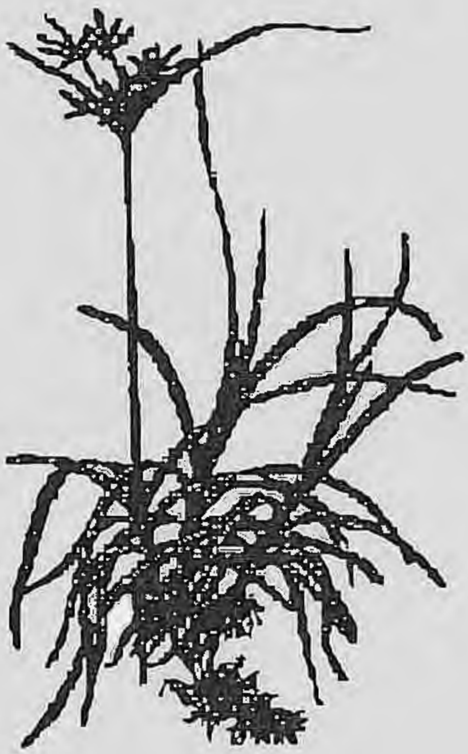
COTTON RESEARCH & DEVELOPMENT CORPORATION

NSW AGRICULTURE

Weed Control in Cotton



DAN 60C

1991 - 1992

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Cotton Research & Development Corporation

WEED CONTROL IN COTTON

Final Report

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1. Summary

DAN 60C was to be a 3 year project, but has been discontinued after the first season, in favour of a new and expanded project, accepted and funded by the CR&DC as N.21. Consequently, this report covers only one seasons results.

This project focused on the control of nutgrass. Nutgrass (*Cyperus rotundus*) is considered to be the world's worst weed and infests over 15% of the cotton growing area. Nutgrass adversely affects cotton by competition for light, nutrients and water, and indirectly through lint contamination, reduced irrigation efficiency and increased soil problems.

The project assessed the effects of herbicides, cultivation and rotation crops on nutgrass control using a number of field experiments located throughout the NSW cotton area. Most of these experiments will run for at least 2 seasons, but only the results of the first season are covered in this report.

A number of the herbicide and cultivation combinations evaluated in these experiments gave surprisingly good results. In cotton, the use of shielded and directed applications of glyphosate resulted in relatively high cotton yields and suppression of nutgrass tuber development. This tuber suppression was enhanced when glyphosate was used in combination with norflurazon.

In a bare fallow, repeated applications of glyphosate gave excellent nutgrass control when compared to untreated plots, although there was still an increase in the tuber number in the artificially wet conditions of the first season. Alternating glyphosate and cultivation gave a similar level of nutgrass control at a much lower cost.

A comparison of the effect of 2,4-D additives to glyphosate efficacy showed no benefit from these combinations.

Rotation crops suppressed nutgrass tuber production, but under dry conditions, the use of glyphosate in spring was apparently detrimental to nutgrass control. Under different conditions, the results of this treatment may have been very different.

Although MSMA herbicide is widely used by the cotton industry for nutgrass control, these experiments have shown no advantage from the use of this herbicide for *C. rotundus* control. Other experiments associated with this project have shown that MSMA controls *C. bifax*, a closely related and commonly mis-identified species of the nutgrass family which also occurs in the cotton areas.

This work was greatly assisted by the development of a tractor mounted herbicide boom and curtained sprayer, which was undertaken as part of the project.

2. Project Objectives

(i) to examine the nutgrass problem and evaluate the long term agronomic and economic efficiency of the current nutgrass control techniques used in cotton, in rotation crops and in fallows.

(ii) to examine aspects of the nutgrass problem, determining and evaluating possible alternative control techniques and control method combinations for nutgrass ecology.

3. Benefits of Research

Field and glasshouse studies completed as part of this project have:

* established a basis to further evaluate nutgrass control options
* shown that nutgrass can be controlled in cotton, allowing satisfactory cotton yields to be achieved in badly infested fields
* demonstrated that repeated applications of glyphosate herbicide can control nutgrass in a fallow
* shown that the efficacy of glyphosate in cotton can be enhanced by combination with norflurazon herbicide
* identified that MSMA herbicide does not give effective control of nutgrass either in cotton or in fallow
* demonstrated the value of rotation crops for nutgrass control

4. Dissemination of Results to Industry

Results arising from this work were presented at the the Sixth Australian Cotton Conference at Broadbeach, Qld, at the Cotton Industry Regional Conferences at Moree, Dalby, Warren and Gunnedah, at the Gwydir Valley Cotton Field Day, Moree, the Dry Land Cropping Field Day, Bellata, the Macquarie Valley Cotton Field Day, Warren, and the Namoi Cotton Field Day, Narrabri.

