Krismat®	Krismat®	Directed spray
5	Sempra®	Sempra®	Directed spray

3.5.2 Results and Discussion

Although there was no significant effect (P<0.05) of herbicide on number of cane shoots 58 days after application (Table 26), there was a trend for Treatment 1 to have lower numbers of live cane shoots. Visual observation indicated that the glyphosate had resulted in death of some cane shoots – mainly prostrate cane shoots growing into the inter-row space that had gone under the spray hood. A count of dead cane shoots (Table 26) showed that Treatments 1 and 2 had significantly higher numbers of dead cane shoots, with the glyphosate treatment having significantly more dead cane shoots than the Flame® treatment. The shielded sprayers used were a fixed width and were not adjustable. This feature, combined with the fact that the block sprayed was an old ratoon with variable row spacing (not established using GPS), has led to some cane shoots being affected by the herbicides applied (Table 26).

Table 26 - Effect of herbicides applied using dual-delivery and directed sprays on numbers of cane shoot, densities of nutgrass shoots and nutgrass vigour 58 days after application

Treatment			Cane shoots/m		Nutgrass in cane row (shoots/m^2)		Nutgrass in inter-row (shoot/m^2)		Nutgrass vigour
#	Inter-row	Row	Live	Dead	Live	Dead	Live	Dead	
1	Glyphosate	Hero®	53	2.6	58	125	50	100	2.5
2	Flame®	Hero®	59	1.4	50	217	100	250	2.3
3	Hero®	Hero®	63	0.3	0	50	133	100	3.0
4	Krismat®	Krismat®	58	0.6	117	117	150	58	3.8
5	Sempra®	Sempra®	57	0	8	350	83	258	1.7
			NS	LSD=1.1	LSD=23	NS	NS	NS	

For herbicides applied to the cane row there were differences in densities of live nutgrass (Table 26). However, care is required in interpreting the results as there appears to have been a lower background nutgrass density in the rows of Treatment 3 plots as total (live + dead) nutgrass densities were markedly lower in this treatment (Table 26). For effectiveness on nutgrass, the herbicides applied to the row area were in the order Sempra® > Hero® > Krismat®.

Considering the inter-row area, there were no significant differences in the densities of either live or dead nutgrass across the treatments applied. There was a trend for gylphosate and Sempra® treatments to have lower densities of live nutgrass shoots. However, in terms of the ratio of dead/total nutgrass shoots, the herbicides were ranked Sempra® = Flame® = gylphosate > Hero® > Krismat®.

The plots were visually rated for nutgrass vigour on a 1-5 scale; where 1 = all nutgrass dead and 5 = vigorous sward of nutgrass present. The averages of these ratings are shown in Table 26 with the Sempra® treatments rated as having the least vigorous nutgrass. The visual score was consistent with the herbicide efficacy rankings discussed above (Sempra®=Flame®=Glyphosate®>Hero®>Krismat®).

On 8 April 2009 the trial was visually assessed for nutgrass regeneration as 4 months had elapsed since treatment application. In terms of efficacy in reducing nutgrass regrowth the treatments were ranked Glyphosate/Hero® > Flame®/Hero® = Sempra®/Sempra® > Hero®/Hero® > Krismat®/Krismat®.

The preliminary results obtained (Table 26) suggest that a dual-delivery sprayer is not essential to obtain satisfactory control of nutgrass in older ratoons. The use of a directed spray with an appropriate nutgrass-specific herbicide will give similar control to that achieved with a dual-delivery system applying glyphosate to the inter-row. Tuber viability data (not recorded in this trial) would be required to support this contention. Given that dual-delivery sprayers are rare in the NSW cane industry, most growers would be relying on boom or directed sprayers to control weeds.

Table 27 - Effect of different nutgrass control herbicides and application methods on the yield of ratoon cane (Q193$^{\Phi}$ variety)

Treatment		Application machinery	Cane yield (t/ha)
Inter-row	Row		
Glyphosate	Hero®	Dual-delivery rig	89.9
Flame®	Hero®	Dual-delivery rig	93.2
Hero®	Hero®	Directed spray	97.1
Krismat®	Krismat®	Directed spray	92.4
Sempra®	Sempra®	Directed spray	99.7
			NS P=0.0653

The trial was harvested in October 2009. Despite no statistically significant effect (P=0.05) of treatment on yield, the cane yield of the glyphosate treatment was lower than that of other treatments (Table 27). At about 2 months after herbicide application, there were significantly more dead cane shoots in the glyphosate and Flame® treatments (Table 26), indicating that these products impacted on the cane. At the time of making the measurements shown in Table 26 we considered that this may not have any impact on cane yield but the trend for lower yield in the glyphosate and Flame® treatments is cause for concern. An adjustable-width shielded sprayer may lessen the impact of these herbicides on cane.

In this trial the highest cane yields were obtained with Sempra® and Hero® herbicides and significantly lower live nutgrass densities were recorded in these treatments earlier in the crop growth (Table 26). The trend for lower yield in the Krismat® treatment (Table 27) is consistent with this product not being as effective on nutgrass as Sempra® and Hero® (Table 26).

Following the cane harvest (23 October 2009), cane and nutgrass densities were recorded on 20 November 2009 (Table 28). While there were no statistically significant treatment effects on cane or nutgrass density (Table 28) some trends are worth mentioning. For the inter-row treatments, glyphosate resulted in the lowest nutgrass density and Sempra® had the second lowest nutgrass density. Hero® herbicide applied as a directed spray (Irvin legs) to the cane row tended to result in a lower nutgrass density than the same herbicide applied with a dropper arrangement (dual-delivery rig; refer Appendix 3). Different water rates and coverage may account for this.

Table 28 - Effect of herbicides applied using dual-delivery and directed sprays (December 2008) on numbers of cane shoots and densities of nutgrass shoots following cane harvest (Nov 2009)

Treatment			Application method	Cane shoots/m	Nutgrass in cane row (shoots/m^2)	Nutgrass in inter-row (shoot/m^2)
#	Inter-row	Row				
1	Glyphosate	Hero®	Dual-delivery rig	48	150	125
2	Flame®	Hero®	Dual-delivery rig	64	92	450
3	Hero®	Hero®	Directed spray	62	0	333
4	Krismat®	Krismat®	Directed spray	60	17	308
5	Sempra®	Sempra®	Directed spray	49	33	233
				NS P=0.704	NS P=0.234	NS P=0.336

3.6 Trials evaluating some 'best-bet' options

Two workshops were held (July 2007 and November 2008) to develop and refine 'best-bet' options and packages of treatments for nutgrass control. The workshop groups comprised:

- Cane growers (using both herbicide and mechanical control measures for nutgrass),
- Local agribusiness,
- NSW DPI Weeds Officer,
- BSES extension and BSES Weeds Agronomist,
- NSWSMC Agricultural Officer.

These workshops formulated the designs of the trials described in this section.

3.6.1 O'Connor Flame®/Hero® trial (Condong)

Methods

This trial was established at G. O'Connor's farm at Condong to evaluate two 'best-bet' options. It was a replicated strip trial with three treatments (Table 29) and two replicate strips of each treatment in a randomised block design. Cane was planted in the first week of October 2007. Following treatment application in 2007/08 the yield of cane was determined in late 2008. Rainfall and flooding prevented any quantitative measurements at the trial site during January-February 2008. After the reapplication of treatments in the 2008/09 summer, weed density and cane shoot numbers were recorded on 27 February 2009. First-ratoon cane biomass yields (stalks plus tops) were measured in each plot in July 2009.

