

WEED CONTROL IN SUGARCANE

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A weed is simply a plant 'growing where it is not wanted'. In the establishment and growing of a crop of sugarcane, the seeds of many native and introduced plants germinate and the subsequent plants attempt to establish themselves within the crop. These plants are weeds.

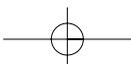
Weeds adversely impact on a sugarcane crop in a number of ways. A significant reduction in yield occurs if weeds are not controlled, as they compete with the sugarcane crop for nutrients, sunlight and moisture. Other weeds, such as vines, climb over and entangle themselves with the sugarcane crop, making harvesting difficult and reducing product quality. Some weeds may also release compounds that are toxic to sugarcane growth.

The combined cost of control and production losses from weeds in the Australian sugar industry is about \$70 million each year. This far outweighs the impact of other pests and diseases and demonstrates that weeds are the most important pest of sugarcane.

Mechanical cultivation, application of herbicides, or the retention of post-harvest

residues control weeds in the sugarcane crop. Sugarcane growers in Australia currently use a combination of all three methods, with herbicides and residue retention being dominant in most areas. Until the 1980s, under a pre-harvest burning farming system, mechanical cultivation was the main form of weed control. However, with the adoption of residue retention and increasing farm sizes in the 1980s and 1990s, herbicides were necessary for weed control.

The use of herbicides for weed control now presents a challenge for the industry. Growers using herbicides must ensure that the products being used, or their metabolites, do not impact on the environment off the farm, and that they are used with due diligence on the farm. It is important that the people involved in applying herbicides are properly trained and the correct safety



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procedures are in place. It is also important to use weed control strategies that reduce the likelihood of herbicide resistance, a factor becoming significant in other crops in Australia and internationally.

TYPES OF WEEDS

Four categories of weeds are found in Australian cane fields: grasses, sedges, broad leaves and vines. Each is important and no one group dominates in terms of importance of control. Detailed information on weed pests of sugarcane is given in the BSES Bulletin publication "Weeds in Australian Cane Fields".

Grasses

Grasses can be either perennial or annual. Annual grasses germinate, grow, seed and die each year, whereas perennial grasses survive beyond one season. Control of grasses is easiest when the seedlings are very small, such as the two-leaf stage. Perennial grasses are very difficult to control in the more mature stages and can become such an uncontrollable problem that they may necessitate a premature ploughout of the sugarcane. Grasses are generally the most prolific weeds and tend to germinate in the early stages of the development of the cane crop. They grow quickly, compete vigorously with the sugarcane crop and, if left uncontrolled, substantially reduce yield.

Some of the more common grasses that occur across districts are barnyard grass (*Echinochloa crus-galli*), couch grass (*Cynodon dactylon*), crows foot grass (*Eleusine indica*), para grass (*Brachiaria mutica*), green summer grass (*Brachiaria subquadripara*), summer grass (*Digitaria ciliaris*), guinea grass (*Panicum maximum*) and wild sorghum (*Sorghum* spp.). The retention of residues after green-cane harvesting suppresses the germination of many grasses and only the stronger, larger seeded grasses tend to germinate. In the development of new cane land, which was

previously improved pasture, the pasture grasses can be difficult to control and have a significant impact on the first cycle of cane cropping.

Sedges

Sedges also occur in all canegrowing districts but generally in the wetter areas. However, the sedge nutgrass (*Cyperus rotundus*) is prevalent in all districts and on all soil types. Nutgrass is very difficult and expensive to control, and is the most prevalent and important weed of sugarcane.

Broadleaf weeds

Although still important to control, broadleaf weeds generally are less of a problem than grasses. Broadleaf weeds can also be annual or perennial and the younger the plant, the easier it is to control. They also tend to be more regional and soil-type specific than grasses, and there are only a few that are common across Queensland.

Some of the most common broadleaf weeds include ageratum (*Ageratum* spp.), pigweed (*Portulaca oleracea*), milkweed (*Euphorbia heterophylla*), square weed (*Spermacoce latifolia*), blackberry nightshade (*Solanum americanum*), noogoora burr (*Xanthium pungens*) and rattlepods (*Crotalaria* spp.).