The field site at Warren was also evaluated by a group of growers and consultants.

5. Recommendations for Future Research

The program has as yet not answered the basic questions on nutgrass control, but has allowed a much better and more focused approach to be taken in the future. The basic field work needs to be continued, and there is a need to examine in more detail the factors which affect herbicide uptake by nutgrass. There are also a number of new herbicides being developed which show some promise for nutgrass control. There is a need to screen the range of herbicide material for alternative herbicide combinations. It may be that even some of less likely candidates have some nutgrass activity, as shown by the good nutgrass control of metolachlor in the in-cotton experiment at Wilona.

There are also many other weeds issues confronting the cotton industry and the weeds program at Narrabri should be broadened to allow input into these areas. Ultimately, the cotton industry needs to develop sustainable weed management systems which are less reliant on residual herbicides and hand chipping. These systems may encompass developments such as genetically engineered cotton, mycoherbicides, and weed activated spraying (WASP) technology.

6. Publications Arising

Charles, G. W. (1992). Nutgrass, a problem weed: a review of the literature. In "Genes to Jeans", Proceedings of the Sixth Australian Cotton Conference, Broadbeach, Queensland, p: 191 - 196.

Charles, G.W. (1992). Norwood: nutgrass control in fallow. Gwydir Valley Cotton Field Day, February 28, p: 23 - 24.

Charles, G.W. (1992). Norwood: nutgrass control in a bare fallow. Gwydir Valley Cotton Field Day Summary, 1991/1992.

7. Nutgrass Experiments - Results to Date

Introduction

Nutgrass (*Cyperus rotundus*) is considered to be the world's worst weed. It has been reported as a weed of 52 crops in 92 countries (Holm *et al.* 1977). In Australia, nutgrass infests 15% of the NSW cotton growing area, and this area is growing each year (Charles 1991). Nutgrass directly affects cotton by competing for light, nutrients and water, and indirectly through lint contamination, reduced irrigation efficiency and increased soil problems. Nutgrass spreads from underground tubers or nuts which are continuously produced throughout the life of the plant, resulting in long strings of tubers. These tubers exhibit strong apical dominance, and lower tubers in the string may remain dormant in the soil for several seasons. Herbicides applied to the plants are poorly translocated to the tubers.

Nutgrass control experiments have traditionally assumed that a uniform nutgrass population occurs prior to the experiment, and that visual changes in the population reflect the real impact of treatments. Earlier work has shown that this assumption is invalid.

Objective

These experiments were designed to evaluate the efficacy of the available nutgrass control techniques and treatment combinations, to document the extent of nutgrass control available with the currently used technology and to identify treatments or treatment combinations giving superior control.

7.1. Nutgrass control in cotton.

Experiments were established in cotton at 'Wilona', Auscott Warren, and 'Goroka', Merah North. Unfortunately the Goroka site had only a very low density of *Cyperus bifax*, not *C. rotundus*, and when this became apparent later in the season, this site was dropped.

The treatments used were combinations of inter-row cultivation, glyphosate, MSMA, metolachlor, benfuresate and norflurazon herbicides. Inter-row cultivation and MSMA herbicide are widely used in the industry for nutgrass management, although cultivation has the distinct disadvantage that as well as potentially controlling competition, it may rapidly spread the weed throughout a field. Glyphosate is used by some growers but is not selective and so successful application requires good conditions and accurate application technology. Norflurazon and benfuresate herbicides are as yet not registered for commercial use but have shown promise in field experiments.

The nutgrass tuber population was recorded prior to the experiment commencing, and again every 12 months to monitor the effect of treatments on the population. The cotton lint yield was also recorded.

A comparison of the herbicide combinations.

Herbicide combination	Cotton lint (kg / ha)		Nuts (per kg soil)	
	1991	1992	Spring 1990	Spring 1991
Metolachlor	1240		2.0	2.2
Benfuresate, norflurazon, glyphosate & cultivation	1210	1270	1.0	1.1
Inter-row cultivation	740	1250	0.7	2.7
Shielded & defoliant glyphosate	1110	1170	0.8	1.2
MSMA, glyphosate & inter-row cultivation	770	1100	0.7	2.4
Shielded & defoliant glyphosate & cultivation	1230	1080	0.9	2.7
Norflurazon & shielded & defoliant glyphosate		1070		
Benfuresate & cultivation	830	1040	1.7	2.6
Untreated	920	970	1.2	3.7
MSMA & defoliant glyphosate	1070	940	0.8	1.8
Defoliant glyphosate & cultivation	1060	850	1.6	3.3
MSMA	1170	840	2.2	2.4
MSMA & cultivation	880	830	0.8	4.3
Norflurazon & cultivation	1150	820	1.9	0.6
Average	**1010**	**1010**	**1.2**	**2.6**

The average cotton lint yield was 1010 kg/ha, or 4.4 bales/ha in both 1991 and 1992. The cotton lint yield in each year was highly correlated to the nutgrass tuber density, where the nut density was estimated as the average number of nuts per kg of soil in the 0 to 15 cm soil zone.