Table 29 - Treatments at the O'Connor trial

Treatment	Details
1. Grower's own practice	Plant cane 2007/08: Mechanical cultivation 1st ratoon 2008/09: 3 weeks after harvest 3 kg/ha atradex + 1 L paraquat; then 1 L paraquat + 1 L 2,4-D; then 3 kg Velpar® K4 at out-of-hand stage
2. Best-bet 1.	Plant cane: Flame® + Soccer® after planting; then Hero® after 4weeks 1st ratoon: Flame® + Soccer® after harvest; then Hero® after 4weeks
3. Best-bet 2.	Plant cane: paraquat + diuron; then Hero® after 4 weeks 1st ratoon: paraquat + diuron; then Hero® after 4 weeks

Results and Discussion

The effect of treatment on nutgrass in the plant-cane crop is shown in Plate 13. There was a strong trend (not statistically significant P<0.05) for higher plant-cane yield in the 'Flame®/Soccer® + Hero®' treatment (Table 30). After treatment reapplication to the first-ratoon crop there was a distinct trend (not significant P<0.05) for Treatment 2 to have more cane shoots (Table 31). Treatment 2 also resulted in the lowest nutgrass densities (Table 31, Plate 14) suggesting that application of two separate nutgrass-specific herbicides in the one season was a superior nutgrass control strategy. Treatment 2 also had the lowest total nutgrass (live+dead) densities as a result of residual effects from the 2007/08 herbicide applications. The apparent failure of the Hero® component in Treatment 3 to control nutgrass (Table 31) is possibly due to the very dry conditions prevailing at the time of Hero® application that reduced its capacity to be assimilated by the nutgrass.

Grower's own practice

Best-bet 1 –Flame® & Soccer®; Hero®

Best-bet 2 – Paraquat & diuron; Hero®

Plate 13 - Treatment effect on nutgrass and other weeds in the plant crop at the O'Connor trial (1 February 2008)

Table 30 - Effect of treatment on cane yield in the plant crop at the O'Connor trial

Treatment	**Cane yield (t/ha)**
1 Own practice 2007/08: Mechanical cultivation 2008/09: 3 weeks after harvest 3 kg/ha atradex + 1 L paraquat; then 1 L/ha paraquat + 1 L/ha 2,4-D; then 3 kg/ha Velpar® K4 at out-of-hand	188
2 Flame®/Soccer® then Hero® after 4 weeks	201
3 Paraquat/Diuron then Hero® after 4 weeks	183
	NS

Table 31 - Effect of treatment on cane and nutgrass shoot density in the first ratoon at the O'Connor trial (27 February 2009)

Treatment	**Cane (shoots/m)**		**Nutgrass ($shoots/m^2$)**			
			Nutgrass in cane row		**Nutgrass in inter-row**	
	Live	**Dead**	**Live**	**Dead**	**Live**	**Dead**
1 Own practice	27	0	186	201	155	17
2 Flame®/Soccer® then Hero®	42	0	14	14	53	3
3 Paraquat/Diuron then Hero®	30	0	219	118	134	17
	NS	NS	LSD = 88	LSD = 48	NS	NS

Plate 14 - Treatment effect on nutgrass and other weeds in the first-ratoon crop at the O'Connor trial (27 February 2009) showing treatments 1, 2 and 3 (left to right)

3.6.2 Fischer Flame® trial (Harwood)

The aim of this trial was to compare grower current practice with two 'best-bet' options for nutgrass control. The trial was established in first-ratoon cane (Empire variety) on a farm where nutgrass is essentially the only weed problem. The original treatments as planned are set out in Table 32 with six replicates of each treatment.

Table 32 - Treatments planned for the Fisher Flame® trial

Treatment		
Program	**After harvest**	**Later**
Current practice	Paraquat & Velpar® K4	-
Best-bet 1	Paraquat & Velpar® K4	Hero®
Best-bet 2	Flame® & Soccer®	Hero®

Seasonal conditions and cane growth precluded the application of Hero® as planned and the trial became a comparison of the grower's current practice versus a tank mix of Flame® and Soccer®. These treatments were applied on 29 November 2008 with densities of weeds and cane shoots recorded on 14 January 2009.

Although there was no difference in cane shoot density (Table 33), the Flame® treatment had markedly set back the cane (visual assessment). Following treatment application (29 November 2009) there was rainfall of 21 mm and 10 mm on 11 and 12 December 2009, respectively. Damage to the cane in the Flame® treatments was first noticed on 20 December, with the worst damage occurring in the sandier parts of the field.

At the time of recording cane and nutgrass densities, the effect of the paraquat had virtually disappeared and the nutgrass in the paraquat treatment was green and actively growing. While the Flame® reduced the density of live nutgrass shoots (not significant $P<0.05$), there was still a moderate density of live nutgrass (Table 33) and a 'follow up' application of a nutgrass-specific herbicide would have been beneficial in reducing nutgrass density. Although the Flame® treatment had visually set back the young ratoon cane, there was no difference in cane yield when the crop was harvested as 2-year old cane in 2010 (Table 33). While Flame® is regularly used in the Condong mill area of NSW, there is little or no use of this herbicide on the lighter textured soils in the Harwood mill area because of damage to cane.

Table 33 - Effect of treatment on cane and nutgrass shoot densities at the Fisher trial

Treatment	Cane (shoots/m)	Nutgrass (live) (shoots/m²)	Cane yield (t/ha)
Paraquat & Velpar® K4	26	304	148
Flame® & Soccer®	26	199	146
	NS	NS	NS

3.6.3 Munro Ploughout/Replant trial

The aim of this trial was to compare current practice with a 'best-bet' option for nutgrass control in a continuous cane system. The treatment packages that were planned are shown in Table 34. A block of old-ratoon Empire variety was selected and the trial design consists of two treatment packages (Table 34) with three replicates of each treatment. The entire block had been sprayed with paraquat/Dual Gold®/Soccer® at 3-leaf stage on 8 November 2008. This trial was started a year later than originally planned and, because the project finished in June 2010, time constraints precluded the complete package of treatments being applied.

Table 34 - Treatment packages – ploughout/replant cropping system

Treatment	Details
T1. Current practice	Year 1. Do nothing about nutgrass in old (last) ratoon crop Year 2. Plough out and replant Use current herbicide practice eg Dual Gold®/Soccer® early and Velpar® K4 at 'out of hand'
T2. Best-bet option	Year 1. In old (last) ratoon crop using dual-delivery spray system apply glyphosate (shields) and Hero® (directed to row). Year 2. Glyphosate over cultivation before planting Flame®/Soccer® on plant Hero® Krismat® at 'out of hand'

The first herbicide application in Treatment 2 was applied on 2 December 2008 using the dual delivery sprayer with glyphosate (3 L/ha) applied to the inter-row and Hero® (250 g/ha) applied to the cane row. At the time of application, soil moisture was good and the nutgrass was actively growing. Cane and nutgrass shoot densities were recorded on 23 February 2009 and treatment averages are shown in Table 35.

Table 35 - Effect of initial treatment on cane and nutgrass shoot density in the ploughout/replant trial

Treatment	Cane (shoots/m)		Nutgrass in row (shoots/m^2)		Nutgrass inter-row (shoots/m^2)	
	Live	**Dead**	**Live**	**Dead**	**Live**	**Dead**
T1. Current practice (do nothing for nutgrass control)	30	0.2	433	117	450	83
T2. Best-bet option (dual delivery of glyphosate and Hero® in last ratoon)	34	0.5	42	458	67	167
	LSD = 3	NS	LSD = 259	NS	LSD = 190	NS

As expected, both Hero® (cane row) and glyphosate (inter-row) significantly reduced live nutgrass shoot density. In Treatment 2, where nutgrass had been suppressed in both the cane row and inter-row space, there were significantly more cane shoots (Table 35). In contrast to the 'shielded sprayer/dual delivery' trial (refer Section 3.5), glyphosate applied to the inter-row did not result in an increase in dead cane shoots in this trial. This may be a variety effect, as Empire is an erect variety with fewer prostrate shoots than Q193$^{\Phi}$ (Table 26). Additionally, the Empire had been planted as single rows on 1.8 m spacing and there was more room for the shielded sprays (900 mm wide) in the interspace. The Q193$^{\Phi}$ had been planted as dual-row (1.8 m) spacing.

