

MANAGING NUTGRASS IN COTTON

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Preface

This document was first compiled in 2002 from extensive research and observations undertaken in the years prior to the release of cotton varieties with the Roundup Ready[®] trait.

The regular and widespread use of glyphosate in crop over the last decade and more has gone a long way to managing this weed and much of the information in this document is no longer essential for managing nutgrass.

However, all the information has been left in the document to assist those who don't use varieties with the Roundup Ready Flex technology.

For those using the Roundup Ready Flex[®] technology, you may choose to skim through a lot of this document, but you will also find a lot of information that will assist you to get the best out of glyphosate for managing nutgrass.



A heavy "nutgrass" infestation in cotton. The field was infested with four different species. The cotton was infested with downs nutgrass and yelka, while dirty Dora and umbrella sedge infested the head ditch.

The four steps for weed management

A successful weed management program is built in four steps. These are:

- **positive identification** of the weed
- **assessment** of the extent of the problem
- targeted **treatment** of the weed, integrating all available management tools, and
- **evaluation** of the farming system, making modifications as required to ensure success.

The nutgrass (*Cyperus*) family

Positive identification is the first step in managing any problem weed, as different management techniques may be needed to control different weeds, even though the weeds may be closely related.

Nutgrass belongs to the genus *Cyperus*, of which 38 species are reported to occur in the cotton growing areas of Australia. Of these, 19 species are native to Australia and the remaining 19 species have been introduced.¹ Three of these species are commonly found in or around cotton fields (Table 1), while another five species occasionally occur around cotton fields (Table 2).

Table 1. Nutgrass species commonly found in and around cotton fields.

Botanical name	Common name
<i>C. bifax</i> C. B. Clarke	downs nutgrass
<i>C. rotundus</i> L.	nutgrass
<i>C. victoriensis</i> C. B. Clarke	yelka

Table 2. Other nutgrass species occasionally found around cotton fields.

Latin name	Common name
<i>C. alterniflorus</i> R. Br.	Tall sedge
<i>C. concinnus</i> R. Br.	Trim sedge
<i>C. difformis</i> L.	Dirty Dora
<i>C. eragrostis</i> Lam.	Umbrella sedge
<i>C. iria</i> L.	Rice flatsedge

This article primarily focuses on the control and management of nutgrass (*C. rotundus*) as by far the most difficult to control of these weeds. Management information for the other species is discussed throughout the article.

Nutgrass (*C. rotundus*) (see p. H3.4)

Nutgrass, called purple nutsedge in the USA, is an introduced, strongly competitive perennial weed that grows from underground tubers. It is an international weed and is a major problem in a range of crops, and especially irrigated farming systems.

Nutgrass favours lighter soil and wetter conditions, but grows well on both dryland and irrigated soils throughout the cotton industry.

It may be relatively short, at 10 - 15 cm, but can grow up to 60 cm high in irrigated cotton. Nutgrass has dark green leaves and stems that are triangular throughout their length. It has a dark purple flower head that is up to 10 cm in diameter and lightens in colour with age. Nutgrass grows in very dense patches, with little space between shoots. Densities of up to 14000 tubers and 2200 shoots/m² have been recorded in irrigated Australian cotton. It can reduce cotton yields by up to 90% at these densities.

Nutgrass can be positively identified from the purple colouration on the outer leaves at the base of the plant stem, around the basal bulb. This colouration is seen by stripping back one or two leaves from the base of the nutgrass shoot. Purple colouration persists through several layers of outer leaves, while the inner leaves are light green and then white.

Nutgrass produces large numbers of seeds, but the seed has very low viability (only 1 or 2%) and the seedlings are weak and easily controlled by herbicides such as trifluralin and pendimethalin. Nutgrass plants rarely establish from seed; reproduction is almost always by vegetative propagation through new tubers.

A single nutgrass plant can produce up to 2000 new tubers in a single season. The first tubers are initiated about four weeks after the nutgrass shoots first emerge. These new tubers then produce new shoots that produce new tubers etc. Most tubers are in the top 15 cm of the soil, although tubers can emerge from 30 - 40 cm depth.

Nutgrass is frost susceptible and becomes dormant over winter when conditions are sufficiently cool. Plants re-establish in spring from dormant tubers. Nutgrass tubers may remain dormant in the soil for several years, but require moisture to survive. Tubers are easily killed by desiccation in a dry soil.

¹ Lazarides M. Cowley K. and Hohnen P. (1997). CSIRO handbook of Australian weeds, CSIRO Publishing, Collingwood, Vic.

Downs nutgrass (*C. bifax*) (see p. H3.5)

Downs nutgrass is a native Australian species and is abundant in much of the flood susceptible, watercourse country.

It is similar to nutgrass, but is generally taller at 60 - 80 cm, its leaves and stems are a lighter green in colour, and its seed head is larger (up to 20 cm across) and lighter in colour, starting off brown or orange and fading with age. Its stems are triangular over their full length, but unlike nutgrass, the outer leaves at the base of the stem are light green, and the inner leaves white.

Downs nutgrass produces a large quantity of viable seeds. Typically, it also produces 5 to 20 new tubers per plant each season, and establishes from both seed and tubers. Most tubers are found in the top 10 cm of the soil and are easily killed by desiccation. New downs nutgrass infestations can occur from seeds carried in floodwater and fodder.

Downs nutgrass grows at much lower density than nutgrass and is much less competitive, although downs nutgrass may be more obvious in cotton due to its greater height.

Yelka (*C. victoriensis*) (see p. H3.6)

Yelka is native Australian species that occurs in the watercourse country and is common on roadsides.

It has erect, dark green stems 100 - 120 cm tall with few leaves. The stems are circular at the base, but become more triangular towards the top. Yelka may have a small, purple flower head, with a few short leaves below the flower, but often the flower head is absent. It grows at low densities, produces few seeds and tubers, and is not very competitive. Most tubers are found in the top 10 cm of the soil and are easily killed by desiccation in a dry soil.

Tall sedge (*C. alterniflorus*) (see p. H3.7)

Tall sedge is a perennial native Australian species that occurs sporadically in wet areas such as river and creek banks, lagoons and irrigation ditches.

Mature plants are around 1 m tall and can form large, dense tussocks. The stems are almost circular at the base but become triangular throughout most of their length.

Tall sedge produces rhizomes and masses of seed, but does not spread rapidly. It can be a nuisance in irrigation channels and water storages.

Trim sedge (*C. concinnus*) (see p. H3.8)

Trim sedge is a native Australian species that occurs sporadically on wet areas and table drains.

It grows to around 50 - 60 cm high and produces both seed and rhizomes. Its stems are triangular throughout their length.

Dirty Dora (*C. difformis*) (see p. H3.9)

Dirty Dora is another native Australian species that invades wet areas. It is a major problem weed in rice and cane production in Australia.

Dirty Dora grows from seed and is readily spread by seed. Even small plants can produce large quantities of viable seed. It has no underground tubers. It tends to be relatively short, up to 50 cm, and is a paler, yellowy colour. The stems of dirty Dora are strongly triangular throughout their length.

Small numbers of small plants may occur throughout cotton fields without being noticeable. Dirty Dora plants have germinated from soil samples taken from fields where the plant has never been observed to occur.

Umbrella sedge (*C. eragrostis*) (see p. H3.10)

Umbrella sedge is an introduced species that invades wet areas and can be a problem in water storages and irrigation channels.

Umbrella sedge grows from seed and is readily spread by seed. Even small plants can produce large quantities of viable seed. It has no underground tubers. Plants are generally around 30 - 50 cm tall, although they can grow to 1 m. The stems are almost circular at the base but become triangular throughout most of their length.

Once established, umbrella sedge plants can grow to form a large tussock.

Rice flatsedge (*C. iria*) (see p. H3.11)

Rice flatsedge is a native annual sedge that occurs in wet areas such as table drains and irrigation channels. It grows to 60 to 80 cm in height and produces large quantities of seed. Its stems are strongly triangular throughout their length.

Mullumbimby couch (*C. brevifolius*) (see p. H3.12)

Mullumbimby couch is an introduced weed that thrives in damp and disturbed areas. It is a rhizomatous perennial weed that readily establishes from seed. It is short, up to 15 cm high, but forms dense, competitive mats and masses of seed.



Nutgrass is a strongly competitive perennial weed that grows from tubers.



Downs nutgrass is a native perennial weed commonly found in the watercourse country. It is not very competitive with cotton, but can be very obvious due to its height and colourful flower heads.



Yelka is a native weed commonly found on roadsides and waste areas. It is tall, but has few leaves and grows at relatively low densities.



Tall sedge is a native weed occasionally found on river and creek banks, irrigation channels and water storages. It can form large, dense tussocks.



Trim sedge occurs sporadically on wet areas and table drains.