In 1991 the relationship was:

Yield = 1239 - 185 * nuts

and in 1992:

Yield = 1448 - 458 * nuts

These relationships accounted for 24% and 58% respectively of the variance in the data.

In 1991, a comparison of the herbicides showed that the norflurazon treatments increased the cotton lint yield by 404 kg/ha, and metolachlor by 354 kg; no other treatments significantly affected yield.

However, in 1992, the shielded and directed glyphosate treatments increased the yield by 502 kg/ha, but shielded and directed MSMA reduced the yield by 261 kg and norflurazon reduced yield by 507 kg.

The metolachlor treatment was dropped in 1992 because its inclusion required that other treatments did not receive a pre-emergent herbicide, leading to weed problems in these treatments. Also, on the basis of visual assessment, the metolachlor treatment did not appear to have any advantage over the untreated plots. The metolachlor treatment was replaced by an extra norflurazon treatment, as this treatment was visually very promising.

At first glance, there seems to be no relationship between the lint yields for the two seasons. However, in the first season, the first directed glyphosate treatment drifted on to the cotton and caused severe stunting. Consequently, the advantage to the cotton from reduced competition as a result of the glyphosate was masked by the stunting caused by the glyphosate. In 1992, a curtained sprayer was used to apply the first MSMA and glyphosate applications, minimising the damage to the cotton, and 5 of the best 6 treatments include shielded (curtained sprayer) and directed glyphosate. The apparently good result with inter-row cultivation in 1992 is surprising, but does show the value of this treatment.

The tuber number at the end of the first season was lower on the treated than the untreated plots (an average of 2.3 compared to 3.7 nuts/kg soil), but there were no apparent herbicide effects on tuber number.

The nut tuber density data from the 1991/92 season will not be available until later this year.

The experiment is being continued with a new design in the 1992/93 season.

7.2. Nutgrass control in cotton fallow

Experiments were established in a fallow following cotton at 'Norwood', Moree, and 'Glencoe', Wee Waa.

The treatments used were combinations of cultivation, glyphosate, MSMA herbicides; norflurazon herbicide was also included at Glencoe.

The nutgrass tuber population was recorded prior to the experiment commencing, and again every 12 months to monitor the effect of treatments on the population.

Glencoe

At the start of the experiment, the Glencoe field had a relatively uniform population of nutgrass tubers, with an average of 1.4 nuts per kg of soil in the 0 to 15 cm soil zone.

However, the population was a mixture of *C. rotundus* and *C. bifax*, and most nuts did not sprout, so that relatively few plots had 'good' nutgrass populations.

The population has increased to an average of 1.8 nuts per kg over the first season, but there were no significant treatment effects. There was a poor relationship between the visual observation of the nutgrass population in April 1991 and either the initial tuber population or the final tuber population, with the best regression fit accounting for only 23% of the variance in the data.

It will be particularly interesting to follow the infestation of nutgrass in the coming cotton season and observe whether 'uninfested' plots become infested, or whether these nuts are in fact dead.

The experiment has been continued for a second season, but the nut tuber density data from this season will not be available until later this year.

Norwood

At the start of the experiment, the Norwood field had a good and relatively uniform population of nutgrass (*C. rotundus*) tubers, with an average of 2.1 nuts per kg of soil in the 0 to 15 cm soil zone.

The population has increased to an average of 12.0 nuts per kg over the first season, and there were highly significant treatment effects on this population. There were very large visual differences between the treatments at the end of the season.

A contrast of the treatments showed that glyphosate reduced the nutgrass population, with a significant improvement in control as the glyphosate rate increased, but that there was an increase in the nutgrass population on the MSMA treatments.

A comparison of the herbicide combinations.

Treatment	**Nuts per kg soil**	
	Spring 1990	**Spring 1991**[1]
Untreated	2.1	19.7[a]
MSMA 2 times	1.2	18.6[a]
Double MSMA 3 times	1.5	17.9[a]
MSMA 4 times	2.4	14.2[ab]
Cultivated 7 times	2.5	15.6[ab]
Glyphosate & MSMA 2 times	2.2	13.6[b]
Glyphosate 2 times	2.6	11.5[bc]
Glyphosate 4 times	2.4	9.4[bcd]
Double glyphosate 4 times	3.1	6.7[cd]
Glyphosate 7 times	2.3	4.8[d]
Glyphosate & cultivation 3 times	1.8	6.2[d]
Average	**2.2**	**12.0**

Note[1] Values followed by the same superscript letter are not significantly different ($P<0.05$).