The site was visually assessed for nutgrass growth and regeneration on 8 April 2009 and Plate 15 shows treatment effects at that time. Cane growth was markedly improved by glyphosate/Hero® (inter-row/row) application. The greater extent of nutgrass regeneration in the row area (treated with Hero®) compared to the inter-row (glyphosate) was also evident (Plate 15).

In September 2009, cane shoot counts, cane biomass and CCS measurement were undertaken in each replicate plot. There was a marked yield increase (not significant P=0.05) where nutgrass-specific herbicides had been applied (Table 36). In contrast to the dual delivery trial (Section 3.5), there was no apparent detrimental effect of glyphosate on yield (Table 36), although additional treatments would have been required to definitively ascertain this. At this site the cane row spacing was 1.8 m single rows and the shielded sprayer used would have been less likely to impact the cane.

Plate 15 - Ploughout/replant trial showing suppressed cane growth in T1 (left) and improved growth in T2 (middle). Regenerated nutgrass in the inter-row and row areas in April 2009 (right)

Table 36 - Effect of nutgrass control on millable stalks, cane biomass and CCS in the final ratoon crop

Treatment	Millable stalks (stalks/m)	Cane biomass (t/ha)	CCS (small mill)
T1. Current practice (do nothing for nutgrass control)	15	39.6	15.6
T2. Best-bet option (dual delivery of glyphosate and Hero® in last ratoon)	16	54.7	15.6
	NS	NS P=0.077	

The old ratoon crop was harvested September 2009 and the cane ploughed out. Nutgrass densities in the formerly row and inter-row areas were recorded on 20 November 2009, about 40 days after ploughout (Table 37, Plate 16). At this site, replanting did not occur for the following reasons:

- initially too dry to plant,
- then 225 mm rain fell and it was too wet to plant,
- by the time the ground could be worked it was too late in the planting window.

Although time and weather constraints precluded completing this trial it is clear that there is a cane yield benefit from controlling nutgrass in old ratoon blocks.

Table 37 - Effect of glyphosate (inter-row) and Hero® (cane row) applied to final ratoon crop (December 2008) on nutgrass density in a fallow (November 2009)

Treatment	Nutgrass density (shoots/m^2)	
	Cane row area	**Inter-row area**
T1. Current practice (do nothing for nutgrass control)	392	150
T2. Best-bet option (dual delivery of glyphosate and Hero® in last ratoon)	50	17
	NS P=0.133	NS P=0.119

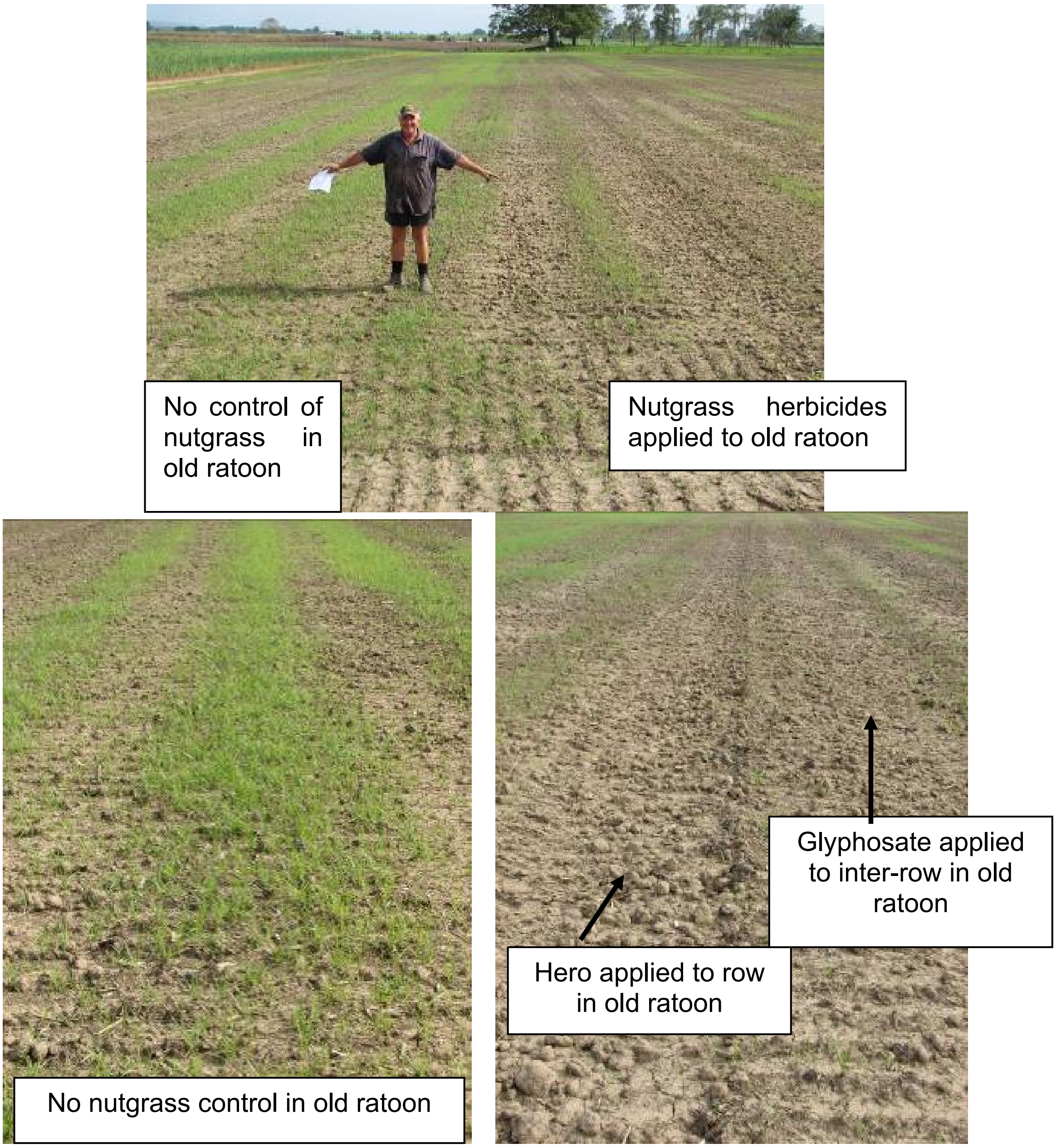

Plate 16 - Effect of herbicide application in an old ratoon crop on nutgrass density in the fallow

3.6.4 Munro soybean fallow/cane system trial

This trial aimed to assess two 'best-bet' options against current practice in a soybean fallow/cane rotation system. Details of the proposed sequence of herbicide applications are shown in Table 38. Both the ploughout/replant trial (Section 3.6.3) and the soybean fallow/cane system trial could not be continued into year 2 owing to weather conditions. In addition, the project finished in June 2010 and to continue these trials would have involved data collection for at least another two years. Given the data collected to date, the project team considered that it was not necessary to continue these trials as it had sufficient information to enable guidelines for a range of packages to be formulated and made available to growers. At the time of recording cane and nutgrass shoot densities (February 2009), both 'best-bet' options (T2 and T3, Table 38) had only the Flame®/Soccer® component of the treatment package applied and were therefore identical treatments. Dry conditions in January coupled with a stressed crop precluded any additional treatments being applied.