Vines

Vines are climbing plants that entangle themselves with and climb up the cane plant. They generally tend to germinate later in the season when the cane is more advanced. Vines are relatively easy to kill but can be difficult to manage. They germinate over a long time and even under a closed canopy it is difficult to remove them in one operation. It is also difficult to control vines beneath the crop canopy after that canopy has 'closed in'.

Vines germinate readily through a trash blanket and grow prolifically. It is difficult to apply pre-emergent herbicides to a trash blanket and so only knockdown herbicides can be used for control. Vines are particularly

important because, if left uncontrolled, they can impede harvesters.

Where vines are prolific, they entangle several rows of cane and harvesters have difficulty separating the rows. Harvester operators may have to stop the machine and manually separate the cane, or the machine can damage the cane crop by pulling it out of the ground. If the harvester manages to separate the cane and feed it into the machine, the vines wrap around the moving parts of the harvester and may require manual removal.

Vines have become more prolific since the adoption of green-cane trash-blanketing. Some of the more common vines in the Australian sugar industry include cucumber (*Cucumis* spp.), morning glory (*Ipomoea* spp.), convolvulus (*Ipomoea* spp.), passion vine (*Passiflora* spp.), and star of Bethlehem (*Ipomoea quamoclit*).

The species and mix of weeds varies in the different regions of Australia as well as within districts and soil types in a region. As effective control of weeds depends on the species mix, it is important for the grower to identify the weeds at a very early stage. Control of weeds varies with the method of control, the product used, the timing of control and the farming system.

LOSSES FROM WEEDS

Weeds compete with sugarcane for light, nutrients and moisture, so reducing crop yields. The effect of weed competition in sugarcane is greater than in many short-season row crops. This is because the wide inter-row spacing, high temperature, rainfall, fertiliser inputs and the perennial nature of sugarcane favour weed growth. The relatively slow establishment of the crop also makes it more susceptible to weed competition.

Yield loss from weed competition is estimated to exceed \$70 million annually. Herbicides are used extensively to control weeds, incurring increased production costs (\$14 million per year) and possible

phytotoxic yield reduction. Poor timing of herbicide application is a major cause of the yield loss from weeds, as weeds are often controlled after the yield loss has occurred. Therefore, determining the critical period of weed competition is important to minimise losses from weeds.

Weed competition in sugarcane is critical in the early stages of crop establishment, from planting to when the top visible dewlap is 10–120 mm high. Recent BSES weed competition trials have further defined yield loss at different periods in crop establishment. Trial treatments attempted to simulate different timing of weed control. The period of weed competition was from crop emergence (spiking) to the time of weed control (4, 8, 12 weeks). After this period, the treatments were kept weed-free until harvest. Trial results from Innisfail, Ayr, Mackay and Bundaberg indicate that yield reduction from weeds is similar throughout Queensland (Figure 1). Results indicate that weeds cause significant yield loss early in crop establishment. Weed growth 4 weeks after spiking caused a yield reduction of 11%. Delaying weed control until 8 and 12 weeks resulted in large yield losses of 23%, and 34%, respectively.

Early losses from weeds can occur because, during the period 3–6 weeks after planting, the cane roots are in transition from sett-roots to shoot roots. During this transition, weeds exert the greatest competitive influence on the slower establishing sugarcane. The extent of the yield loss from weeds will also vary with the competitive nature of the weed species present, the availability of moisture and nutrients, and the time of year.

The practical implication for weed control is to prevent weed establishment early in crop growth. Post-plant, pre-emergent herbicides and early application of knockdown herbicides (2–3 leaf stage of weeds) provide effective, economic weed control during this early critical period.

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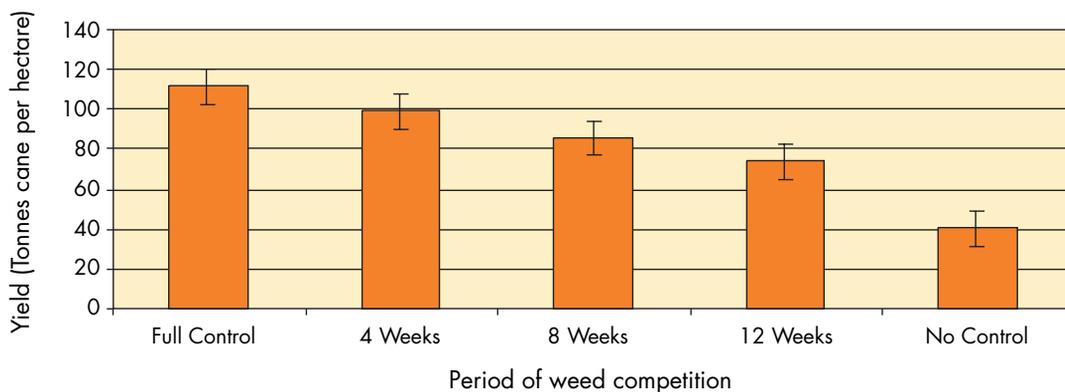