Although there was an increase in the tuber population on all plots, this increase was much smaller on the glyphosate treatments, with the higher rates giving better control. Monthly glyphosate treatments gave the best control, although alternating glyphosate and cultivation gave comparable control at a much lower cost. Increasing the glyphosate rate from 1.1 to 2.2 L a.i. per ha gave little added control. There was no evidence that MSMA controlled the nutgrass population.

There was a strong relationship between the visual observation of the nutgrass population in October 1990 and the initial tuber population, with the regression accounting for 78% of the variance in the data, where the visual observation (V) = 5 times the tuber population (T). However, there was no relationship between the visual observation in February 1991 and the tuber population in the following spring.

At the start of the experiment, it was decided to water the plots whenever the cotton was irrigated, and so water the cotton in the furrows below the experiment. However, by January it became apparent that the nutgrass was not receptive to glyphosate under this regime of constant watering, and from then on the experiment was given every second watering. This seemed to tip the balance, and the glyphosate treatments in February and March appeared to be much more effective.

From the first seasons results, the glyphosate treatments are very promising, although there is a need to clarify the possible interaction between glyphosate efficacy and soil moisture content. Although the cost of monthly glyphosate applications may at first appear to be prohibitive at around $50 per ha per application, this treatment will be very competitive if the WASP spraying unit is developed sufficiently to identify individual nutgrass plants. Particularly in the second year of the experiment, most of the glyphosate has been applied to bare plots, with very few nutgrass shoots present.

The experiment was expanded to include a norflurazon treatment in the second season, as this treatment was very promising in the Wilona experiment. The experiment has been continued, but the nut tuber density data from this season will not be available until later this year.

7.3. Nutgrass control in fallow

An experiment was established at 'Paloma', Premer, in a non-cotton situation to evaluate the effect of 2,4-D additives to glyphosate for nutgrass control.

While it is not presently feasible to consider the use of 2,4-D in the cotton area during the cotton season, with the future introduction of genetically engineered 2,4-D tolerant cotton, this approach becomes possible. 2,4-D has been used for nutgrass control over the past 20 or more years, and this experiment was established to examine any advantages of products such as Tillmaster over strait glyphosate herbicide.

The site used was in a dry-land paddock over 30 km from the nearest cotton.

The nutgrass tuber density in the 0 to 15 cm soil zone has been determined every 12 months to monitor changes in the nutgrass population.

The average nut count in spring 1991, from a 0 - 15 cm soil core.

Treatment	**Nuts per kg soil**			%
	(12 - 12 - 89)	(19 - 9 - 90)	(30 - 8 - 91)	change
Untreated	14.7	10.6	15.7	7
Glyphosate CT 2.4 L	22.2	10.6	11.3	- 49
Glyphosate 3 L	29.2	10.7	9.5	- 63
2,4-D amine 4.5 L	34.2	5.8	11.5	- 66
Tillmaster CT 11 L[1]	30.2	12.2	10.2	- 66
Tillmaster 12 L[2]	17.6	9.3	11.1	- 37
Glyphosate 3 L + 2,4-D ester 1.4 L	16.6	11.1	10.2	- 39
Glyphosate 3 L + 2,4-D ester 2.8 L	15.1	10.0	8.9	- 41
Glyphosate 3 L + 2,4-D ester 2.8 L + Boost 2%	12.6	9.6	16.8	33
Average	**21.4**	**10.0**	**11.7**	

Note[1] Tillmaster CT at 11 L contains 3 L of glyphosate and 2.25 L of 2,4-D amine.
Note[2] Tillmaster at 12 L contains 3 L of glyphosate and 4.5 L of 2,4-D amine.

There were no significant differences between the treatments in 1991, although the difference between the untreated and treated plots is approaching significance. However, the overall trend in the data shows a decrease in nutgrass tuber density on the treated plots, and indicates that the 2,4-D additions have not improved the efficacy of glyphosate.

This experiment has been expanded to include some additional treatments and is being continued. The results from the current season will not be available until later this year.

7.4. Nutgrass control in rotation crops

Experiments were established at Norwood and Glencoe to look at the effect of rotation crops on nutgrass control, using wheat, safflower and bare fallow in combination with one or two glyphosate applications. The fields were initially sown to wheat and the safflower plots were then over-sown; Fusilade was used to remove the wheat from the safflower plots, and glyphosate was used on the bare plots.

The nutgrass tuber density was estimated both before and after the experiment, and the viability of tubers at the end of the experiment was also determined, but this data has not yet been analysed.