Table 38 - Treatment packages – soybean fallow/cane rotation system

Treatment	Description
T1. Current practice	No treatment specifically for nutgrass in old ratoon (Balance®/Soccer®) Trifluralin for soybean grass control Hoe in soybean stubble and prepare ground for plant cane Plant cane and use herbicides such as atrazine/diuron plus cultivation Velpar® K4 at 'out of hand'
T2.	In old (last) ratoon Flame®/Soccer® and then Hero® later Glyphosate applications prior to planting soybean Soccer® or Dual Gold® at planting soybean Spinnaker® to soybean crop for nutgrass & vines Glyphosate applications to soybean stubble Plant cane -2009 – Direct drilled Apply Dual Gold®/atrazine or Dual Gold®/Soccer® Hero® Atrazine or 2,4-D/Krismat® at 'out of hand' depending on nutgrass presence Ratoon crops – 2010 Flame®/Soccer® Hero®
T3	In old (last) ratoon crop Flame®/Soccer® then using DD spray apply glyphosate (shields) and Hero® (directed to row). Glyphosate applications prior to planting soybean Soccer® or Dual Gold® at planting soybean Apply Spinnaker® to soybean crop for nutgrass & vines Glyphosate applications to soybean stubble Plant cane – 2009 – Direct drilled Apply Dual Gold®/atrazine or Dual Gold®/Soccer® Hero® Atrazine at 'out of hand' Ratoon crops – 2010 Krismat® early 2,4-D/Krismat® at 'out of hand'

Results for cane-shoot and nutgrass densities recorded on 23 February 2009 are presented in Table 39. While the Flame®/Soccer® treatment did not completely remove nutgrass, there was an increase in numbers of cane shoots (not significant $P<0.05$) in these treatments (Table 39).

Table 39 - Effect of treatment on cane and nutgrass density in the soybean fallow/cane rotation trial

Treatment	Cane (shoots/m)		Nutgrass in row (shoots/m^2)	
	Live	Dead	Live	Dead
T1. Current practice (do nothing for nutgrass control)	22	0.3	567	333
T2. Flame®/Soccer®	31	0.3	117	167
T3. Flame®/Soccer®	29	0.3	367	292
	NS	NS	NS	NS

3.7 Economic evaluation

Data from the yield effect trials and the tuber viability trial provided the opportunity to undertake an economic evaluation of the effects of nutgrass and selected control measures.

3.7.1 Economic assessment using data from yield-effect trials

The net benefits of nutgrass control calculated for yield effect trial data are shown in Tables 40 and 41 with the average presented in Table 42. In calculating the values in Tables 40 and 41, we made the following assumptions:

- all cane had a mill average pol of 12.9,
- a payment price of $190 per tonne relative pol,
- harvesting and levy costs of $8 per tonne.

These net benefits do not include herbicide costs. However, total control of nutgrass resulted in a large dollar benefit and values give an indication of the amount that could be spent on nutgrass control while still returning a profit.

Table 40 - Effect of treatment on net benefit at the Mororo yield-effect trial

Treatment	Cane yield (t/ha)	Tonnes rel pol/ha (at mill av)	$/ha after harvest cost	Net benefit $/ha
No nutgrass	96.7	12.5	1,597	431
Nutgrass for 4 weeks & then controlled	85.6	11.0	1,413	248
Nutgrass for 8 weeks & then controlled	79.2	10.2	1,308	142
Nutgrass for 12 weeks & then controlled	72.1	9.3	1,190	25
Nutgrass not controlled	70.6	9.1	1,166	0

Table 41 - Effect of treatment on net benefit at the Woodford Island yield-effect trial

Treatment	Cane yield (t/ha)	Tonnes rel pol/ha (at mill av)	$/ha after harvest cost	Net benefit $/ha
No nutgrass	103.9	13.4	1,715	466
Nutgrass for 4 weeks & then controlled	103	13.3	1,701	451
Nutgrass for 8 weeks & then controlled	94.7	12.2	1,563	314
Nutgrass for 12 weeks & then controlled	84.2	10.9	1,390	140
Nutgrass not controlled	75.7	9.8	1,250	0

Table 42 - Average net benefit across the two yield-effect trial sites

Treatment	Average net benefit ($/ha)
No nutgrass	448
Nutgrass for 4 weeks & then controlled	349
Nutgrass for 8 weeks & then controlled	228
Nutgrass for 12 weeks & then controlled	83
Nutgrass not controlled	0

At the Woodford Island site, selected treatments were sampled for pol in cane (PIC) and net benefits calculated using these are shown in Table 18.

Table 43 - Effect of treatment on PIC and net benefit

Treatment	Cane yield (t/ha)	Pol in cane	Sugar yield (t PIC/ha)	$/ha after harvest cost	Net benefit $/ha
No nutgrass	103.9	14.7	15.3	2,076	1,161
Nutgrass for 4 weeks & then controlled	103	11.7	12.1	1,475	561
Nutgrass not controlled	75.7	10.6	8	914	0

3.7.2 Economic assessment using data from ratoon-cane trials

The net benefit of having little or no nutgrass present in a ratoon crop is shown in Table 44. On average across the three ratoon blocks sampled, there was a $657/ha higher crop return in the 'no nutgrass' areas of the field. Assuming a block had patchy nutgrass with 30% of the area infested with nutgrass, then the benefit from controlling the nutgrass would be $197/ha. This is more than enough to cover the cost of nutgrass control and still enhance dollar return from the block.

Table 44 - Net benefit from having little or no nutgrass in ratoon cane

Site & crop	Nutgrass intensity (shoots/m^2)	Cane biomass (t/ha)	Tonnes rel pol/ha (at mill average)	$/ha after harvest cost	Net benefit $/ha
Farm 1277 Block 4100 Q124 4th ratoon 1.8 m single rows	Moderate (575)	63.9	8.94	1,144	525
	No nutgrass (0)	101.1	13.04	1,669	
Farm 1279 Block 4110 Q155 2nd ratoon 1.8 m dual rows	Heavy (1100)	101.0	13.03	1,668	784
	Light (<25)	148.5	19.16	2,452	
Farm 1162 Block 2210 Empire 1st ratoon 1.5 m single rows	Moderate (255)	79.1	10.2	1,306	573
	Light (40)	113.8	14.68	1,879	

3.7.3 Economic assessment using data from the tuber-viability trial

Most treatments in the tuber-viability trial comprised a single spray application of a nutgrass-specific herbicide (Section 3.4) and, therefore, approximate what an average cane grower might do in a season. Cane yields obtained from this trial in 2008 provided data for calculation of net returns that incorporated the cost of the herbicides (Table 45). All herbicide treatments resulted in a substantial net benefit over allowing the nutgrass to grow uncontrolled. Even a herbicide such as Sempra®, that in the past has been considered relatively expensive for nutgrass control, was profitable for the nutgrass density and yield response obtained in this trial.

The data suggest that, even where nutgrass is patchy, growers could outlay in $60-100/ha for nutgrass control and still obtain a substantial net benefit.

Table 45 - Net benefits calculated for herbicide treatments used in the tuber-viability trial

Treatment	Cane yield (t/ha)	Tonnes rel pol/ha (at mill av)	$/ha after harvest cost	Herbicide cost $/ha	Net return $/ha	Net benefit $/ha
Check (no nutgrass control)	51.6	6.66	852	0	852	0
Hero® (250 g/ha)	79.7	10.28	1316	61.3	1255	403
Sempra® (130 g/ha)	82.6	10.66	1364	148.0	1216	364
Krismat® (2 kg/ha)	74.2	9.57	1225	72.3	1153	301
Krismat® (2 kg/ha) & Actril® DS (400 mL/ha)	69.3	8.94	1144	82.5	1062	210
2,4-D (1.9 L/ha) and then Krismat® (2 kg/ha) 4 weeks after 2,4-D.	83.8	10.81	1384	88.5	1295	443

3.8 End-of-project survey

An end-of-project survey was mailed to all NSW cane growers in early May 2010. Appendix 4 lists the survey questions. Questions 2-4 of the survey were identical to questions asked in 2007 in the survey undertaken at the start of the project. The following analysis is based on 124 survey forms returned representing 23%, 19%, and 20% of Harwood, Broadwater and Condong growers, respectively.