Figure 1. *The effect of weed competition on plant cane yield (Bundaberg 1997-98).*

Maintaining the weed-free threshold from spiking to the out-of-hand stage is also important in reducing losses from weeds. Often there is limited time available for weed control. Wet weather may prevent weed control at the critical stage, resulting in large yield loss. An option is to use residual herbicides, which provide weed control when field access is prevented for cultivation or knockdown herbicide application.

Results indicate that late weed control (12 weeks from spiking) is still beneficial in limiting the yield loss from weeds. Although late weed control on established weeds is more difficult and expensive, the economic return is normally better than without weed control. Preventing further weed infestation at this stage is important to reduce populations of problem perennial weeds in ratoons, reduce the weed seed bank, and prevent the build-up of rats.

METHODS OF WEED CONTROL

Mechanical, chemical and biological controls can be used against weeds. The method of weed control has changed through the history of the industry as farming practices, technology and farm sizes changed. Until the 1980s, the dominant form of weed control was mechanical. This changed from manual labour, to horse-drawn implements, to

tractor-drawn implements. This method of weed control is reasonably effective but requires significant labour and is capital intensive.

During the 1980s, the increased retention of residues after both green- and burnt-cane harvesting meant that mechanical methods of weed control were not practical or satisfactory and the use of herbicides gained popularity.

Today, residue retention and herbicides are the dominant forms of weed control. The use of herbicides has allowed growers to obtain better weed control, reduce the cost of weed control, and farm larger areas with the same amount of labour. The residue retention farming systems and the use of herbicides have enabled the Australian sugar industry to reduce the cost of production and survive falling commodity prices.

The industry will also face challenges in the future with offsite impacts not being acceptable to the general community and herbicide resistance now becoming a reality in many crops within Australia.

Mechanical weed control

The earliest methods of weed control were physical. Weeds were manually 'pulled' from the ground or 'chipped out' of the ground with hand-held implements. These were often

combined with cultivating implements that were towed through the fields. These implements cultivated or disturbed the soil surface and, in doing so, dug out the weeds that were competing with the cane crop. With no soil to grow in, the weeds would dry in the sun and die. Such methods were not totally effective, and the implements would also damage the cane crop. In wet conditions, where there was no drying effect, these methods did not always kill the weeds and weeds would merely be transplanted from where they were to a new position. The soil disturbed by cultivation was also more prone to erosion when rain occurred.

Plant cane

In plant-cane crops, mechanical cultivation is still a widely used method in the control of weeds up to the out-of-hand stage.

Cultivation of plant cane after planting has the dual purposes of weed control and gradual filling in of the furrow. While the cane drill is still open, cutaway or 'cotton king' and scratcher tines are usually used for weed control and tillage operations. These implements can effectively cultivate the shoulders and base of the drill, remove weeds and remove excess soil cover on top of the planted cane.

Grubbers or similar tined implements are used to cultivate the interspace and, at the appropriate time, to allow soil to be moved into the drill. Once the drill is partly filled in, implements such as a multiweeder can be used to provide good weed control.

In some situations, where the weed pressure in the drill is severe, a spinner is used to provide aggressive removal of weeds in the cane row. Care is needed with the operation of these machines, as they can remove billets and damage shoots if there is insufficient cover over the billets.

Once the plant crop furrow is filled in, successive cultivations aim to keep the crop free of weeds and provide an acceptable row profile for harvesting.

Ratoon cane

Since the 1980s, there has been a major change in cultural practices in ratoon cane. The length of the ratooning cycle has increased and the cultivation of ratoons has been reduced significantly. The advent of reduced tillage systems in conjunction with burnt cane and green-cane trash-blanketing (GCTB) has meant a greater reliance on herbicides rather than cultivation for weed control.