Autumn 1991 was relatively wet and sowing of the rotation crops was delayed until the 2nd and 3rd of July. Forty one mm of rain fell a week after sowing, but only a further 39 mm fell before harvest, and the safflower establishment was not as good as anticipated. There was some rain in late spring which stimulated the nutgrass, but the nutgrass was stressed at spraying.

Norwood

The tuber population increased from an average of 8.7 nuts per kg of soil in July to 11.9 nuts in December. Comparison of the treatments not receiving glyphosate showed that whereas there was no change in the tuber density were wheat or safflower were present, there was a 40% increase in the tuber density in the bare fallow treatment; this difference can be directly related to competition from the crops.

The nutgrass tuber density in December 1991.

Crop	Untreated	Glyphosate (3 L/ha)	
		October	Oct & Nov
Bare	11.1	15.2	8.9
Wheat	7.8	8.3	17.6
Safflower	8.8	17.5	11.5

Unfortunately, as well as controlling nutgrass, the glyphosate treatments removed the crop competition, and there was a consequent increase in tuber production on most of the plots which received glyphosate; there is no apparent explanation for the smaller than expected tuber number increase in the wheat treatment which received glyphosate only in October. However, it may be that although the tuber number was increased by the glyphosate treatments, many of the tubers were killed by the glyphosate, and the number of live tubers may actually be lower on the treated than the untreated plots; unfortunately the nut viability data has not yet been analysed.

Percentage change in the tuber population from July to December.

Crop	Untreated	Glyphosate (3 L/ha)	
		October	Oct & Nov
Bare	43	71	90
Wheat	- 6	-1	90
Safflower	-1	98	44

Glencoe

The Glencoe site had a higher initial nutgrass density than at Norwood, but the field was drier and the establishment of both wheat and safflower was poorer. There were on average 18.8 nuts per kg soil in July, but this dropped to an average of 12.9 nuts in December., and there were no significant treatment effects on this nutgrass population.

8. Development of a Tractor Mounted Herbicide Boom

A Kubota M6030 two wheel drive tractor was purchased and delivered in mid-October 1991. The M6030 was purchased instead of the proposed M4030 because of its greater wheel width of 2.00 m compared to 1.85 m. Unfortunately this tractor cost an extra $4 000, which caused some difficulty with the remainder of the budget.

The tractor was set up with a 300 L main tank, a 100 L and two 50 L side tanks, parallel hydraulically powered centrifugal and electric pumps, and a Dicky-John spray controller. A boom spray was set up on the sled cultivator used in the nutgrass experiments.

This equipment was used from November 1991 and has been extremely useful, although some modifications of the original design are warranted. Not withstanding this, the equipment allowed accurate and timely application of herbicides to areas ranging in size from 0.008 to 1 ha. The spray controller and two pumps allow the output to vary from less than 1 L per min to over 70 L per min.

The shielded sprayer was also built in October and November 1991 and used in November, although it also requires some further modification.. It performed very well, allowing in-crop herbicide application to occur in adverse weather conditions, minimising herbicide drift problems.

9. Appendix 1 - Publications

9.1 - Nutgrass, a problem weed: a review of the literature

Graham Charles, Research Agronomist (Weeds),

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Introduction

Nutgrass (*Cyperus rotundus* L.), a plant native to India, is known as the world's worst weed (11)* . It is a member of the family Cyperaceae, which contains approximately 3000 species, of which about 220 species are important weeds (2). Nutgrass is cold sensitive (2), only growing during the warmer months and will not survive in the colder parts of Australia. It is adapted to most soil types and soil moisture regimes (11).

Nutgrass species in cotton

Twenty two species of the genus Cyperus occur in western NSW (5), of which I have observed six species in or near cotton. However, only two species, *C. rotundus* and *C. bifax* C.B. Clarke. (Downs nutgrass) are problems in cotton. Identification of these species is described in an article in the Australian Cotton Grower (3).

Nutgrass propagation

Nutgrass reproduction is primarily by underground tubers. There are varying reports on nutgrass seed production, but it is generally agreed that although nutgrass commonly flowers, very few if any viable seeds are produced and seedlings are of little importance. For example, in the US, from 170 inflorescences (flower heads), containing 95,000 flowers, only 43 seeds were collected, none of which germinated (18). A Queensland study of nutgrass from 9 locations found on average 3 seeds per inflorescence, of which 7% germinated, although these values ranged up to 14 seeds and 37% germination (10).

Nutgrass spread

Nutgrass can spread very rapidly by tubers, which develop on rhizomes (underground stems), producing a chain of tubers attached to the growing plant. One study under ideal growing conditions, reported that 4 weeks after planting, a single

* The numbers in brackets in the text correspond to the references listed at the end of this paper.

tuber had produced 15 shoots and 27 new plants (7). By 8 weeks there were 172 plants and 75 new tubers. By the end of the season (20 weeks), a single tuber had produced 300 plants and 940 new tubers (7). By the end of 2 seasons, the population was equivalent to 2600 tubers per m^2 or 26 million nutgrass tubers per ha (6).