3.8.1 Perception of nutgrass as a problem

As for the 2007 survey results most growers considered nutgrass a problem on their farm (Table 46). For Condong and Broadwater growers there was little change in the perception of the problem on their farms over the past three years. However, for Harwood growers, there appears to have been a shift towards perceiving nutgrass as a more significant problem than was the case in 2007. This may be partly explained by the greater opportunity of Harwood growers to view the ‘yield effect’ trials that were undertaken in the Harwood mill area.

Table 46 - Grower perception of nutgrass as a problem. Values in parenthesis are 2007 results

Severity of nutgrass problem	Mill area			All mill areas
	Condong	Broadwater	Harwood	
Not a problem	14% (13%)	17% (14%)	8% (11%)	13%
Small problem	64% (62%)	63% (59%)	36% (59%)	52%
Significant problem	22% (25%)	20% (27%)	56% (30%)	35%

The majority thought it was a problem in both plant and ratoon cane with fewer growers thinking it was a problem in soybean crops (Table 47). Again, a greater proportion of Harwood growers perceived it as a problem in both plant and ratoon crops possibly because of greater exposure to trial results in this mill area.

Table 47 - Grower perception of nutgrass as a problem in various parts of the crop cycle

Occurrence of nutgrass problem	Mill area			All mill areas
	Condong	Broadwater	Harwood	
Mainly a problem in plant cane	44%	24%	19%	31%
A problem in plant & ratoons	44%	56%	65%	69%
A problem in soybean fallows	12%	20%	16%	20%

3.8.2 Perception of nutgrass effects on cane and soybean yield

In the 2007 survey, 58% of NSW cane growers considered that nutgrass affected yields of both plant and ratoon cane with little variation across the mill areas (50% at Condong, 54% at Broadwater and 64% at Harwood). The ‘end-of-project’ survey showed an increased awareness of the effects of nutgrass on cane yield, with 83% then believing that nutgrass affects both plant and ratoon yields (Table 48). Presumably, this results from the dissemination of trial data from the project to NSW growers. The project also demonstrated an effect of nutgrass on soybean biomass.

In the 2007 survey, approximately 15% of NSW cane growers believed that nutgrass had no effect on cane yield. The 'end-of-project' survey shows that this figure dropped to 7% (Table 48), and perusal of individual survey returns indicated that many of these have no nutgrass problem on their farm.

Table 48 - Grower view of the effect of nutgrass on cane and soybean yield

View regarding nutgrass effect on crop yield	Mill area			All mill areas
	Condong	Broadwater	Harwood	
Has no effect on cane yield	4%	6%	7%	7%
Only affects plant cane yield	13%	18%	4%	10%
Affects both plant & ratoon yields	83%	76%	82%	83%
Affects soybean yield	30%	21%	30%	28%

3.8.3 Methods/products for nutgrass control and their effectiveness

Growers were asked to rank methods and products that they had used for effectiveness of nutgrass control (refer Question 4, Appendix 4). Results are summarized in Table 49. Only products/methods where 10 or more growers had rated their effectiveness are shown in Table 49. For all products rated and a breakdown analysis of each mill area refer to Appendix 5.

Table 49 - Effectiveness of methods and products used by growers for nutgrass control. Data for all NSW mill areas combined. Data are ranked for 'good' rating.

Method or product	Percentage of growers for each effectiveness rating			Number of growers using product
	Good	Average	Poor	
Sempra®	71%	24%	5%	17
Hero®	64%	31%	5%	36
Krismat®	54%	38%	8%	13
Glyphosate	52%	40%	8%	67
Spinnaker®	41%	47%	12%	17
Flame®	40%	40%	20%	10
Actril® DS	27%	62%	11%	34
Mechanical cultivation	24%	43%	33%	74
2,4-D	20%	56%	24%	64
Velpar K4®	12%	59%	29%	17
Paraquat	9%	49%	42%	45

Although mechanical cultivation was the method most used (Table 49), it was ranked low in terms of a 'good' method of nutgrass control. As stated previously, this was expected to be the case in wetter coastal environments. The aim of this project has been to get growers to adopt a more integrated approach to nutgrass control.

The relatively ‘newer’ products, Hero® and Krismat®, were rated as being reasonably effective. Grower perception of the effectiveness of Sempra® is supported by trial results from this project.

Literature reports clearly indicate that glyphosate is the most effective herbicide for reducing viable nutgrass tuber density. However, grower ratings of the effectiveness of glyphosate (52% rated it as ‘good’) were lower than expected. One explanation for this may be that glyphosate is not being used effectively. During this project, spray technology workshops were held in the Harwood mill area and discussions/demonstrations of appropriate procedures for glyphosate application were held at Harwood Canecheck shed meetings. A breakdown of survey results by mill area (Appendix 5) shows that glyphosate was more highly rated (64% ‘good’) by Harwood growers than growers from other mill areas.

3.8.4 Changes in priority and methods for nutgrass control

The ‘end-of-project’ survey asked growers if they had increased their priority for nutgrass control over the past three years. Across all NSW mill areas about half of the growers had increased their priority for nutgrass control, with 54%, 47%, 52% and 56% increasing priority in plant cane, ratoon cane, fallow, and soybean crops, respectively. In the Condong and Harwood mill areas where nutgrass is more problematic, the percentage of increased priority was higher at around 60-70% (Table 50).

Table 50 - Percentage of growers with increased priority for nutgrass control

Crop stage	Mill area			All NSW
	Condong	Broadwater	Harwood	
Plant cane	60%	41%	60%	54%
Ratoon cane	65%	25%	56%	47%
Fallow	61%	32%	61%	52%
Soybean	75%	25%	72%	56%

About 40% of NSW growers had changed their methods of nutgrass control in the past 3 years (Table 51). In general, these changes involved the use of the more ‘recent’ nutgrass-specific herbicides on the market, such as Hero® and Krismat®, with some also now using Sempra®. However, a number also indicated that they had changed to the use of glyphosate in fallow situations.

Table 51 - Percentage of growers that changed method of nutgrass control

Mill area			All NSW
Condong	Broadwater	Harwood	
44%	27%	46%	39%

When asked about changes to the density/level of nutgrass on their farms over the past 3 years, 30% of NSW growers said that it had decreased, 23% indicated an increase and 47% stated that it had remained the same. However, for growers who stated that they had changed their methods of nutgrass control in the past 3 years, 53% indicated a decrease in the nutgrass density/level on farm and only 14% said that it had increased.

3.8.5 Perception of effects of paraquat and 2,4-D on nutgrass tuber viability

One of the premises on which this project was initiated was that *ad hoc* applications of paraquat or 2,4-D did little for the long-term control of nutgrass. As indicated previously, the key to long-term nutgrass control is reduction in the number of viable tubers. Although trial work evaluated the effects of a range of nutgrass-specific herbicides on tuber viability, the effects of paraquat and 2,4-D on tuber viability were not assessed. There is certainly no reason to expect that paraquat would affect tuber viability and little evidence for 2,4-D effects. Therefore, it was somewhat disappointing that 41% of growers believed that applications of paraquat or 2,4-D reduced numbers of viable tubers.

3.8.6 Economic benefits of nutgrass control

Almost all growers (96%) thought that there were economic benefits in controlling nutgrass in cane or in cane/soybean rotations.

3.8.7 Conclusions

The 'end-of-project' survey strongly suggests that grower awareness of nutgrass effects on cane and soybean yield has increased markedly. Survey results also suggest changes in the methodology used to control nutgrass and that these have generally resulted in a reduction in nutgrass levels. It is intended that a summary of these survey results be presented in a newsletter to all NSW growers. Survey results also suggest that 'follow up' extension work is required to address the following topics:

- 2,4-D, paraquat, Actril® DS effect/no effect on tuber viability (41% believed that these products reduced tuber viability)
- improved adoption of gylphosate
- improved effectiveness of glyphosate applications (48% thought its effectiveness was average to poor).