Even with conventional cultivation, the number of operations for ratooning has reduced over time. The normal sequence of ratooning operations includes raking and burning of tops and trash, cultivation of the interspace using a ripper tine, grubber tines, ratoon discs or some combination of these, fertiliser application, and subsequent cultivations with grubber tines for the interspace and scratcher tines for the cane row for weed control up to the out-of-hand stage.

Changing cultural practices

Minimum tillage and zero tillage were cultural practices introduced during the 1970s to reduce soil disturbance, soil erosion, and farming costs. They also had a considerable effect on weed control practices. By reducing the level of soil disturbance, they reduced the number of new weed seeds brought to the surface ready to germinate. They did, however, require herbicides to remove the weeds that initially grew in the crop.

Minimum-tillage farming systems and green-cane harvesting produced further benefits for weed control in sugarcane crops. Green-cane harvesting left a thick layer of cane trash covering the cane stubble. This physical barrier over the soil surface stopped most weeds from germinating and growing up through the trash blanket. This greatly reduced the amount of grass and broadleaf weeds that grew in the crop after harvest, and reduced the reliance on herbicides for weed control.

As this farming system stabilised, the types of weeds that infested cane fields changed.

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Stronger, more vigorous weeds that could penetrate through the trash layer became dominant. Weeds such as vines, nut grass, couch grass and guinea grass have often become greater problems after the introduction of GCTB.

Chemical weed control

From the early days of cane growing, different types of chemicals have been used to control weeds. Problem weeds were eliminated in cultivated fields with single or multiple applications of 'weedicides', but this practice was confined to small treated areas.

Early explorations of herbicides included the testing and use of several contact weed killers. Most of these had limitations. Sulfuric acid was dangerous to operators, arsenic compounds were poisonous, kerosene had some soil-sterilising effects, common salt adversely affected the soil, and sodium chlorate created a fire risk. These were not practical solutions to weed problems.

During World War II, the synthetic plant hormone 2,4-D (2,4-dichlorophenoxy acetic acid) was developed. If this weedicide was sprayed on weeds and grasses, most of the broadleaf weeds were affected and there was little effect on grasses. This selective action was very obvious. The chemical could also be sprayed onto a clean soil surface to stop or prevent germination of small weeds and grasses. This action was not selective. The concepts of pre-emergent spraying and post-emergent spraying had been introduced.

Research by the 1950s had identified many chemicals for controlling weeds in and around cane fields. Another synthetic plant hormone, MCPA, was developed soon after 2,4-D and, during the 1950s and early 1960s, other herbicides were developed. These included diquat, paraquat, diuron, atrazine, fenac, trifluralin and ioxynil, to name only a few. Two broad groups of herbicides were the selective herbicides and non-selective herbicides. This meant that very few weed pests could not now be successfully controlled or managed with herbicides.

During this period, the sugar industry considered herbicides too expensive for widespread use on Australian cane farms. However, as labour became more expensive, and farm size increased, weeds were not being adequately controlled by cultivation or hand weeding, so herbicides started to form a permanent part of the farmers' management arsenal.

The advent of pre-emergent herbicides and the use of knockdown herbicides combined with pre-emergent products changed farm-management practices when growers embraced this strategy in the late 1970s and early 1980s. Selective herbicides have allowed various grasses and broadleaf weeds to be controlled during the early crop establishment stages, as well as at the out-of-hand period of cane growth.

The adoption of herbicides as part of a farm weed-management package was aided by the development of herbicide application equipment for both ground and aerial use. A wide range of products, plus equipment to successively apply them at all crop growth stages, meant canegrowers had a cost-effective weed management tool that could achieve effective results across most environmental conditions.

In more recent times, herbicide chemistry has become more sophisticated. Herbicides have become more selective (specific) in the types of weeds controlled and more expensive as a result of the cost of development. These herbicides are often less robust and need precise application equipment to achieve the best results.

New formulations are continually being developed to ensure herbicides are more effective, and easier and safer to use. Water-soluble granules and controlled-release technology are examples of product development targeted at extending the useful farm life of herbicides and, at the same time, enhancing their performance.

Research into sugarcane's tolerance to herbicides, application methods, and the use of adjuvants to enhance the herbicides'

performance has entrenched these products as farm labour-saving and production-enhancing tools. An understanding of weed growth stages and characteristics is vital for growers to achieve this result.