These tubers have strong apical dominance, so that only the top tuber in the chain is active at any time and the remaining tubers are dormant. There is no data on how long these dormant tubers remain viable in the soil, but their survival will be counted in years if their root system is intact.

Most nutgrass tubers occur in the top 15 cm of the soil (15), and are rarely found below 40 cm, although nutgrass roots may extend to 1.35 m (1). In a typical soil, 66% of tubers are in the 0 - 10 cm soil layer and 90% in the 0 - 20 cm layer (19).

Nutgrass competition with cotton

Nutgrass competes with cotton for light, nutrients and water, but also adversely affects cotton by reducing irrigation efficiency, reducing pesticide penetration, reducing harvesting efficiency and contaminating lint. Cotton is also damaged by some of the herbicides and cultivation practices used to manage nutgrass.

Although nutgrass is a very competitive weed, it does not tolerate shading (11). Under 73% shade, nutgrass growth was reduced by 65 to 70% (13). Nutgrass responds to competition by increasing shoot length and proportionally increasing tuber production compared to flower production (20).

In my experiment at Warren in the 90/91 season, the cotton yield fell from 7.9 bales per ha in the absence of nutgrass, to 1.6 bales in heavily infested plots. These plots had up to 1250 nutgrass tubers per m^2, but received no treatments for nutgrass control. In practice, by using management tools including herbicides and cultivation, growers can achieve much better than 1.6 bales per ha in spite of large nutgrass infestations. However, the cost of the necessary additional inputs for nutgrass infested fields may prohibit cotton production, particularly where uninfested land is available and water is the primary limiting resource.

Nutgrass control

Nutgrass tubers are susceptible to high temperatures and dehydration. Isolated tubers on the soil surface were killed by 4 days exposure to sunlight and 12 days exposure killed tubers at up to 5 cm soil depth. As temperature increases, tubers were killed within 48 hours by exposure to 50°C and by 1 hour exposure to 60°C (15). Clearly, some nutgrass control can be achieved by cultivation. Research has shown that a 90% reduction in nutgrass tubers is achievable when cultivation occurs every 4 weeks throughout a single season (16), although in practice I have found that cultivation every 4 weeks has not adequately controlled nutgrass in the field. In a glasshouse experiment where nutgrass shoots were removed every 2 weeks, some tubers still had sufficient reserves to produce new shoots after 15 months of treatment (17). Cultivation also has the advantage of breaking apical dominance (15), so that a much higher percentage of tubers will sprout and may be receptive to other treatments.

Many herbicides have been used for nutgrass control with varying degrees of success. The problem has generally been that although there are a number of herbicides which will kill nutgrass, most herbicides are not sufficiently well translocated to kill the dormant nutgrass tubers attached to the treated plant. As soon as 3 or 4 weeks after treatment, some dormant tubers can sprout and produce new tubers, returning the area to a nutgrass density equal to or greater than that present at the time of spraying.

In the 1960's, amitrole, 2,4-D, EPTC (sold as EPTAM) and the arsenicals were used to control nutgrass. Researchers in the US found that two applications of amitrole (9 kg per ha) within 4 weeks of nutgrass emergence, one application of EPTC (11 kg per ha), or 9 applications of 2,4-D (2.2 kg per ha) starting within 2 weeks of emergence, all gave good nutgrass control (9). However, these results were only achieved after complete cultivation by rotary-hoeing to 15 cm two weeks after each treatment to initiate uniform sprouting. This approach is difficult to implement in our situation with summer rainfall and high water holding capacity soils, where a delay in cultivation for 3 or 4 weeks after rain could see the nutgrass population return to pre-treatment levels. In another study, amitrole reduced a nutgrass population by 70% when applied within 4 weeks of shoot emergence, but was ineffective when plants were 6 or more weeks old (8). EPTC controls nutgrass by inducing tuber dormancy, but dormancy is only maintained as long as high soil EPTC levels are maintained. In practice, nutgrass control with EPTC has been very variable, being least effective in soils with high organic matter contents and best in soils with high sand and silt contents. EPTC is volatile and may be rapidly lost from the soil, so that repeated applications are required for long-term nutgrass control (12).

In the 70's and 80's, glyphosate and MSMA have become the principle herbicides used against nutgrass. MSMA (3.4 kg per ha) has been shown to prevent nutgrass regrowth (14), and 3 applications (2 kg per ha) can reduce nutgrass plant numbers by 66% and tuber numbers by 88% (21). Three applications of glyphosate reduced a nutgrass plant population by 97% and the tuber population by 92%. However, with no further treatment, the nutgrass density increased from 3% to 35% of the pre-treatment population within 10 weeks (21).