Having 40% of farmers change their practices, with over half of these reporting positive results, is a significant change. An estimate of the value of the project to industry each year is shown in Table 52. Even if farmers attained half the response achieved in the plant and ratoon cane trials undertaken in this project, the annual return to industry would be $750,000.

Table 52 - Benefits to industry

Av yield increase	CCS (ignores CCS increase)	Area harvested with 'significant' problem (ha)	% farmers who changed practice	% reporting positive result	Sugar price per tonne		Benefit to industry
31 t/ha	11.5	5,000	40%	53%	$400	=	$1.51M

4.0 OUTPUTS

- Factsheet / Decision support package (Appendix 6)
- Presentation at GIVE 2009 conference, Ingham
- Preliminary evaluation of shielded sprayer technology for cane
- ABC radio interview
- Seminar on nutgrass by Graham Charles during Condong 2007 roving field tour
- Seminars (2007) by Graham Charles at Broadwater and Harwood mill areas
- Condong 2008 roving field tour
- Articles in Sunshine Sugar News (NSWSMC newsletter)
- *BSES Bulletin* article
- Presentation to NSW R & D committee
- Condong Newsletter (Sept 2009)
- Presentations at NSW Farming Systems Group meetings 2007 to 2010.

5.0 OUTCOMES

- Enhanced capacity of industry to reduce impact of nutgrass on cane production,
- Better grower knowledge of effectiveness of various herbicide products for nutgrass control,
- Reduction in number of non-effective spray applications returning a benefit to the environment,
- Increased cane production,
- Increased profitability,
- Reduction in use of 2,4-D and its possible offsite impacts,
- Enhanced collaboration between growers and agricultural/agribusiness staff and between growers and cotton/grains industry personnel,
- Increased adoption of improved cropping system (soybean fallow, controlled traffic, zero tillage etc.) as it offers better opportunities for nutgrass control.

6.0 FUTURE NEEDS AND RECOMMENDATIONS

- Further evaluation of shielded-sprayer technology for cane.
- Monitor future developments and application of weed identification/spot sprayer and Weedseeker® technologies for cane.
- Better understanding of double-knock strategies (eg 2,4-D/Krismat® or 2,4-D/Hero® or 2,4-D/Sempra®) in regard to the rate of 2,4-D and the time between the two applications.

7.0 PUBLICATIONS ARISING FROM THE PROJECT

7.1 Scientific publication

Munro, A.J., Aitken, R.L., Charles, G.W., McGuire, P.J. and Beattie, R.N. 2009. Having no nuts means more yield: quantifying nutgrass effects on cane yield. Proc. Aust. Soc. Sugar Cane Technol. 31, 580.

7.2 Bulletin article

Aitken, R.L. and Munro, A.J. 2009. Banish nutgrass and reap the rewards. BSES Bulletin, 21, 8-10.

7.3 Newsletter articles

Clarence Cane News. 2008 (April). Nutgrass trials show effect on cane growth.

Australian Canegrower - SRDC Update. 2009. An integrated approach to nutgrass control.

Clarence Cane News. 2009 (April). What nutgrass takes from cane or soybean.

Clarence Cane News. 2008 (September). Nutgrass affects yield of ratoon cane and soybean.

Sunshine News. 2009 (May). Herbicide effect on nutgrass tubers.

Condong Courier 2007 (Sept). Effects of nutgrass on ratoon yields.

8.0 ACKNOWLEDGEMENTS

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We thank Steve Lokes and Wayne Davis for assistance with field measurements.

We are extremely grateful to Bayer CropScience, Crop Care Australia Pty Ltd, Nufarm Ltd and Syngenta Crop Protection for the supply of herbicides for the trials.

9.0 REFERENCES

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Hogarth. D.M. and Skinner, J.C. (1967). A sampling method for measuring yields of sugarcane in replicated trials. Bur. Sugar Exper. Stns Tech. Comm. 1, 1-24.

Holm, L.G., Plucknett, D.L., Pancho, J.V., and Herberger, J.P. (1977). The World's Worst Weeds. The University Press of Hawaii, Honolulu.

Turner, P.E.T. (1984). Preliminary investigations into the competitive effects and control of *Cyperus rotundus* L. in sugarcane fields. Proc. S. Afr. Sug. Technol. Ass. 58: 143-8.

APPENDIX 1 – Pre-project survey

Pre-project Survey

(Please tick appropriate box, for some issues you may tick more than one box)

1 Your mill area: □ Condong □ Broadwater □ Harwood

2 What cropping system do you use?

□ Ploughout/replant □ Soybean fallow □ Grass fallow

3 What is your current method for control of weeds in general?

□ Combination of mechanical & chemical in plant cane
□ Combination of mechanical & chemical in ratoons
□ Chemical only in ratoons
□ Mechanical cultivation only in ratoons
□ Other ………………………

4 What is the usual proportion of year old and 2 year old cane on your farm?

…..% year old
……% 2 year old

5 What is your perception of nutgrass as a problem?

□ Not a problem on my farm
□ Small problem on my farm
□ Significant problem on my farm

□ Mainly a problem in plant cane
□ Mainly a problem in plant & ratoons
□ Mainly a problem in soybean fallows

6 What is your view on nutgrass effects on cane yield?

□ Nutgrass has no effect on cane yield
□ Nutgrass only affects plant cane growth
□ Nutgrass affects both plant and ratoon yields
□ Nutgrass affects soybean yields

7 The following are some products/methods for specific control of nutgrass, tick products you have used and rate their effectiveness as <u>good</u>, <u>average</u> or <u>poor</u> by ticking the appropriate box.

□ Mechanical cultivation …	□ Good	□ Average	□ Poor
□ Sempra	□ Good	□ Average	□ Poor
□ Flame	□ Good	□ Average	□ Poor
□ Hero …….	□ Good	□ Average	□ Poor
□ Krismat ……….	□ Good	□ Average	□ Poor
□ Actril ……	□ Good	□ Average	□ Poor
□ Paraquat …	□ Good	□ Average	□ Poor
□ Sprayseed ……..	□ Good	□ Average	□ Poor
□ 2,4-D ………..	□ Good	□ Average	□ Poor
□ Glyphosate ……..	□ Good	□ Average	□ Poor
□ Spinnaker ………	□ Good	□ Average	□ Poor
□ Velpar K4 …..	□ Good	□ Average	□ Poor
□ Daconate …….	□ Good	□ Average	□ Poor

□ Actril/Viking ………... □ Good □ Average □ Poor
□ Other (please specify) …… □ Good □ Average □ Poor

8 Describe your preferred method for nutgrass control:

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

9 If you mechanically cultivate for nutgrass control how often do you cultivate: ………………..

10 If you fallow blocks do you use glyphosate during the fallow: □ Yes □ No

11 If you use glyphosate during the fallow::
How many applications do you make per fallow? ………….

What rate of glyphosate do you use? ……………………….

12 Would you use glyphosate in the inter-row of cane if suitable technology (eg. shielded sprayers) was available? □ Yes □ No

13 Have you previously used glyphosate in cane to control nutgrass or other weeds in cane?:
□ Yes □ No

14 If you have previously used glyphosate in cane to control nutgrass or other weeds please describe the method you used:

……………………………………………………………………………………………

……………………………………………………………………………………………

Thank you for taking the time to complete the survey.

Please return this survey in the envelope provided.

APPENDIX 2 - An apparent allelopathic effect of nutgrass on soybean growth

- Fallow paddock with patches of nutgrass
- Sprayed with Roundup® CT (3 L/ha) (22/1/2008)
- Soybeans planted the next day (23/1/2008)
- Dual Gold® pre-emergent applied 24/1/2008
- 370 mm rain from planting over 28 days until the photos (shown below) were taken (20/2/2008)
- Unlikely to be a moisture effect reducing germination and growth

Poorer growth of soybean in patch of sprayed-out nutgrass (front) and better soybean growth (back).