Dirty Dora is a native species that invades wet areas. It produces masses of seed and can spread very quickly.



Umbrella sedge is an introduced weed that invades wet areas and spreads rapidly from seed.



Rice flatsedge is a native species that invades wet areas.



Mullumbimby couch is an introduced weed that invades wet and disturbed areas and can spread rapidly from seed and rhizomes.

Understanding nutgrass (*C. rotundus*)

Nutgrass produces and survives from vegetative tubers in the soil. These tubers are up to 10 mm in diameter and up to 20 mm in length. Tubers are formed at the end of underground rhizomes that develop from each vegetative plant. A new plant develops from each tuber. Tubers appear to be formed in chains, but each tuber gives rise to a vegetative plant, which gives rise to new tubers, and so on.

These tubers can become dormant in winter or during dry conditions and can survive for years in the soil, extracting moisture through their roots. However, they are vegetative plant structures and cannot survive without water. Tubers are rapidly killed if they are exposed to very dry soil or are exposed at the soil surface after their roots are cut. Tubers without roots into moist soil die within a few hours when exposed at the soil surface in the middle of summer.

Tubers can be found throughout the soil profile, but are most common in the 0-10 cm soil layer. The results from 120 soil cores are shown in Table 3. Cores were from heavily infested fields in the Moree and Wee Waa areas. No tubers were detected below 40 cm, although a small number of tubers have been found at up to 1m depth. These tubers probably fell down cracks in the soil and are of no importance, except when they become exposed by deep cultivation, erosion, earth works, or after levelling.

Table 3. Distribution of nutgrass tubers down the soil profile (0 to 100 cm). Percentage found in each soil layer.

	Soil depth (cm)			
	0 - 10	10 - 20	20 - 30	30 - 40
Field 1	66	25	7	1
Field 2	50	38	10	2
Field 3	42	42	14	3
Average	53	35	11	2

Emergence from tubers placed at depth in a sandy soil and a black soil are shown in Table 4. Nutgrass shoots emerged readily from tubers down to 20 cm in depth, with some emergence from 40 cm in the sandy soil. Emergence was slower from the lower depths and was much slower in the black soil. The results from the sandy soil show that shoots could emerge from at least 40 cm in a black soil, where shoots emerge through cracks in the soil. Poor emergence was observed from tubers placed on the soil surface, which were probably killed by desiccation.

Table 4. Percentage emergence and days to emergence from tubers placed at depth in sandy and black soils in pots.

Depth (cm)	Sandy soil		Black soil	
	Emergence	Days	Emergence	Days
0	43	13	0	
2.5	100	9	100	7
5	100	9	75	18
7.5	100	12		
10	100	12	100	41
12.5	100	11		
15	100	14	100	54
20	100	18	75	51
25			0	
30	0		0	
40	25	38	0	
50			0	

Post-emergence observations indicated that the depth of the tuber did not affect subsequent plant growth.

Biological control of nutgrass

A range of organisms attack nutgrass, including rust, head smut, scale insects and a caterpillar that bores down through the stem (*Bactra trunculenta*). Feral pigs and other animals will also dig for and eat nutgrass tubers. These organisms normally have little impact on nutgrass infestations, attacking only a small proportion of plants, but can be found in large numbers in heavy nutgrass infestations.

The possibility of biological control of nutgrass has been examined in a number of countries, but has not been effective in significantly reducing weed numbers.



Leaf rust on nutgrass (top left), and downy mildew on nutgrass (bottom left) and stem rust on yelka plants (right).



Nutgrass affected by smut. This is of little importance, however, as nutgrass spreads primarily by tubers not from seeds.



Nutgrass tubers and shoots parasitised by a scale insect (white spheres).

Treatment options

Nutgrass can most easily be managed using a long-term, integrated weed management (IWM) approach, of which glyphosate is the central component. There are a number of tools that help control nutgrass, and practices that enhance control. These tools need to be used in combination. There are also a number of practices that should be avoided whenever possible.

One of the key components of an effective IWM strategy for nutgrass is to develop a 'whole-farm' approach. It is essential that nutgrass infestations are managed not just in-field, but also on roadways, channels, storages, non-cotton fields and waste areas. Strict field hygiene protocols are needed, especially where large areas of nutgrass are present in non-cotton areas and it is not practical to control the nutgrass on these areas. Nutgrass rarely establishes from seed. Most infestations are caused by tubers being spread from field to field and farm to farm by machinery. It is common to see nutgrass plants initially establish at the end of a field, where they have fallen from cultivators that were previously operating in infested fields. Subsequent cultivation passes spread the infestations throughout the fields.

More information on IWM is covered in the [Integrated Weed Management \(IWM\) Guidelines](#), Section B3 in [WEEDpak](#).

IWM tools for nutgrass control

Nutgrass can be controlled using:

- cultivation,
- residual herbicides,
- contact herbicides, and
- crop competition.

Cultivation

Mechanical cultivation can be very effective in controlling nutgrass, but it is also the most common means of spreading nutgrass. All too often nutgrass tubers and plants are lifted by a cultivator only to be transplanted further down the field.

Cultivation is effective in controlling nutgrass when it severs all the roots from the tubers, provided that the soil is sufficiently dry to kill the tubers. If the soil is not dry, nutgrass plants will rapidly re-establish after cultivation, and may be spread by the cultivator to new parts of the field or to new fields.

Inter-row cultivation is usually ineffective in controlling nutgrass in cotton, as cultivation generally occurs at relatively high soil moisture content to avoid excessively damaging the cotton, and is not deep enough to fully sever the roots of nutgrass plants and tubers.



Inter-row cultivation can be useful for suppressing very heavy nutgrass infestations, but has the major limitation that it can't control nutgrass in the cotton plant line.

Inter-row cultivation in lightly infested fields will often spread nutgrass and exacerbate the problem. Cultivation of lightly infested fields should be avoided where possible, or the cultivator should be lifted over nutgrass patches or cleaned down after passing through nutgrass patches. A small amount of time spent in cleaning down cultivation machinery can save large costs in time and money required to control the weed in the future.

Multiple inter-row cultivation passes can be used to suppress nutgrass in heavily infested fields, where the spread of tubers is of no importance. Multiple cultivation passes will help the cotton to establish and produce a crop. There will, however, be no lasting reduction in the nutgrass population, which will need to be controlled by another means at a later date.

Heavy cultivation (cultivation to at least 30 cm) is most effective in controlling nutgrass when the soil is completely dry following a cotton or rotation crop. A crop such as lucerne is ideal for completely drying out the soil in the nutgrass root zone. Cultivation should be timed to occur in mid-summer when no rain is forecast and the lucerne crop has dried the soil as much as possible. Heavy cultivation in these conditions can almost completely eliminate a nutgrass infestation from a field. The main limitation to control is the cost of the operation and the practical depth of cultivation.

Cultivation that disturbs the hills prior to planting can also be useful, as it appears to delay nutgrass emergence.



A trailing ripper set up for heavy cultivation of nutgrass after picking. Note the steel cable across the rippers (top photo) designed to cut the nutgrass roots during ripping.

Residual herbicides

Norflurazon (Zoliar[®], Group F)²

Zoliar is the only residual herbicide currently registered for controlling nutgrass (*Cyperus* sp.) in cotton. It is highly persistent, with a half-life of up to 180 days³. Zoliar requires thorough soil incorporation and needs to be used over at least 3 consecutive seasons.



Nutgrass affected by Zoliar, as indicated by the white leaves. Most plants have been severely affected by Zoliar, and some plants in the background have been killed by the herbicide.

Zoliar is registered for application at 2.8 to 4.2 kg/ha, depending on soil type and whether Zoliar was applied in the previous season. Zoliar should be applied at the higher rate in the first season (depending on soil type), but the rate can be reduced in following years. Ideally, it is applied to nutgrass patches in autumn prior to a cotton crop planted in spring. Lower rates should be used if application occurs closer to planting.

Zoliar is readily adsorbed to clay and organic matter in the soil and is relatively immobile. Its efficacy is affected by soil pH and clay content. High rates are required on heavy, alkaline clay soils, but much lighter rates should be used on sandy and acid soils.

² Herbicides are grouped according to mode of action and the risk of weeds developing resistance to the herbicide. Always try to avoid using repeated applications of herbicides belonging to the same herbicide group.

More information on herbicide groups is covered in [Managing Herbicide Resistance in Cotton](#) Section C2 in [WEEDpak](#).

³ Technical information for all products was compiled from label information and from information from the *Herbicide Handbook* (1994) Seventh Edition. Ed. William H. Ahrens, Weed Science Society of America, Champaign, Illinois, USA.

Zoliar's activity is triggered by a rainfall or irrigation event. It is readily absorbed through plant roots when the soil is wet (near or above field capacity), but is not absorbed from a dry soil.