MSMA has been ineffective in controlling nutgrass in my experiments, but repeated applications of glyphosate have given good results, although the timing of glyphosate applications is important. Glyphosate toxicity to nutgrass is greatest with high humidity and no moisture stress (4), and warm temperatures.

Conclusions

* Nutgrass is a severe weed problem because of its competitive nature and its ability to rapidly produce large numbers of active and dormant tubers.
* Nutgrass control measures must be applied rigorously and frequently. Any lapse in control may result in rapid reinfestation of the treated area.

References used in this article

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9.2 - Norwood
Nutgrass control in fallow

This experiment is designed to examine the effect of herbicides and cultivation alone, or in combination, on the control of nutgrass (*Cyperus rotundus*) in a bare fallow between cotton crops. The area was fallow in the 90/91 and 91/92 seasons and will be in cotton in 92/93. Shielded and directed herbicide applications will be applied on some treatments in the cotton crop.

The density of nuts in the soil was assessed in spring 1990 and 1991, and will be assessed again in 1992 and 1993 to determine the effect of treatments on the nutgrass population.

Rep 4		Rep 3		Rep 2		Rep 1	
		G3 42	M2 35	Z 28	M2 21	Zg 14	G2 7
	C 49	U 41	Gc 34	Md 27	G3 20	Z 13	M2 6
Md 55	U 48	C 40	G7 33	U 26	G2 19	G7 12	M4 5
M2 54	G2 47	G2 39	Gm 32	G4 25	Zg 18	Gm 11	Md 4
G4 53	Gm 46	G4 38	M4 31	C 24	Gd 17	C 10	Gc 3
Z 52	Gd 45	Zg 37	Md 30	M4 23	Gc 16	G3 9	G4 2
G7 51	M4 44	Gd 36	Z 29	Gm 22	G7 15	Gd 8	U 1
Zg 50	Gc 43	R3 56'		Head Ditch			

Treatments are:

- **C** = Control (no treatment)
- **U** = Cultivated monthly from October to May
- **G2** = Glyphosate 1.4 kg ai/ha, in January & April
- **G3** = Glyphosate at 1.4 kg ai/ha, in Nov, Feb & April
- **G4** = Glyphosate at 1.4 kg ai/ha, in Oct, Dec, Feb & April
- **G7** = Glyphosate monthly at 1.4 kg ai/ha, from October to May
- **Gd** = Glyphosate at 2.7 kg ai/ha, in Oct, Dec, Feb & April
- **Gc** = Glyphosate at 1.4 kg, and cultivation alternating monthly Oct to May
- **Gm** = Glyphosate at 1.4 kg in Nov & Dec, and MSMA at 2.2 kg in Feb & Apl
- **M2** = MSMA at 2.2 kg ai/ha in Nov & Jan
- **M4** = MSMA at 2.2 kg ai/ha in Nov, Dec, Jan & Feb
- **Md** = MSMA at 4.3 kg ai/ha in Nov, Jan & Mch
- **Z** = Norflurazon at 4 kg ai/ha in May
- **Zg** = Norflurazon at 4 kg in May, and glyphosate, 1.4 kg in Nov, Jan & Mch

The glyphosate treatments appeared to be very effective at the start of last season, but by February (the time of the last field day), the nutgrass had bolted away from all the treatments. However, by mid-March, the situation had again reversed, with big visual differences between most treatments. Throughout autumn, the glyphosate treatments appeared to be very effective, with few if any live nutgrass plants present, while the MSMA treatments appeared to be relatively ineffective.

In spring 1990, there were on average 2.2 nuts/kg of soil, per plot, although this number ranged from 0 to 12 nuts/kg; nut number was determined from 14 soil cores, 75 mm diameter by 150 mm depth per plot. By spring 1991, the nut number had increased to an average of 11.9 nuts/kg of soil, an 8.6-fold increase; this reflects the period last summer when the nut grass populations on all the treatments 'bolted'. The best nutgrass control was on the treatment which received monthly glyphosate applications (a 90% increase in nut number), although the combination of glyphosate and cultivation also gave a 'good' result, with only a 170% increase in nut number over the season; this should be considered beside the 1008% increase in the control treatment, and the 3230% increase in an MSMA treatment!