Poor soybean in nutgrass patch

Improved soybean in area of low nutgrass density

APPENDIX 3 – Dual-delivery sprayer

The photographs below show stages of construction. A set of four 'Redball' shields were purchased and the dual-delivery spray rig was constructed by Alan Munro.









The sprayer features:

- all-new componentry made possible by supplementing the $5,000 capital allocation for the project with some of the NSW Farming Systems Group Innovators $10,000 Award,
- a front 600 L tank for over-the-row spraying,
- a rear 300 L tank for glyphosate (or other chemical) application to the interspace,
- electric in-cab controls for ease of operation,
- Redball flow monitors for the in-shield sprays,
- a folding 4-row boom, adjustable to suit 1.5 m and 1.8 m row spacings,
- four redball shields, 900 mm wide fitted with three drift-guard nozzles per shield (other nozzles and configuration will be evaluated),
- fully adjustable droppers for in-the-row chemical application,
- a construction robust enough for growers use outside of trial purposes.

APPENDIX 4 – End-of-Project Survey - Nutgrass in cane

Over the past three years we have received SRDC funding to undertake trials in NSW to look at the effects of nutgrass on cane yield and evaluate some best-bet options for nutgrass control. At the start of the project in 2007 we surveyed NSW cane growers and this is a follow-up survey at the end of the project.

(Please tick appropriate box, for some issues you may tick more than one box)

1 Your mill area: □ Condong □ Broadwater □ Harwood

2 What is your perception of nutgrass as a problem?

□ Not a problem on my farm
□ Small problem on my farm
□ Significant problem on my farm

□ Mainly a problem in plant cane
□ Mainly a problem in plant & ratoons
□ Mainly a problem in soybean fallows

3 What is your view on nutgrass effects on yield?

□ Nutgrass has no effect on cane yield
□ Nutgrass only affects plant cane growth
□ Nutgrass affects both plant and ratoon yields
□ Nutgrass affects soybean yields

4 The following are some products/methods for specific control of nutgrass, tick products you have used and rate their effectiveness as <u>good</u>, <u>average</u> or <u>poor</u> by ticking the appropriate box.

□ Mechanical cultivation …	□ Good	□ Average	□ Poor
□ Sempra	□ Good	□ Average	□ Poor
□ Flame	□ Good	□ Average	□ Poor
□ Hero …….	□ Good	□ Average	□ Poor
□ Krismat ……….	□ Good	□ Average	□ Poor
□ Actril ……	□ Good	□ Average	□ Poor
□ Paraquat …	□ Good	□ Average	□ Poor
□ Sprayseed ……..	□ Good	□ Average	□ Poor
□ 2,4-D ………..	□ Good	□ Average	□ Poor
□ Glyphosate ……..	□ Good	□ Average	□ Poor
□ Spinnaker ………	□ Good	□ Average	□ Poor
□ Velpar K4 …..	□ Good	□ Average	□ Poor
□ Daconate …….	□ Good	□ Average	□ Poor
□ Actril/Viking ………...	□ Good	□ Average	□ Poor
□ Other (please specify) ……	□ Good	□ Average	□ Poor

5 Over the past 3 years have you increased your priority for control of nutgrass in:

(a) plant cane?:	□ Yes	□ No
(b) ratoon cane?:	□ Yes	□ No
(c) fallow?:	□ Yes	□ No
(d) soybean?:	□ Yes	□ No

6 In the past 3 years have you changed your methods of nutgrass control?

□ Yes □ No

If yes, please indicate what you now use (tick appropriate boxes below):

Plant cane	Ratoon cane	Fallow	Soybean
□ Mechanical cult. □ Hero □ Krismat □ Sempra □ Actril □ Flame □ 2,4 D □ Other ………… ……………………	□ Mechanical cult. □ Hero □ Krismat □ Sempra □ Actril □ Flame □ 2,4 D □ Other ………… ……………………	□ Mechanical cult. □ Roundup □ Hero □ Krismat □ Sempra □ Actril □ Flame □ 2,4 D □ Other ………… ……………………	□ Spinnaker in soybean crop □ Roundup before planting soybean □ Roundup after soybean and before planting cane crop □ Roundup with shielded sprayer in soybean crop □ Other ………… ……………………

7 On your farm over the past 3 years has the density/level of nutgrass:

□ Remained the same □ Increased □ Decreased □ No nutgrass on my farm

8 The key to long-term control of nutgrass is to reduce the number and viability of tubers (nuts). Do you believe that applications of paraquat or high rates of 2,4 D do anything to reduce the number of viable tubers (nuts)?

□ Yes □ No

9 Do you believe that there are economic benefits in controlling nutgrass in cane or cane/soybean rotations?

□ Yes □ No

Thank you for taking the time to complete the survey.

Please return this survey in the envelope provided.

APPENDIX 5 - Mill area responses to Question 4 – End-of-project survey

Method or product	Mill area	Number of growers for each effectiveness rating			Number of growers
		Good	Average	Poor	
Sempra®	All NSW	12	4	1	17
	Condong	3	1		4
	Broadwater	4	1	1	6
	Harwood	5	2		7
Hero®	All NSW	23	11	2	36
	Condong	6			6
	Broadwater	6	3	1	10
	Harwood	11	8	1	20
Krismat®	All NSW	7	5	1	13
	Condong	2	3		5
	Broadwater	2	1		3
	Harwood	3	2	1	6
Glyphosate	All NSW	35	27	5	67
	Condong	10	9		19
	Broadwater	4	8	3	15
	Harwood	21	10	2	33
Spinnaker®	All NSW	7	8	2	17
	Condong	2	1		3
	Broadwater	1	2	1	4
	Harwood	4	5	1	10
Flame®	All NSW	4	4	2	10
	Condong		2	2	4
	Broadwater		1		1
	Harwood	4	1		5
Actril®	All NSW	9	21	4	34
	Condong	3	5		8
	Broadwater	1	3	1	5
	Harwood	5	13	3	21
Mechanical cultivation	All NSW	18	32	24	74
	Condong	3	5	10	18
	Broadwater	5	7	7	19
	Harwood	10	20	7	37
2,4-D	All NSW	13	36	15	64
	Condong	3	10	3	16
	Broadwater	3	8	5	16
	Harwood	7	18	7	32
Velpar K4®	All NSW	2	10	5	17
	Condong	1			1
	Broadwater		3	2	5
	Harwood	1	7	3	11
Paraquat	All NSW	4	22	19	45
	Condong	2	9	5	16
	Broadwater		6	5	11
	Harwood	2	7	9	18
Sprayseed®	All NSW	1	7	1	9
	Condong	1	3		4
	Broadwater		3	1	4
	Harwood		1		1
Daconate	All NSW	2	4	1	7
	Condong		1		1
	Broadwater	1	2	1	4
	Harwood	1	1		2

APPENDIX 6 - Factsheet / decision-support package

BSES QCROPS Growing your bottom line

Australian Government Sugar Research and Development Corporation

Sunshine Sugar

Information Sheet **IS10016**

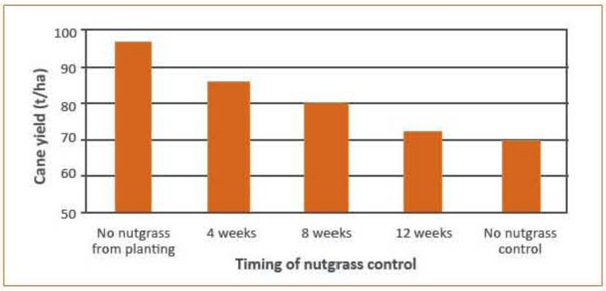
Managing nutgrass in cane

Benefits of nutgrass control

Trials undertaken from 2007 to 2010 in NSW showed cane yield losses of around 30% in both plant and ratoon cane where nutgrass was allowed to grow without any control. Even allowing the nutgrass to grow uncontrolled for 4 to 8 weeks after planting or ratooning resulted in a reduction in cane growth.