Zoliar acts on the plant's photosynthetic pathways and destroys chlorophyll and lipids in the cell membranes, and cell proteins. This has the effect of turning affected leaves white. The affected leaves and plants die if this effect lasts sufficiently long.

It is common under Australian conditions for Zoliar to become less active again within a few days of the triggering rainfall or irrigation event. When this happens, the plant recovers from the herbicidal effect and resumes growing. Sections of white along the length of a leaf can indicate Zoliar activity has occurred in the past. Some suppression of nutgrass does continue at lower soil moisture levels.



This grass plant has been affected by Zoliar, but will probably recover as some leaves are still photosynthesising.

Zoliar has the primary advantage that it needs to be applied only once for the season and is most effective during wetter conditions, when the nutgrass would otherwise be most actively growing, and other control measures are difficult or impossible to implement. Zoliar also has the advantage of being equally effective across both hills and furrows.

In addition to controlling nutgrass, Zoliar controls a broad range of grass and broadleaf weeds. Zoliar is relatively expensive, but the cost can be partly offset by substituting Zoliar for some of the other residual herbicides that would normally be used. For example, the grass herbicides such as trifluralin and pendimethalin should not be required in a field treated with Zoliar.



The wheat in this patch was killed by Zoliar that was applied in an earlier season.

Unfortunately, Zoliar is also active against a range of other crop plants. The plant-back period to cereal crops is 30 months after a single herbicide application; a longer plant-back period is required following multiple applications. Zoliar is best suited to heavily infested fields because of its cost and the limitations with rotation crops.

Imazapyr (eg. Arsenal[®], Group B)

Arsenal is registered for controlling nutgrass (*Cyperus* spp.) in non-crop situations. It inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition rapidly leads to plant death. Arsenal is a residual soil sterilant, effective in controlling most plant species. It is both root and shoot absorbed, and can act as a contact herbicide as well as a residual herbicide.



Arsenal will kill cotton and rotation crops for years after application. It should never be applied in-crop or in an area where soil or water movement could carry the herbicide into a sensitive area.

Arsenal is highly persistent, with a half-life of up to 142 days. It can control weeds for up to 3 years when applied at the registered rate. It is ideal for controlling nutgrass patches on roadways, the outsides of channel banks, and other non-crop areas.

When applying Arsenal to a nutgrass patch, it is good practice to apply the herbicide to an area 1 or 2 metres larger than the obviously infested area. This ensures that all nutgrass plants are controlled by the application. All too often the Arsenal controls the nutgrass in the sprayed patch, but treatment fails because a few plants remain outside the sprayed area and the infestation re-develops from these plants.

Arsenal is weakly adsorbed to soil and can move many metres from the site of application. It should never be applied in-crop or in an area where soil or water movement can carry the herbicide into a sensitive area, such as in the rotobuck area, or on the inside of ditches and channels.

Contact herbicides

MSMA (eg. Daconate[®], Group K)

Daconate can be a useful tool for nutgrass management, as it can be applied over-the-top of cotton, or as a directed spray. It is normally applied to small cotton in spring, although it can be applied up until flowering. Daconate can not be applied after the crop commences flowering.

Daconate is readily absorbed into nutgrass foliage and rapidly affects plants. It does not necessarily kill nutgrass plants but will suppress nutgrass growth, allowing the cotton to establish and shade the weed. Daconate is also effective in controlling a range of other weeds.

Daconate is an arsenical compound (contains arsenic). It has little soil activity but has a half-life of about 180 days in soil. Arsenic build up in the soil is not a problem when it is used in accordance with the label directions.

Table 5. Yield reduction in cotton sprayed over-the-top with Daconate[®] in November and December.

Date	Yield reduction (%)
Late November	2
Early December	13
Late December	18

Daconate is not completely safe to cotton. It can burn cotton leaves and delay cotton growth. To reduce this crop damage, Daconate should be applied as a directed spray to young cotton where possible, rather than an over-the-top application. Daconate should be directed to avoid the growing terminal of the cotton plants.

Damage to older cotton can be more serious as shown in Table 5. Nevertheless, in a field heavily infested with nutgrass, Daconate when properly applied, does far more damage to the nutgrass than it does to the cotton, with the end result that a Daconate application helps the establishing cotton and ultimately improves cotton yields.

Daconate should be applied during hot conditions, as the efficacy is temperature related. That is, Daconate is more effective under hotter rather than cooler conditions. Daconate is also more damaging to cotton as temperatures increase. Growers should consider using lower rates when spraying Daconate over-the-top of cotton under very hot conditions, especially later in the season. Label recommendations suggest that Daconate should be applied under hot, dry conditions, at temperatures above 25°C. This temperature requirement means that Daconate should not be applied under cool, cloudy conditions, as it is unlikely to be effective under these conditions.

Temperature variation within a day, however, does not have much effect on the efficacy of Daconate as shown in Table 6. Daconate is absorbed into the plant and has its herbicidal effect over time, so that efficacy is more affected by the temperature over a number of hours following spraying, rather than the actual temperature at the time of spraying.

Table 6. Yield reduction on cotton sprayed over-the-top with Daconate® at different temperatures and times on the same days.

	Time		
	6 am	10 am	3 pm
15 December Temperature (°C)	14	22	26.5
Yield reduction (%)	20	22	26
22 December Temperature (°C)	19.9	26	35
Yield reduction (%)	24	22	19



Sempra® applied through a shielded sprayer (foreground plot) controlled nutgrass in the furrow (sprayed area), but gave little control of the unsprayed plant-line.

Halosulfuron-methyl (Sempra® , Group B)

Sempra is registered for controlling nutgrass in cotton, but must be applied through a shielded sprayer, to avoid herbicide contact to the cotton. Sempra inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition stops plant growth and plant death occurs 14 to 21 days after application.

Sempra does not persist for long in the soil, with a half-life of up to 34 days. However, most rotation crops are very sensitive to Sempra and the recommended plant-back period to rotation crops is 24 months.

Sempra has the advantage that it kills nutgrass plants reasonably quickly and can be very effective early in the cotton season. However, Sempra does not tend to translocate through the nutgrass rhizomes. Consequently, Sempra does not give good control of tubers attached to sprayed plants and gives little control of unsprayed nutgrass in the plant-line when it is applied through a shielded sprayer, as shown in Table 7.

Table 7. Reduction in leaf number and tuber number of sprayed and unsprayed nutgrass plants attached to sprayed plants. Plants were grown in divided pots and sprayed 4 or 10 weeks after first shoot emergence. They had on average 59 and 153 leaves at spraying, respectively.

Sempra rate (g/ha)	Nutgrass age	Sprayed	Unsprayed
Reduction in leaf number (%)			
70 g	4 weeks	12	0
	10 weeks	0	0
140 g	4 weeks	56	0
	10 weeks	56	0
Reduction in number of viable tubers (%)			
70 g	4 weeks	58	0
	10 weeks	39	0
140 g	4 weeks	92	0
	10 weeks	79	23

Glyphosate (various trade names, Group M)

Glyphosate is registered for controlling nutgrass in cotton. In conventional cotton and varieties with the Liberty Link[®] trait, glyphosate must be applied through a shielded sprayer, with the spray nozzles positioned so as to **avoid any spray contacting** the cotton foliage. Glyphosate can be applied pre-cotton emergence, in-crop as a shielded spray, at defoliation, or after picking. Up to 4 applications of Roundup Ready Herbicide[®] can be applied over-the-top of cotton varieties with the Roundup Ready Flex[®] trait up to 22 nodes of growth. If 3 or fewer applications are made up to the 22 node growth stage, a further application can be made at defoliation, between 60% open bolls and picking. For more information, refer to the Roundup Ready[®] herbicide label, [Managing Roundup Ready[®] Cotton](#) and [SPRAYpak/ Spray Application](#) in [WEEDpak](#).

Note, most glyphosate formulations are not registered for over-the-top use in Roundup Ready Flex cotton, but Roundup Ready Herbicide is not the only glyphosate formulation registered for this use. Information in this document applies equally to the other registered products.

Glyphosate inhibits EPSP synthase, which prevents protein synthesis and kills the plant. Glyphosate is effective against most plants, but the herbicidal effect is quite slow, often taking 2 to 3 weeks. Glyphosate is far more effective when applied to rapidly growing plants. Spray failures can occur when glyphosate is applied to stressed plants. This is particularly true with nutgrass, where glyphosate applications to stressed plants are often ineffective.

Glyphosate is rapidly adsorbed and inactivated on contact with the soil. Consequently, it has no residual effect, although its breakdown in the soil is comparatively slow, with a half-life of approximately 47 days.