Herbicides are an essential tool in integrated weed-management systems. To overcome weed problems, herbicides have to be used to reduce weed populations to levels where farming practices with reduced reliance on chemical weed control can be implemented. Rotation of herbicide groups will reduce the chance of developing herbicide resistance in weed species, and the promotion of problem weed species through management practices or herbicide influence.

Types of herbicides

Herbicides are generally divided into two main groups: selective herbicides and non-selective herbicides.

Selective herbicides damage or kill only certain plant species. For example, 2,4-D amine will kill broadleaf weeds (such as *Ipomea* spp.) but will have no effect on grasses. Many herbicides are selective at low rates but are non-selective at high rates.

Selectivity is influenced by the ability of a plant to either tolerate a particular herbicide or to break the herbicide down into harmless by-products as it is absorbed.

Non-selective herbicides kill a wide range of weed species. For example, paraquat will damage tissue of and kill both broadleaf and grass weeds.

The selectivity of a herbicide is influenced by a number of factors, including the growth stage of the weed, chemical formulation and application rate, method of application, and environmental conditions.

Mode of action of herbicides

Herbicides can also be grouped by the way they act on the plant.

Contact herbicides only affect the parts of the plant that they are applied to and move little inside the plant. They normally act rapidly inside the plant and are used for

control of annual weeds and young perennial weeds. In advanced perennial weeds, only the top of the plant is killed and regrowth will occur, resulting in unsatisfactory weed control.

Thorough coverage of the weed foliage is essential for successful control with contact herbicides. Good coverage is achieved by applying the herbicide when weeds are small and actively growing, using higher water rates, and setting up equipment to produce smaller droplets which are targeted toward the plant foliage. Contact herbicides can be either selective or non-selective at normal application rates. Many become non-selective at high application rates.

Translocated herbicides are applied to the foliage and stems of weeds and then move throughout the plant. They usually act more slowly and have a wider range of effects on the weed than contact herbicides. Effects include destruction of the green leaf pigment (chlorophyll), which prevents the weed making its food, which in turn halts growth and results in plant death.

Because translocated herbicides move through the plant, coverage of weeds with these products is not as critical as for contact herbicides. Hence, they are effective for controlling perennial weeds. However, favourable environmental conditions following the application of translocated herbicides are more critical to effective weed control because of their slow acting nature. Translocated herbicides may be selective (e.g. 2,4-D amine) or non-selective (e.g. glyphosate).

Residual herbicides are translocated herbicides that are applied to the soil surface where they persist until they are taken up by the target weeds. The roots and shoots of germinating seeds and seedlings absorb these products. Residual herbicides are relatively ineffective against established weeds. They can be selective (e.g. trifluralin) or non-selective (e.g. diuron). At higher rates, some selective residuals become non-selective.

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The effectiveness of a residual herbicide relies on its ability to persist in the soil until soil conditions promote germination of weeds. The ability of a herbicide to remain active in the soil depends on factors such as the amount of herbicide present, soil type, soil pH, rainfall, temperature, sunlight, organic matter, and the presence of herbicide-aggressive microorganisms.

FACTORS AFFECTING HERBICIDE PERFORMANCE

There are many factors that can affect herbicide performance. This section deals with the common factors that can influence how well a herbicide performs in the field.

Common errors or sources of failure include incorrect identification of the weed, using the wrong herbicide, reducing the herbicide rate, or incorrect calibration. Others are inadequate agitation of wettable powders, failure to use a wetting agent to maximise leaf contact with post-emergent herbicides, soil movement due to irrigation or rainfall after the application of pre-emergent herbicides, using very hard or dirty water, spraying plants covered in dust, and insufficient coverage of the foliage. The last is particularly important when using herbicides with limited systemic action, e.g. paraquat and diuron. Where coverage with such herbicides has not been adequate, only those parts of the plant actually sprayed will die or lose colour. Death of the growing point is harder to achieve with grasses than broadleaf weeds. On broadleaf weeds, the growing point is at the top of the plant and is exposed to direct spray contact. The growing point of grasses is protected from direct spray contact by a whorl of developing leaves. Some translocation of herbicide to the growing point is essential.