Nutgrass reduces the soil moisture and nutrients available to the cane crop. In moderate to heavy infestations nutgrass tops can take up around 25 to 45 kg N/ha that would otherwise be available to the cane crop. Similarly nutgrass tops can take up around 45 to 50 kg K/ha (equivalent to the K applied in many planting mixes).

A thick sward of nutgrass can remove the equivalent of 11 to 12 mm rain from the plough layer in 4 to 8 days.



Below: The effect of different levels of nutgrass control on cane growth 100 days after planting

Nutgrass not controlled.

Nutgrass allowed to grow for 4 weeks then controlled.

Nutgrass controlled since cane planting.

Sugarcane for the future bses.com.au

BSES QCROPS
Growing your bottom line

Information Sheet **IS10016**

Know your nutgrass

- Nutgrass reproduces and survives from vegetative tubers (nuts) in the soil.
- The tubers are up to 10 mm in diameter and up to 20 mm long.
- A new plant develops from each tuber.
- In ideal growing conditions a single tuber can produce a further 100 tubers in 90 days.
- In northern NSW cane lands, about 90% of the tubers are in the 0-15 cm depth.
- Tubers are killed when exposed to very dry soil or are brought to the surface after their roots are cut.
- Mechanical cultivation is an effective control strategy only if conditions remain dry after the tubers are brought to the surface. If rain occurs shortly after cultivation it can increase tuber numbers and enhance nutgrass spread.
- Nutgrass can only be managed using a long-term integrated approach. The key to long-term control is to reduce the number of viable tubers.
- No single 'one-off' treatment will control nutgrass. Repeated treatments are the only sure way of controlling nutgrass. A single 'one-off' treatment will reduce nutgrass competition in the short term but, because of its ability to rapidly propagate under suitable conditions, repeated treatments are imperative.

Tactics for managing nutgrass in cane - current treatment options

A long-term integrated approach involving repeated treatments is required.

Mechanical cultivation

- Mechanical cultivation has been shown to be effective in drier environments. Provided the tubers are brought to the surface and dessicated it can be effective in reducing tuber density.
- Cultivation will only be effective if soil is dry prior to cultivation and the cultivation is timed to occur when no rain is forecast. Our studies in NSW cane lands suggest that about 90% of the tubers are in the 0-15 cm depth. However, cultivation to 30 cm is likely to be required to effectively control nutgrass.
- On the coastal floodplains of northern NSW it is likely to be less successful due to the wetter environment.
- If rain occurs shortly after a cultivation, or if the soil is moist, then cultivation will enhance nutgrass spread. Studies have shown that cultivation under moist conditions can increase shoot and tuber numbers.
- For minimum tillage, cultivation is not an option and nutgrass specific herbicides are required.

Shading

- Shading may provide some control after canopy closure but large yield losses will occur if nothing is done to control nutgrass in the period before canopy closure.

Herbicides

- No residual/pre-emergent hebicides are currently registered for nutgrass in cane.
- Applications of paraquat or high rates of 2,4-D, while temporarily retarding nutgrass, do little to reduce tuber viability. If growers want a long term solution to nutgrass they will need to move away from these temporary, ad-hoc treatments.
- There are a number of contact/systemic herbicides registered for nutgrass in cane (see Table 1).
- Best results are achieved when nutgrass is actively growing. Avoid spraying when nutgrass is stressed.

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Information Sheet **IS10016**

Table 1: Herbicides currently registered for use in cane (May 2010)

Product	Active	Group	Rate / ha	Comments
Actril® DS	2,4-D Ioxynil	C I	1-1.5 L	Add diuron for 3-4 weeks suppression, two applications for satisfactory supression; fast burn-off.
Flame®	Imazapic	B	400 ml	Registered for broadleaf and grasses in cane. Nutgrass (suppression only) 4-6 leaf stage in peanuts. Only once/year. High Al, Fe and low pH reduce pre-emergence value.
Hero®	Ethoxy sulfuron	B	250 g	Only one application to a crop in 1 year.
Krismat®	Ametryn Trifloxy sulfuron	C B	1.5-2 kg	Don't apply more than two applications per year. Don't plant crops other than cane for 24 months after application.
Roundup CT	Glyphosate	M	2.4 L + 2.4 L	Follow-up treatments made as part of a nutgrass control program.
Sempra®	Halosulfuron	B	65-130 g	6-7 days for visual effects, 4-6 weeks for full effects. Maximum 200 g/ha/yr.

The rotation of soybean with cane provides additional opportunities for an integrated approach to nutgrass control.

- Use glyphosate before and after the soybean crop to reduce tuber viability.
- Use Spinnaker® in the soybean crop.

Plant cane with this level of nutgrass has already lost 10% of the yield potential

Economic guidelines for nutgrass control

Trials in NSW have shown that it is highly economic to control nutgrass in cane. Total control of nutgrass resulted in large dollar benefits ($350-$450/ha) and these values give an indication of the amount that could be spent while still returning a profit. Trials evaluating 'one-off' herbicide treatments for nutgrass have also shown net benefits of around $200-$400/ha after allowing for herbicide costs. This indicates that even where nutgrass is patchy growers could outlay in the order of $60 to $100/ha for nutgrass control and still obtain a substantial net benefit.

Summary of trial results

An SRDC funded project in NSW from 2007 to 2010 undertook numerous trials evaluating individual herbicides registered for nutgrass in cane. The following points summarise the findings:

- Actril® - fast burn-off, suppresses nutgrass for 2-4 weeks, no evidence of reduced tuber viability, two (1 L/ha) applications 4 weeks apart gave good suppression but single applications of other nutgrass specific chemicals produced better results.
- Flame® - reasonable knockdown effect, no data collected about effect on tuber viability, potential to damage cane in lighter textured soils in NSW.

BSES QCROPS Growing your bottom line

Information Sheet **IS10016**

- Glyphosate - best herbicide for reducing tuber viability, effective and economic in fallow, if shielded sprayers are not set up correctly small cane yield losses may occur with glyphosate application to inter-row areas.
- Hero® - effective on nutgrass, some evidence for reduced tuber viability.
- Krismat® - gives good general weed control as well as nutgrass suppression. Effectiveness enhanced by a pre-application of 2,4-D prior to Krismat® application (see 'double knock' treatment below).
- Sempra® - apart from glyphosate, the most effective in reducing viable tuber numbers. Highest cost/ha herbicide but still very cost effective.
- 'Double knock' treatments - 2,4-D at high rate (2 L/ha) followed 4 weeks later by either Krismat®, Hero® or Sempra® showed potential for very good control of nutgrass and reduced tuber viability.
- Although not evaluated in replicated trials, lower rates of 2,4-D (1 L/ha) with a shorter interval (eg 2 weeks) to application of nutgrass specific herbicide may be very effective.

Table 2: Options for nutgrass control at various stage in the cane cycle

Cropping phase	Options
Fallow from PO to pre-soybean	1. Glyphosate 2. Mechanical cultivation
Soybean crop	1. Spinnaker® 2. Glyphosate with shielded sprayer
Fallow, post soybean to cane planting	1. Glyphosate 2. Mechanical cultivation 3. Glyphosate and pre-emergent (eg Flame®)
Plant cane crop	1. Hero® 2. Krismat® 3. Sempra® 4. 2,4-D and either Hero® <u>or</u> Krismat® <u>or</u> Sempra® later 5. Mechanical cultivation
Ratoon crop	1. Hero® 2. Krismat® 3. Sempra® 4. 2,4-D and either Hero® or Krismat® or Sempra® later 5. Mechanical cultivation 6. Glyphosate with shielded sprayer/ dual delivery rig
Final ratoon crop	As for ratoon crops plus dual delivery spray application (for growers with the appropriate equipment).

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A. Munro, NSW Farming Systems Group.

R. Aitken, BSES Limited, Harwood.

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