Glyphosate can be effective in controlling nutgrass. It translocates within the sprayed nutgrass plant and also to attached tubers and plants. This translocation means that glyphosate can kill the nutgrass plants it is sprayed on, but can also kill attached tubers and nutgrass plants in the cotton row that were not sprayed.



Glyphosate applied through a shielded sprayer controlled nutgrass in the furrow and controlled some nutgrass in the unsprayed cotton plant-line.

Glyphosate resistance

Nutgrass has a low risk of developing resistance to glyphosate as it primarily reproduces vegetatively, with every daughter plant genetically identical to the parent. However, nutgrass does produce some viable seed and some seedlings establish, leading to some genetic variability in the species in Australia. This genetic variability opens the door for nutgrass to develop resistance to glyphosate and a nutgrass management strategy which relies exclusively on glyphosate places extremely high selection pressure on this weed. Consequently, even though the risk of nutgrass developing resistance to glyphosate is low, it isn't zero. There is a small, but real risk of resistance.

Given the lack of good alternative control options and very low risk of resistance developing to glyphosate, it is not unreasonable to continue using glyphosate as the main tool for nutgrass control. Nevertheless, growers should always be on the lookout for nutgrass plants that have not been affected by a glyphosate application and could be resistant to glyphosate. If a patch of nutgrass remains green following a glyphosate application when all the surrounding nutgrass plants have been killed, assume the worst (resistance) and treat the patch as if it is resistant, controlling it with an alternative option, regardless of the cost. Physically removing a suspect patch of nutgrass with an excavator may be a very cheap option compared to the long-term havoc that glyphosate resistant nutgrass would cause to the industry.

Contact the author immediately if glyphosate resistant nutgrass is found or strongly suspected. For more information on herbicide resistance, refer to [Herbicide Resistance](#), Section C of [WEEDpak](#).

Herbicide efficacy on the major species

Zoliar is effective against all nutgrass species, as it is effective against both tubers and seedlings. Heavy rates of Zoliar are necessary to control plants growing from tubers, but much lighter rates of Zoliar should be adequate to control seedlings, with application timed to occur prior to expected weed germination. Much shallower soil incorporation should also be used for seedling control, as seedlings will not emerge from more than a few mm depth. Lighter rates, shallowly applied should give good control of species that only grow from seed such as dirty Dora, umbrella sedge and rice flatsedge.

Arsenal is equally effective against all nutgrass species, controlling seedlings and emerging shoots.

The three major species, nutgrass, Downs nutgrass and yelka have differing sensitivities to the contact herbicides. All herbicides are more effective on younger rather than older plants (Tables 8, 9 & 10).

Table 8. Herbicide efficacy of the contact herbicides on nutgrass (*C. rotundus*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	0
		2.8 L	25
	Sempra	70 g	46
		140 g	100
	Roundup CTXtra	1 L	96
		2 L	100
8 weeks	Daconate	1.4 L	0
		2.8 L	0
	Sempra	70 g	8
		140 g	0
	Roundup CTXtra	1 L	81
		2 L	87

Daconate, which suppresses nutgrass, is much more effective on Downs nutgrass and yelka.

Sempra is effective on young nutgrass plants, especially at the higher rate, but is much less effective on older plants. Sempra is more effective on downs nutgrass and yelka, but the same trend occurs with age, being more effective on younger plants.

Glyphosate gave good control of all species at both growth stages, although results in the field are not always so consistent.

Table 9. Herbicide efficacy of the contact herbicides on downs nutgrass (*C. bifax*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	29
		2.8 L	50
	Sempra	70 g	67
		140 g	75
	Roundup CTXtra	1 L	92
		2 L	100
8 weeks	Daconate	1.4 L	44
		2.8 L	50
	Sempra	70 g	11
		140 g	25
	Roundup CTXtra	1 L	94
		2 L	100

Table 10. Herbicide efficacy of the contact herbicides on yelka (*C. victoriensis*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	100
		2.8 L	75
	Sempra	70 g	69
		140 g	100
	Roundup CTXtra	1 L	87
		2 L	100
8 weeks	Daconate	1.4 L	42
		2.8 L	50
	Sempra	70 g	0
		140 g	37
	Roundup CTXtra	1 L	100
		2 L	87

Factors that affect Zoliar efficacy

Zoliar is best suited to light, acid soils, where it is very effective at relatively light rates. In Arizona (USA), for example, Zoliar is very effective when applied post-cotton emergence at 1.5 kg/ha, but will kill cotton if applied pre-planting at this rate. Lighter rates should be used when applying Zoliar to light acid soils in Australia.



Cotton and nutgrass on a light, acid soil in Arizona severely affected by 1.5 kg of Zoliar.

Zoliar can behave quite unpredictably in alkaline, heavy clay soils, and must be applied at higher rates on these soils to be effective (4 kg/ha in the first season with lower rates used in subsequent seasons). In some situations, it appears that Zoliar is somehow “bound-up” in the soil for some weeks after application, apparently becoming effective only six or so weeks after application. The length of this time period is influenced by soil moisture.

Consequently, it is recommended that Zoliar be applied to alkaline, heavy clay soils in about May, prior to a cotton crop. Thorough incorporation is essential for best results. This is most easily achieved by broadcasting Zoliar before listing. Zoliar is then thoroughly incorporated into the hills through listing, although the Zoliar rate in the furrows may be relatively low.

Good results have been achieved by applying very heavy rates of Zoliar to heavily infested nutgrass patches in fields, and on head and tail ditches. These rates could not be safely used on lighter soils.

Results from an experiment using very heavy rates of Zoliar are shown in Table 11. In this experiment Zoliar was applied over-the-top of 4-leaf cotton. Use of these rates is contrary to the pesticide label. To use higher than label rates, growers must first obtain a use permit from the NRA (National Registration Authority).

The combination of Zoliar applied pre-planting and glyphosate applied in-crop gave the most effective control of nutgrass in this experiment. The very high rates of Zoliar did cause significant leaf

damage to the cotton (applied over-the-top of young cotton), but did not adversely affect crop yield.

Table 11. *Shielded Roundup and heavy rates of Zoliar for nutgrass control applied over 2 seasons. The initial nutgrass infestation averaged 456 tubers/m². Specific permit permission must be obtained from the NRA before pesticides can be used outside the label recommendation.*

	Rate/ha	Tubers per m ²	Lint yield (kg/ha)
Untreated	-	1213	1467
Roundup CT	2.4	1076	1674
Zoliar	4	434	1564
Zoliar	16	133	1791
Roundup CT + Zoliar	2.4 + 4	152	1600
Roundup CT + Zoliar	2.4 + 16	35	1759

Factors that influence glyphosate efficacy

Glyphosate seldom gives 100% control of nutgrass in the field, even under the best conditions. One reason for this is that a nutgrass population includes plants at all stages of growth, including dormant tubers, shoots that have not emerged above the soil surface at the time of spraying, and newly emerging shoots. Dormant tubers and un-emerged shoots are effectively protected from glyphosate and newly emerged shoots are difficult or impossible to spray due to their small size and because they are often protected from the spray by other plant material. The problem of spray penetration can be a major limitation to control of a dense stand of nutgrass.

An apparent spray failure with glyphosate may not be caused by poor herbicide efficacy, but by the emergence of new nutgrass shoots from previously dormant tubers and from plants that were not sprayed. This is especially true with early season glyphosate applications, as new shoots may continue to emerge through to early summer. These shoots are connected to previously dormant tubers that were not previously susceptible to treatment. The emergence of new shoots after spraying should not be viewed as a spray failure but as an opportunity to treat a new portion of the nutgrass population. A dense nutgrass infestation can contain up to 14 000 tubers/m², but will have only about 2200 shoots/m² (only 16% of the population). This means that a high proportion of tubers may not be directly connected to live shoots.

Repeated treatments are the only sure way of controlling nutgrass with glyphosate.

Growers should always aim to apply at least two in-crop applications of glyphosate in cotton. These applications should be timed to occur after irrigation in about mid-December and mid-January, before the canopy closes. Ideally the second

application should occur about four weeks after new shoots begin to emerge following the first glyphosate application.

Nutgrass age

Nutgrass plants are most susceptible to glyphosate when they are young, and become progressively more tolerant as they age. Freshly emerged shoots are much easier to kill than are mature plants. This is shown in the data in Tables 8 and 13. Flowering has little impact on glyphosate susceptibility, but flowering plants are much less susceptible than are younger plants.

However, except during early spring, or after cultivation or a successful herbicide application, a nutgrass population includes plants at all stages of plant maturity. Almost from the moment the first shoot appears in spring, nutgrass plants produce new tubers that produce new plants, that produce new tubers, and so on. These new tubers are initiated within days of the first shoot emergence. Viable new tubers and new plants can be formed within 4 to 6 weeks of the first shoot emerging. Consequently, at any point in the season, a nutgrass population includes freshly emerged shoots, through to mature plants.