Treatment	Nut density		Change	**Change**
	1990	1991	(91 - 90)	**(X-fold)**
Control	2	21	19	10.8
Cultivated 7 times	3	17	15	7.6
Glyphosate twice	4	11	9	6.3
Glyphosate 4 times	2	10	7	2.8
Glyphosate 7 times	2	5	3	0.9
Glyphosate 2*rate, 4 times	3	10	7	2.5
MSMA 2 times	1	15	14	20.8
MSMA 4 times	2	15	13	8.0
MSMA 2*rate, 4 times	1	15	14	32.3
Glyphosate & cultivation 3 times	2	5	4	1.7
Glyphosate & MSMA 2 times	2	13	11	8.1
Average	**2.2**	**11.9**	**10**	**8.6**

Although most treatments have been continued this season, the design has been altered to include two norflurazon treatments. Also, the site has not been irrigated, reducing nutgrass growth, and enhancing the cultivation effect. While the results from last season show the capacity of nutgrass to reproduce when given any opportunity, I expect that the best treatments this season will show a reversal, with a decrease in the nutgrass populations.

9.3 - Norwood
Nutgrass control in a bare fallow

Graham Charles, NSW Agriculture, Narrabri Research Station

This experiment has again stimulated some thinking and re-evaluation of ideas about nutgrass control. Unfortunately the final results from this season will not be available until late this year. However, it is appropriate to clarify the visual effects that we could all see at the time of the field day, along with some other observations.

Table 1. The effect of some nutgrass treatments on nutgrass control in a bare fallow.

Treatment	Rate	Nutgrass rating[1]		
	L/ha	1990[2]	1991	1992
Untreated		6	3	10
Cultivated 8 times (monthly Oct to May)		6	5	6
Glyphosate twice (Jan & April)	3.0[3]	4	0	2
Glyphosate 3 times (Nov, Feb & April)	3.0		3[2]	2
Glyphosate 4 times (Oct, Dec, Feb & Apl)	3.0	6	0	2
Glyphosate 8 times (monthly Oct to May)	3.0	6	1	0
Glyphosate 4 times (Oct, Dec, Feb & Apl)	6.0	7	0	0
MSMA 2 times (Nov & Jan)	4.3[4]	5	4	9
MSMA 4 times (Nov, Dec, Jan & Feb)	4.3	6	8	10
MSMA 4 times (Nov, Jan, Mch & May)	8.6	4	9	8
Glyphosate & cultivation alternating (Oct to May)	3.0	6	2	0
MSMA (Nov & Dec) & glyphosate (Feb & Apl)	4.3 & 3	4	0	1
Norflurazon (Aug)	4.0		2[2]	10
Norflurazon (Aug) & glyphosate (Nov, Jan & Mch)	4 & 3		3[2]	2

Note [1] Plots were visually rated as 0 (no nutgrass) through to 10 (100% of the plot severely infested with nutgrass). A rating of 4 for example indicates that 40% of the plot is severely infested with nutgrass.

Note[2] the first set of numbers show the nutgrass density on the plot before the experiment began.

Note[3] the glyphosate formulation contained 360 g a.i. / L.

Note[4] the MSMA formulation contained 500 g a.i. / L.

Over the duration of the treatments, there has been a noticeable increase in the nutgrass density on the untreated plots, the three MSMA treatments and the norflurazon treatment. Monthly cultivation has maintained the nutgrass density at the pre-experiment levels, and treatments including glyphosate have resulted in a decrease in the level of nutgrass. The visual estimates are not sufficiently sensitive to differentiate between glyphosate treatments on the number of glyphosate application used in a treatment, but the data presented at the field day showed that the treatments using the greatest number of glyphosate applications resulted in the greatest reductions in nutgrass density.

As in the earlier data, the treatment using alternating cultivation and glyphosate applications[1] gave an excellent result, and would be much less expensive than the monthly application of glyphosate. Alternating cultivation and glyphosate has the advantage of breaking nut chains, and so maximising the proportion of nuts which are active and receptive to the glyphosate. Also the cultivation removed surface trash and old nutgrass plants, so that the nutgrass was actively growing and physically available for the spray application. This compared to the MSMA treatments which resulted in an enormous bulk of actively growing, sensing and dead plant material which confounded the spray application, with a high proportion of the herbicide being applied to dead and unreceptive plant material.

On an in-cotton nutgrass experiment at Warren last season, treatments using three in-crop glyphosate applications gave extremely good nutgrass control. However, this contrasted with poorer control from the same treatments, on the same plots the previous season. From the results of these two experiments over two seasons, it is apparent that glyphosate can give good control of nutgrass both in-fallow and in-crop, but that the efficacy of glyphosate depends on some external factors, of which I suspect soil moisture to be one of the most important.

I am planning to run three separate in-cotton experiments in this field next season, firstly using the best treatments from the Warren experiment, secondly examining a wide range of herbicides and combinations for efficacy, and thirdly looking at the effect of irrigation timing on glyphosate efficacy. I hope that the results of these experiments will clarify a number of points concerning nutgrass control.

Note[1] This treatment used cultivation in Oct, Dec, Feb & April, and glyphosate in Nov, Jan, March & May.