Other common errors or sources of failure include poor timing of application. Spraying actively growing plants at the correct stage of growth will give the best results, whereas spraying advanced and mature weeds,

especially grasses, at a rate suitable for smaller plants is a common error. Poor incorporation of pre-emergent herbicides such as atrazine, trifluralin and pendemethalin is also common. For effective mechanical incorporation, soil should be in reasonable tilth, not wet or cloddy.

Water penetration is important for herbicides such as diuron and Velpar K4®, and these should receive irrigation or rainfall after application.

Drill shape is important when applying pre-emergent herbicides to plant cane. The drill should be wide enough to prevent untreated soil falling back to the bottom of the drill.

Nozzle selection and adjustment must be correct. Factors to be considered include selecting even fan nozzles for band spraying, and ensuring that tapered fan nozzles must be set at the correct height above the target. Striping can result from using incorrect height.

Excess organic matter or ash will tie up pre-emergent herbicides. Poor results may occur where cane tops have been raked and burnt or where mill mud/ash mixtures have been applied.

Care must be taken to avoid using incompatible herbicides. The product label provides information on compatibility.

Effect of the environment

Humidity and temperature

Humid conditions greatly improve the leaf absorption of most herbicides. Spray droplets dry slowly under humid conditions, thus keeping the herbicide dissolved longer. This allows easier entry into the leaf. Stomata (leaf pores) are one of the main entry points for herbicides. In hot, dry conditions, the stomata will close to conserve moisture in the plant. This severely limits herbicide uptake. The other main entry point for herbicides is through the leaf surface, which is covered with a waxy coating known as the cuticle. In hot, dry weather, the cuticle

becomes less permeable. Spraying under these conditions should be avoided.

Temperature influences the rate of herbicide absorption, the rate of movement within the plant and the plant's metabolic rate. Cool conditions following the application of herbicide will often produce poor results. For example, MSMA should not be applied if the air temperature is likely to drop below 21°C. High temperatures can also lead to the loss of herbicide through volatilisation.

Rainfall and dew

Because most herbicides enter plants in a soluble form, the presence of dew can assist uptake by keeping the herbicide in solution for longer. However, where the leaves are covered by heavy dew, applied spray droplets will roll off the leaf.

Similarly, a light shower of rain can redissolve herbicides that have dried on the leaf, thus assisting uptake. Usually, however, rain acts to wash off the herbicide. The length of the 'rain fast' period depends on the herbicide. Paraquat is rain fast in minutes, 2,4-D in 4 hours and glyphosate in 6 hours.

Plant factors

Plant age

The younger the plant the greater is the percentage of growing tissue. Thus, mature plants have limited sites for herbicide activity.

Growth rate

In general, fast-growing plants are more susceptible than slow-growing plants.

Annual or perennial

The stage of growth determines the pattern of movement within the plant. This pattern depends on whether the weed is annual or perennial. Spraying perennial weeds, such as guinea grass and stinking passion fruit (*Passiflora foetida*), early in the regrowth stage limits the translocation of herbicide to the roots.

Annual weeds tend to have shallower root systems than perennials. Soil-applied herbicides may not reach the root zone of perennial weeds.

Degradation and loss of herbicides

There are many pathways by which herbicides are lost from the soil or degraded into other compounds while in the soil.

Leaching

Leachability is a product of a herbicide's solubility and how strongly it adsorbs onto soil particles. Soil-applied herbicides, such as trifluralin, which have very low solubility, must be incorporated or receive rainfall to achieve good distribution. Soluble products, such as atrazine, move with the soil water which can leave the field through runoff or leaching through the soil profile.

Incorporation can be either physical (cultivation) or with irrigation or rainfall that can move small herbicide particles into the soil.

Soil movement

Soil movement occurs not only with erosion but is also caused by irrigation. Travelling irrigators cause soil 'splash' and can leave areas with insufficient herbicide. Furrow irrigation of cultivated soil causes the soil to 'slump' or settle, leaving gaps in the treated area. Furrow irrigation can also cause soil erosion near the fluming.

Plant uptake

Removal via plant uptake is often overlooked. With very high weed populations, which often occur under irrigated conditions, the weeds may take up considerable herbicide. However, because each weed accounts for only a small portion of the uptake, the weeds may not be killed.