The potentially rapid increase in a nutgrass population is shown in Figure 1. Competition from cotton can greatly reduce this rate of reproduction in the cotton row. Vigorously growing cotton may also shade the furrow and compete strongly with the nutgrass.

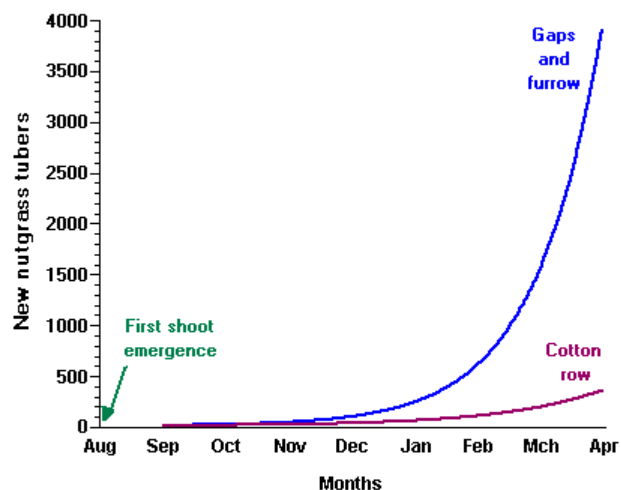


Figure 1. Nutgrass tuber production in cotton starting from a single tuber in spring. Nutgrass is intolerant of shading and produces fewer tubers in the cotton row.

The glyphosate labels generally recommend that spraying be delayed until nutgrass plants reach at least 20% flowering, in about February. This recommendation is based on a misunderstanding of the need for nutgrass to be flowering before herbicide application. This misunderstanding assumes that older nutgrass plants are more sensitive to glyphosate and that nutgrass plants translocate assimilates to their attached tubers after flowering in autumn. Neither of these assumptions is correct.

Unlike many other perennial plants, nutgrass does not predominantly move assimilates (nutrients) down to its roots and tubers in autumn prior to plant dormancy. The movement of assimilates in nutgrass is a continuous process and is more apparent in younger plants than older plants. Almost from initial shoot emergence, nutgrass produces new tubers and assimilates are being continuously moved down to the roots and tubers, to provide for the production of these new roots and tubers. Consequently, glyphosate translocation to attached tubers occurs equally well at all stages of the season, although glyphosate is more effective in killing young plants and tubers than older plants.

Ideally, glyphosate should be applied to nutgrass within 4 to 6 weeks of first shoot emergence. This timing gives the best kill of plants and attached tubers, and ensures that plants are controlled before they reproduce, **provided that plants are not stressed at spraying**. Stressed plants are far less susceptible to glyphosate, and are unlikely to be killed by an application.

Stressed plants

Nutgrass is capable of very rapid growth, but is very easily stressed by factors such as low temperatures, low soil moisture, cultivation and other herbicides. Like most weeds, nutgrass is far more susceptible to glyphosate when the weed is rapidly growing. Even very high rates of glyphosate are likely to be ineffective in controlling nutgrass when it is stressed.

Moisture stressed plants are best controlled by cultivation. Where this is not possible or not practical, spraying should be delayed until after plants have resumed normal growth.

Low temperatures

While early spring may seem to be an ideal time to apply glyphosate to nutgrass, there have been many spray failures at this time caused by the nutgrass being stressed by low temperatures.

Glyphosate applications can be very effective in warm to hot conditions in October and November, but are likely to be ineffective when temperatures drop too soon after application. For effective control, hot conditions must continue for at least a week after spraying. A drop in temperature, or cool nights, may result in a spray failure.

Similarly, cool conditions in autumn are likely to result in spray failures.

Reliable control of nutgrass can generally be achieved from mid-November onwards, although this date will be earlier in the northern regions and can be much later in the cooler areas.

Nevertheless, spraying earlier in the season can be very effective when conditions are favourable.

Low soil moisture

Nutgrass has a shallow, fibrous root system that makes it very prone to moisture stress in the cotton system. Experience has shown that nutgrass is most susceptible to glyphosate when the weed is rapidly growing, immediately after irrigation or rainfall. Ideally, glyphosate should be applied to the nutgrass as soon as possible after irrigation or rainfall.

The exception to this is that glyphosate can be very effective when applied to moisture stressed nutgrass, provided that rain or irrigation occurs within hours of the application. Applying glyphosate to nutgrass immediately before irrigation can be a practical way to overcome the difficulty of wet tail ditches etc.

Cultivation

One of the practical difficulties of controlling nutgrass with glyphosate can be the need to delay inter-row cultivation to allow nutgrass to grow sufficiently to be sprayed.

Nutgrass should be allowed to grow for at least four weeks between cultivation and spraying. Cultivation should then be delayed for at least one week after spraying and two weeks if possible. Cultivating within a week of spraying can reduce spray efficacy, as shown in Table 12.

Table 12. Reduction in Roundup CT efficacy from simulated, post-spraying cultivation. Nutgrass plants were sprayed 6 weeks after first shoot emergence of plants growing in pots.

Herbicide rate (L/ha)	Post-spraying cultivation	% Kill	Leaves per plant
-	-	0	125
2.4	-	75	0.3
2.4	2 days	25	7
2.4	4 days	50	3
2.4	8 days	25	14

Glyphosate rate

Most glyphosate labels recommend a split application of herbicide at **1 L active** per ha per application. This rate has generally been adequate to control nutgrass in most situations, with the second application greatly improving the final result.

A range of other glyphosate rates has been used on nutgrass over the years with varying success. Half the recommended rate has been adequate to control nutgrass under ideal conditions, as shown in Tables 13 and 16, but has often lead to spray failures (also shown in Table 13). A higher rate (such as 2 L active/ha) will give better control in some situations, but is not generally needed and may not be cost-effective. Increasing the rate beyond 1 L active/ha will not generally overcome limitations such as the plant being stressed by cool temperatures or lack of soil moisture, but will greatly increase the risk of damage to the crop when applied as an inter-crop spray to conventional or Liberty Link varieties.

Water quality

One of the desirable characteristics of glyphosate is its ability to be rapidly adsorbed to soil particles and inactivated. This makes glyphosate ideal as a knockdown herbicide prior to planting or even between planting and crop emergence. Glyphosate can also be inactivated by metals and ions in the spray solution, and is very sensitive to zinc, which is present on galvanized surfaces.

These qualities make glyphosate very sensitive to water quality. Glyphosate efficacy can be reduced by dirty water, by hard water, by alkaline water and by metal ions. To avoid problems with water quality, it is important to use the best quality water available and to ensure that glyphosate remains in the spray tank for as short a time as possible.

Under most circumstances, however, water quality should not be a major factor reducing the efficacy of glyphosate on nutgrass, provided the spray mixture is not allowed to sit for an extended period.

A comparison of glyphosate efficacy using a range of water sources where the mixture was allowed to sit for 24 hours (Table 13) showed that poor water quality could have a large effect on herbicide efficacy, but that the effects were not consistent. Results from a second experiment where the spray was used 3 hours after mixing showed no reduction in efficacy due to water quality.

In both experiments, herbicide rate and nutgrass age had as much impact on herbicide efficacy as did water quality.

Table 13. Herbicide efficacy of two rates of Roundup CT on nutgrass applied 3 or 6 weeks after first shoot emergence of plants grown in pots. The herbicide was applied in 100 L water/ha with 0.4% Turbo P (non-ionic surfactant) added. The spray mix was allowed to sit for 24 hours before spraying. Water quality is shown in Table 14.

Age	Rate (/ha)	Source	% Kill
3 weeks	1.2 L	Distilled	82
		Bore A	98
		Bore B	76
		River	100
		Channel	58
	2.4 L	Distilled	88
		Bore A	99
		Bore B	77
		River	94
		Channel	100
6 weeks	1.2 L	Distilled	37
		Bore A	5
		Bore B	0
		River	1
		Channel	0
	2.4 L	Distilled	78
		Bore A	42
		Bore B	93
		River	0
		Channel	81

Table 14. Water quality of the sources used in Table 13. The channel water was allowed to sit in storage for an extended period before use.

Source	pH	Conductivity (dS/m)	Hardness (Ca + Mg)	Chloride (mg/L)
Distilled	6.65	0	0	10
Bore A	6.62	0.36	164	15
Bore B	8.18	0.57	157	48
River	9.48	2.59	98	370
Channel	9.21	0.18	67	25

Water rate

Most glyphosate labels recommend a maximum water rate at or below 100 L/ha. Common farm use is in the range of 40 to 60 L/ha, well below the maximum recommended rate.

Lower water rates improve spraying efficiency by increasing the area that can be covered by each tank load, but may also reduce the coverage of droplets on the target plant. Coverage and spray penetration into the plant canopy can be improved by using higher nozzle pressure, but this leads to the production of more small spray droplets and more spray drift.

Coverage can also be improved by using higher water volumes. Larger droplets and water volumes of around 100 L/ha should be used when spraying dense nutgrass patches to ensure adequate spray penetration. High water volumes and lower nozzle pressures are desirable when using an in-crop shielded application of glyphosate to reduce spray drift and thereby reduce damage to the crop.

Additives

A large range of wetters, surfactants and other additives is available for use with glyphosate and other herbicides. These additives can improve herbicide efficacy in some situations, but generally are not required with glyphosate. Some additives may have an inconsistent or negative affect in some situations, as shown in Table 15.

Table 15. The effect of some spray additives on glyphosate efficacy on nutgrass, sprayed 8 weeks after first shoot emergence.

	Treatment	% Kill	Leaves per plant
1	Untreated	0	234
2	Roundup 3 L	0	231
3	Roundup 3 L + 3% Agral 600	100	0
4	Roundup 3 L + Herbex 3 L	75	1
5	Roundup 3 L + Prep 0.3 L	0	50

The addition of Prep® (ethephon) to glyphosate for example, may improve control in some situations, but Prep is antagonistic to glyphosate, causing the chemicals to come out of solution and may reduce glyphosate efficacy.

Both percentage kill and leaves per plant data are shown in this and some other tables. Leaves per plant gives an indication of the suppression of plants that survived the treatment. A comparison of treatments 1 and 2, in Table 15 shows that the Roundup application (without additive) not only failed to kill the nutgrass, it failed to even suppress the weed. Treatment 5 (Roundup + Prep) also failed to kill the nutgrass, but did suppress the weed, causing a 79% reduction in leaf number.

Additives are often used to overcome poor application conditions, poor water quality, or antagonism from other tank-mixed herbicides. Generally, these additions do not fully overcome the problems. No additive will make stressed nutgrass plants receptive to glyphosate.

However, experience in the field has shown that the addition of a non-ionic surfactant at around 0.2% will often improve glyphosate efficacy, as shown with Agral 600 in Table 15. Data in Table 16 shows an improvement when using a non-ionic surfactant with low glyphosate rates, but no improvement when using the recommended rate of glyphosate.

Table 16. Nutgrass leaf production and % kill from three rates of Roundup CT with 4 rates of added non-ionic surfactant (Turbo-P).

Roundup CT rate	Surfactant rate (%)	% Kill	Leaves per plant
-	-	0	110
0.6	-	0	133
	0.2	25	80
	0.5	25	43
	1.0	25	75
1.2	-	25	61
	0.2	100	0
	0.5	100	0
	1.0	100	0
2.4	-	100	0
	0.2	100	0
	0.5	100	0
	1.0	100	0

Additives should never be used with over-the-top glyphosate applications to Roundup Ready Flex cotton, except as directed on the product label. The use of other additives could affect the activity of glyphosate and cause damage to the Roundup Ready Flex cotton.

Tank-mixing

Glyphosate can be tank-mixed with a range of other herbicides. However, tank-mixing with some of the more commonly used cotton herbicides is likely to reduce glyphosate efficacy to some extent, as many of these herbicides contain clay that will inactivate the glyphosate. The amount of reduction of glyphosate efficacy will depend on water volume and quality, the amount of clay in the tank-mixed herbicide and the length of time the mixture stands in the spray tank.

Tank mixing with clay-based products should be avoided if possible. Ammonium sulfate should be added when tank-mixing with a clay-based product is necessary and higher glyphosate rates should be considered. Always ensure good agitation and that these mixtures remain in the spray-tank for as short a time as possible.

Re-spraying interval

Glyphosate is frequently used to control other weeds at a lighter rate than the 1 kg active/ha used for nutgrass. Ideally, nutgrass patches should be sprayed with a heavier rate at the same time by using a boom spray fitted with a second boom line with larger nozzles or by slowing the tractor to increase spray rate. The additional boom line is likely to give the better result of these two options as it is far easier for the operator to switch on or off an additional boom than to be constantly changing tractor speed.

Table 17. Effect of timing of a 1.4 L/ha (0.63 L active/ha) application of Roundup CT after a 1 L/ha (0.45 L active) application on nutgrass 3 or 6 weeks of age.

Nutgrass age	Initial spray rate	Time to re-spraying with 1.4 L	% Kill	Leaves per plant
3 weeks	-	-	0	108
	1 L	-	50	49
		at spraying	100	0
		1 week after	75	7
		2 weeks after	100	0
		3 weeks after	75	1
		4 weeks after	25	71
6 weeks	-	-	0	166
	1 L	-	0	32
		at spraying	25	1
		1 week after	25	52
		2 weeks after	50	1
		3 weeks after	0	4
		4 weeks after	0	24

However, if the two applications can't occur on the same day, the second application should be delayed for around two weeks, as shown in Table 17.

Herbicide efficacy is reduced when the two sprays are too close together due to the stress on the plant caused by the first spray. Glyphosate applied to a plant with the second spray is unlikely to be readily translocated or to be very effective, as the plant is already stressed and damaged by the first spray. However, if the sprays are too far apart, the affect of the first spray is lost.

For best control, nutgrass should be resprayed approximately four weeks after green shoots emerge.

Herbicide combinations

The best control of nutgrass has been achieved using multiple applications of glyphosate on a field that previously received Zoliar. However, this can be a very expensive option, as unless the nutgrass patches are well defined, the Zoliar must be applied to most or all of the field. GPS mapping of the nutgrass patches may be used to greatly reduce this cost.

An alternative strategy for lighter infestations of nutgrass that has been successfully used by some growers is to apply a tank mix of Zoliar and Semptra as a spot application through a shielded sprayer in December, with a follow-up application of glyphosate in January. The combination of Zoliar and Semptra is very expensive on a per hectare basis, but the applications can be very cost-effective when applied through a weed-activated sprayer so that the herbicide is only applied to the weed infestation.

Spraying equipment

In-crop applications of glyphosate must be applied so as to avoid contact with the crop foliage. The only exception to this is Roundup Ready Flex cotton, which can be sprayed over-the-top with Roundup Ready herbicide up to 22 nodes of growth, in compliance with the product label.

Glyphosate can be applied in-crop to conventional or Liberty Link varieties as a directed spray or through a shielded sprayer. A range of equipment is available, at a range of prices, ranging from basic rubber or steel shields against the crop, to completely enclosed sprayers. The primary differences between these extremes of design is their ability to be safely operated in windy conditions, their ability to be adjusted to meet a range of requirements and crop size, and their ability to be used in a range of crop sizes without causing excessive physical damage to the crop.

It is essential when using any spray equipment to ensure that the equipment is properly set up and is used only under appropriate conditions. Generally, the more open the equipment design is, the more sensitive it is to windy conditions. Any air movement into the shield area will cause air movement back out of the shield area. This air is likely to carry fine spray droplets that may then be deposited onto the crop. Shields that have open fronts and tops are most prone to this movement, but some air movement is inevitable in even the best designed shields.

Nevertheless, even an open shield design can be used safely in the crop provided that it is used at low tractor speeds and low wind conditions, and with correctly set up and operated spray nozzles. Fine mesh, such as shade cloth, can be used to enclose the shields, greatly reducing air movement within the shield area and reducing the risk of crop damage from spray drift.

A range of nozzle designs is available, including low drift nozzles. Low nozzle pressure (pressures towards the bottom end of the recommended range for the nozzle) and high water volumes (allowing the use of larger nozzles) will also help reduce the production of fine spray droplets.

Once a shielded sprayer has been set up, it is important that it is regularly checked to ensure that nozzles are operating correctly, and that the operator is aware of the operating conditions. Operating a sprayer in windy conditions will inevitably lead to crop damage.

Crop competition

Although nutgrass can compete very strongly with cotton, nutgrass does not itself tolerate strong competition. Nutgrass has a fibrous, relatively shallow root system. This enables it to compete strongly early in the cotton season and to respond quickly after rain and irrigation, but it does not compete well with irrigated cotton later in the cotton season when soil moisture in the surface soil layers is limiting.



A section of a cotton crop severely infested with nutgrass. No harvestable cotton was present in this portion of the field.

Nutgrass is also relatively intolerant of shading and has a greatly reduced growth rate when shaded by a taller crop.

One of the keys to growing cotton and other crops in a field that is infested with nutgrass is to ensure that the crop establishes as quickly as possible and is able to shade-out the nutgrass. There are a number of management practices that can influence crop competitiveness, including:

- stubble management
- soil conditions
- crop species and variety selection
- sowing date, rate and depth
- seed dressings
- fertilizer type, rate and placement
- irrigation management (pre- and post planting)
- herbicides - residuals and knock-down pre-emergence and post-planting
- cultivations
- weed control (of nutgrass and other weeds)

These practices should be optimised to maximise crop competitiveness. The result of not optimising these factors can be that the crop does not establish vigorously on nutgrass infested areas and competes poorly, allowing the nutgrass to establish and spread. This worst-case scenario can result in a crop failure with no harvestable crop.

One of the most common problems with establishing rotation crops is inadequate soil moisture and nutrition in the nutgrass infested areas. The main part of a field may have good moisture and nutrition following a cotton crop, but both these inputs are likely to be lacking on nutgrass infested areas, as the weed has already used these resources during the cotton season. Consequently, crop establishment is comparatively poor on the nutgrass infested areas. Irrigation at planting and inclusion of a starter fertilizer with the crop can make a large difference to the crop's competitiveness and its impact on nutgrass.

Developing an IWM program for nutgrass

Nutgrass is a perennial weed that will not be controlled with any single treatment. Successful nutgrass management is built on using as many management tools as possible, at every available opportunity, over a number of years.

No one management program is suitable for every field and every season. The management tools can be successfully used in a variety of ways, depending on the extent of the problem and available resources.

The type of nutgrass program required for any individual field will depend on the extent of the problem and the management resources available.

Results from field experiments conducted over a number of seasons and a number of sites are shown in Tables 18 to 21. These results allow comparison of some treatments and treatment combinations.

Of the contact herbicides, multiple glyphosate applications have given the most reliable nutgrass control over a number of sites and seasons. However, glyphosate is only effective on actively growing nutgrass. The combination of glyphosate (applied on actively growing nutgrass) and cultivation (on moisture stressed nutgrass) can be used very effectively (Table 18).

The best results in cotton were achieved using a combination of Roundup and Zoliar (Table 19), with Zoliar incorporated pre-planting and two in-crop shielded applications of Roundup applied each season. This treatment (Treatment 8) resulted in an 88% decrease in the nutgrass population over two seasons, compared to a 5-fold increase in the nutgrass population where no treatment was imposed (Treatment 1).

The Roundup and Zoliar combination also resulted in the best cotton yield, 117% (3 bales/ha) higher than the untreated comparison (Treatment 1). This yield increase of 3 bales would have more than paid for the cost of treating the nutgrass. In addition, use of this treatment would result in a field starting the next season with a lower density of nutgrass than was initially present, potentially resulting in even better yields than were recorded over these two seasons.

Results using a range of herbicides and herbicide combinations on an initially much lighter nutgrass population were similar (Table 20), with the best nutgrass control (an 87% reduction in tuber density) from three in-crop Roundup applications (Treatment 4) and the best yield (a 47%, 1.7 bales/ha increase) from 2 in-crop applications (Treatment 3). The slight reduction in yield associated with the third Roundup application was probably caused by crop damage from the

additional herbicide application, as the herbicide was applied through a poorly designed shield which allowed some herbicide drift to the conventional (not Roundup Ready Flex) crop.

The improvements in crop yields after treatment would probably have been even better if better designed equipment and/or Roundup Ready Flex cotton had been used. Generally, any damage to the cotton from the herbicide application is more than compensated for by the associated reduction in weed competition resulting from the reduction in the nutgrass population. Nevertheless, it is essential to only apply glyphosate through a well designed and properly set-up shielded sprayer, operating in appropriate conditions unless the variety includes the Roundup Ready Flex trait.

Results from a more extensive comparison of Roundup and Zoliar combinations are shown in Table 21. In this experiment, the best nutgrass control was achieved using a single Roundup application in early December (Treatment 4), which resulted in a 97% decrease in the nutgrass density.

However, results from a single Roundup application were highly variable (compare Treatments 2 to 7). This variability reflects the normal variability of results often achieved with glyphosate and was caused by a number of factors including the condition of the nutgrass at the time of spraying. On some occasions, the nutgrass was highly stressed at spraying, resulting in a poor kill. Growers should be able to achieve much better results by targeting conditions that are more suitable for glyphosate when nutgrass is actively growing.

Table 18. Changes in nutgrass density in a fallow with treatments over 2 seasons. The area initially had an average nutgrass infestation of 334 tubers/m².

Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²
Untreated	-	-	3879
Cultivation	-	8	1114
MSMA	2.8	2	2895
MSMA	2.8	4	789
Roundup CT	2.4	2	668
Roundup CT	2.4	4	346
Roundup CT	4.8	4	150
Roundup CT	2.4	8	47
Cultivation + Roundup CT	2.4	4 + 4	118

Table 19. Changes in cotton lint yield and nutgrass density with in-crop and residual herbicide treatments over 2 seasons. The area initially had an average nutgrass infestation of 1348 tubers/m².

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			7194	582
2	Roundup CT	2.4	1	3728	547
3	Roundup CT	2.4	2	797	856
4	Roundup CT	2.4	3	611	891
5	MSMA + Roundup CT	1.8 + 2.4	1 + 1	741	987
6	MSMA + Roundup CT	1.8 + 2.4	2 + 1	1194	873
7	Zoliar + Roundup CT	3 + 2.4	1 + 1	786	660
8	Zoliar + Roundup CT	3 + 2.4	1 + 2	160	1262

Table 20. Changes in cotton lint yield and nutgrass density with in-crop treatments over 2 seasons. The initial nutgrass infestation averaged 338 tubers/m².

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			1097	819
2	MSMA	1.8	2	577	871
3	Roundup CT	2.4	2	223	1206
4	Roundup CT	2.4	3	43	1173
5	MSMA + Roundup CT	1.8 + 2.4	1 + 1	385	930
6	MSMA + Roundup CT	1.8 + 2.4	2 + 1	231	1126
7	MSMA + Roundup CT	1.8 + 2.4	1 + 2	108	1018
8	Sempre	0.14	1	552	944
9	Sempre	0.07	1 + 1	367	1047
10	MSMA + Sempra	1.8 + 0.07	1 + 2	386	1061
11	MSMA + Sempra + Roundup CT	1.8 + 0.14 + 2.4	1 + 1 + 1	278	992
12	MSMA + Roundup CT + Sempra	1.8 + 2.4 + 0.14	1 + 1 + 1	278	1143

Table 21. Changes in nutgrass density with in-crop treatments over 2 seasons and cotton lint yield in the first season. The initial nutgrass infestation averaged 456 tubers/m². The Zoliar was applied over-the-top of the cotton after crop emergence and the Roundup CTXtra was applied as a directed spray.

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			1213	1467
2	Roundup CTXtra	2	early Nov	615	1588
3	Roundup CTXtra	2	late Nov	210	1661
4	Roundup CTXtra	2	early Dec	39	1486
5	Roundup CTXtra	2	late Dec	685	1532
6	Roundup CTXtra	2	early Jan	1076	1674
7	Roundup CTXtra	2	late Jan	410	1493
8	Roundup CTXtra	2 + 2	early Nov + late Dec	328	1371
9	Roundup CTXtra	2 + 2	late Nov + early Jan	667	1543
10	Roundup CTXtra	2 + 2	early Dec + late Jan	173	1532
11	Zoliar	4	Oct	434	1564
12	Zoliar + Roundup CTXtra	4 + 2	Oct + early Jan	152	1600
13	Zoliar + Roundup CTXtra	4 + 2 + 2	Oct + early Dec + early Jan	226	1573

A management program for heavy infestations

Cotton yields are reduced by nutgrass competition on a field heavily infested with nutgrass. Consequently, it is important to try to reduce the weed infestation as quickly as possible to improve crop yields. To do this, it is necessary to use a range of treatments in combination, using as many treatments as practical each season. Examples of intensive management plans for conventional and Roundup Ready cotton are shown in Tables 22 and 23. It may not be practical or appropriate to use all of these treatments each season, but it is important to use as many treatments as possible, until the nutgrass population is reduced to a more manageable level.

Table 22. A management plan for back-to-back conventional or Liberty Link cotton in a heavy nutgrass infestation. Treatments directly used for nutgrass control are shown in bold green type. An additional glyphosate application could replace the deep ripping operation if the soil is wet and the nutgrass is actively growing.

Operations	Crop
September cultivation planting	Cotton
October	
November MSMA application inter-row cultivation	
December glyphosate application	
January glyphosate application lay-by herbicide	
February	
March glyphosate application at defoliation	
April picking slashing	
May deep ripping Zoliar application incorporation	
June listing	
July herbicide or cultivation	Fallow
August	

A management program for lighter infestations

A less intensive nutgrass management program can be used once the weed density on a field has been reduced to a level where the nutgrass is not reducing cotton yield. This program needs to be responsive, allowing for additional treatments should they become necessary, and must include regular field inspection. Failure to adequately treat nutgrass can result in a field becoming rapidly reinfested.

Such a management program would probably not include broadcast applications of Zoliar but may include a spot application of Zoliar to nutgrass patches. The main component of the management program should be in-crop shielded applications of glyphosate, with at least one application each season. Ideally, a second application will be allowed for in case the first application is not effective.

Table 23. A management plan for back-to-back Roundup Ready Flex cotton in a heavy nutgrass infestation. Treatments directly used for nutgrass control are shown in bold green type.

Operations	Crop
September cultivation planting	Cotton
October	
November Roundup application inter-row cultivation	
December Roundup application	
January Roundup application lay-by herbicide	
February	
March Roundup application at defoliation	
April picking slashing	
May	
June listing	
July herbicide or cultivation	Fallow
August	

Summary

Eight different nutgrass species are commonly found in or around cotton fields. These species are quite different in their ability to spread from seed or rhizomes, and consequently require specific management strategies. Positive identification of the problem species is essential as the first step in a management program.

A range of management tools is available to manage these weeds. These tools include residual and contact herbicides, cultivation, and crop competition. There are also some management practices that can exacerbate a nutgrass problem and should be avoided whenever possible.

Management of nutgrass needs a long-term approach, as these weeds will not be eliminated by any single management input. A successful management program will include all the management tools, used in combination as opportunity arises.

Glyphosate and Zoliar® herbicides have given the most effective control of nutgrass over time. Glyphosate should ideally be applied in-crop at least twice each season. It must be applied through a well constructed, properly set up shielded sprayer, operating under favourable conditions, when applied in conventional or Liberty Link cotton varieties. Roundup Ready Herbicide can be applied with much greater safety in Roundup Ready Flex cotton varieties.

Zoliar is a residual herbicide that must be applied in consecutive seasons to be fully effective. It has a long plant-back period to most rotation crops.

Farm machinery can be a major contributor to spreading nutgrass around a farm. Attention to machinery hygiene can be pivotal in a successful management program.

Case studies of grower experiences with nutgrass

Nutgrass on Kilmarnock

John Watson

I remember nutgrass starting to be noticeable on channels in 1975; it was endemic in the dryland cropping paddocks and grazing country. The local pharmacist and then chemical supplier gave me a few mLs of something in a small plastic bottle. It was to be the answer to our potential problem and think it was probably Roundup! I was overseas for three years and by 1978 there were now small patches in some of the fields. Despite all our efforts it got progressively worse.

Many chemical products were tried, all of which gave variable and inconsistent results. Zoliar was effective if thoroughly incorporated on the flat before hilling up. It's extended use led to problems in rotation crops. Cotton grown in a field with a relatively low population of nutgrass at planting could see it so thick after three months that yield would be affected if no action was or had been taken.

Graham Charles commenced trial work in the 1990's on our worst block, which, at the time, was on the leased property "Nandewar". He tested a number of products over three years and the best results indicated multiple applications of one or more chemicals. Overall, the trials showed that a cost effective result could be obtained from an early application of Zoliar and single in crop spray of Roundup using shielded sprayers.

The nutgrass control program is now largely based on control in the fallow phase, Roundup or chisel ploughing dry soil; rotations, cereal every second or third year; and in crop shielded spraying. It can sometimes be advantageous to do a broadacre application of Roundup after planting but before crop emergence. The result is quite variable, probably because of low temperatures especially here in the upper Namoi.

Roundup Ready® cotton will allow an over the top application after emergence and should therefore give better control as temperatures should be higher. Other than this obvious advantage, we will use much the same practices with Roundup Ready cotton, but will be looking to alternate some of the non-crop sprays with other chemistry to delay the onset of resistance of weeds to Roundup.

Case studies of grower experiences with nutgrass

Nutgrass Control at Norwood

Peter Glennie and Kylie May

Nutgrass has always been present on “Norwood”. Years of flood inundation (prior to development), grazing and cultivation led to the gradual spread of the weed around the farm.

Early control methods consisted of cultivation and herbicides such as MSMA and glyphosate - all to varying degrees of success. The late 80's saw the introduction of Zoliar, which was incorporated into the control program. The worst areas were attacked first. The cost of Zoliar prohibited full field sprays in all but the worst fields, so various methods of spot spraying were tried, including manually turning small tractor mounted booms on and off, a spray boom on the back of a slasher at picking time and spraying with a quad. Zoliar was applied both at planting and picking and it was discovered that it wasn't until about the third year into the Zoliar program, that the nutgrass really started to respond to the applications. The patches were still there, but they were getting smaller and thinner.

The early 90's saw little or no irrigation water from Copeton and not much more rain. Water was conserved in the soil by preparing the hills early then leaving them to sit until planting time. Although this was a good drought strategy, the reduced disturbance saw nutgrass areas increase again.

A very dry winter in 1994 resulted in no winter crops being planted. This left an opportunity to grow a green manure crop the following summer. A lablab/forage sorghum mix was planted in December and left to grow for three months before being rolled and ploughed back into the ground. The following summer saw a marked reduction in the amount of nutgrass in those fields, probably due to a combination of the competition from the lablab/forage sorghum, and the extra cultivations needed to work the high amount of dry matter back into the soil. This result has been repeated in other years with lucerne and again this season with another lablab/forage sorghum mix that was planted last summer. Although this did reduce the amount of nutgrass in the field, other methods of control are necessary to keep the patches from increasing.

Zoliar still forms part of the nutgrass control program on “Norwood”, although it is now mostly applied with a GTS sprayer, which has allowed more accurate targeting of the weed. Other methods of control are continually being trialled, both for better control and to hopefully reduce the amount of Zoliar in the soil, which limits rotation crop choice. Increased seed bed preparation, particularly deep cultivation, is having an affect, although more work still needs to be done.

This season (2001/02), saw the first commercial use of Roundup Ready cotton and herbicide. The herbicide had a dramatic effect on nutgrass patches, at a time of the season, when control is most important. It has allowed the cotton to out compete the nutgrass, without the need for extra cultivations. The wet November possibly helped contribute to the good result, by keeping the nutgrass fresh and more receptive to the Roundup Ready herbicide. It will be interesting to see if the result can be repeated over the next few seasons - here's hoping it will.

Currently we are trialling a more aggressive approach with the use of a large ripper with a wire cable connecting all the tynes. This cable is situated at the back of the tyne and is pulled by a D9N bulldozer, about 1 foot into the ground. The thought is that it will cut off the nuts from below and dry out the nuts above. So far the results are promising.

Case studies of grower experiences with nutgrass

Nutgrass control on Auscott Narrabri

David Wood

Nutgrass has been a problem on Auscott for a long time, but the issue came to a bottleneck over the last couple of years. Some fields were becoming so heavily infested that it was no longer economical to continue growing cotton.

The increase in the nutgrass populations was due to number of factors,

1. Succession of wet winters
2. Lack of effective in crop control options
3. Reduced tillage at depth

The run of wet winters reduced opportunities to use tillage as a control method, and resulted in operations for seedbed preparation being undertaken in less than ideal conditions. This made it very difficult to uproot and expose the tubers to desiccation as the nuts remained in moisture. Consequently, this simply spread the nutgrass from head ditch to tail drain.

In the past Zoliar was used as a broad acre spray across heavy infestations, however, its use was limited because of the restrictions that it imposed on future rotation crops. Due to the rotation issue Roundup was then used as an in crop control through shields. This also provided challenges with drift onto susceptible plants. MSMA was then used because of the greater crop safety, though unfortunately its success was variable. Semptra was also tried but was relatively ineffective. Together they gave reasonable control to continue cotton production, but were unable to stop the population from steadily increasing.

The situation took a turn for the better with the onset of Roundup Ready cotton. The Roundup Ready technology provided the opportunity to attack the nutgrass in the plant line early season, allowing the cotton to grow away and out compete the weed. The results from the Roundup spray are still sometimes variable, however, the successive applications achieve good brown off of the shoots more regularly, which is then followed by cultivation. In some cases it was taking the nutgrass 3-4 weeks to come back.

Zoliar is still an important part of the program on Auscott. Fields with light infestations are spot sprayed with a row weeder to prevent patches from spreading. It is also now sprayed through all rotobuck and tail drains in an attempt to stop cultivators from dragging the nuts down the field.

In combination with the chemical approach, rotation and tillage play an important role. The use of deep rooted crops, such as lucerne or safflower, dry out the soil profile and allow for deep ripping to expose nuts to desiccation. The advantage of lucerne over other crops is that if rains just prior to tillage, then it can be left to continue growing and draw the moisture out again, which is something that safflower or wheat cannot do if they have reached maturity.

At the end of the cotton season a Roundup spray at 2-3L/ha straight after harvest has shown signs of significantly reducing nutgrass populations in the following year. We are not sure if it will work each year, however, the results are encouraging.