Adsorption

Adsorption is the bonding of herbicide onto soil particles. The adsorptive ability of soil particles depends on their size and chemical properties. Adsorption increases with

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increasing levels of organic matter, clay content and cation exchange capacity. Adsorption also depends on the nature of the herbicide. Molecules of paraquat and diquat are strongly charged, enabling them to attach firmly to the soil particles.

Biological degradation

Soil-living fungi, actinomycetes and bacteria break down herbicides. Degradation occurs most rapidly in warm, moist, well-aerated soils. Soil pH is important, with medium to high pH soils favouring bacteria and actinomycetes and fungi tolerating lower pH values. In temperate areas, the loss of substituted urea herbicides, e.g. diuron and bromacil, from the soil is due mainly to biological degradation. Biological breakdown of triazine herbicides, such as atrazine and simazine, is less important.

Photodecomposition

Sunlight provides energy, which can break down herbicides. This is particularly important in tropical and subtropical areas, which receive more UV light than temperate areas. Photodecomposition is a major source of diuron breakdown.

Volatilisation

Volatilisation or evaporation is the major pathway through which some herbicides are lost. The triazine herbicides such as atrazine and ametryn are prone to volatilisation at high soil temperatures, and spraying onto hot, dry soils maximises losses to volatilisation. Soil surface temperatures of 70°C have been recorded in the Burdekin and surface temperatures of 50–60°C are common in summer.

Where volatilisation is likely to be a problem, avoid spraying onto unshaded soil and where incorporation or irrigation is required, do it as soon as possible.

Chemical degradation

Herbicides left in the soil will degrade over time independently of any biological activity

or photodecomposition. Degradation occurs most quickly in warm, moist conditions.

Varietal susceptibility

Sugarcane varieties have inherent differences that affect their sensitivity to herbicides. The varietal response to herbicides is broadly classified as tolerant or susceptible. Determining this interaction is important in minimising any negative impact on cane yield.

Phytotoxicity of herbicides to sugarcane usually appears as chlorosis of leaves and stunting of shoot growth. Previously, BSES field trials attempted to evaluate the variety reaction to herbicides by visual assessment of these symptoms. However, recent data indicate a poor relationship between visual symptoms and yield from herbicide phytotoxicity. Therefore, any non-visual phytotoxicity from herbicides needs to be assessed.

Rapid development of new varieties and herbicides requires herbicide phytotoxicity to be continually evaluated. Field phytotoxicity screening is slow, as the crop has to be harvested to assess yield. Other variables such as weed competition, soil type, nutrition and moisture may also influence results of herbicide trials.

BSES has developed a pot-trial methodology to overcome the problems of field phytotoxicity trials. Pot trials involve growing sugarcane varieties in pots to rapidly assess herbicide phytotoxicity. Herbicides are applied using precision spray equipment and growth variables which correlate to the field response are monitored.

The herbicide by variety interaction can now be determined in 3 months compared to 12–18 months in the field.

Herbicide resistance strategies

Resistance of weeds to herbicides is becoming a major issue in many Australian and overseas crops. It is only a matter of time before one of the greatest threats to the viability of the southern Australian grain

industry, resistance of weeds to herbicides, spreads to the Australian sugar industry. In the southern grain industry, resistance has been reported to a number of products commonly used in sugarcane including atrazine, glyphosate (Roundup®), trifluralin, pendimethalin (Stomp®) and paraquat (Gramoxone®). So far, no confirmed cases of weed resistance have been reported in the sugar industry.

Development of resistance will cause costly chemical application failures, limit the types of herbicides that are available for a particular weed control situation, and may require alternative control measures that result in reduced production, such as long fallowing and rotation crops. Once developed, herbicide resistance will persist for many years.

Survival of plants

Herbicide resistance is the inherent ability of a weed to survive a herbicide application that would normally control it. This survival is due to the plant's genetic makeup and is different from poor control due to poor application technique.

Resistance development

A small number of plants present in a weed population may be naturally resistant to a particular herbicide. Repeated doses of one herbicide, or herbicides with the same mode of action, will result in susceptible plants being controlled, while resistant weeds will survive and set seed. Eventually, resistant weeds will make up the bulk of the population and the herbicide will no longer give effective control.

Resistance also can develop in a weed population following a mutation. This occurs when changes in a weed's genetic makeup occur between generations allowing them to survive a herbicide application. The more specific a herbicide's mode of action is, the greater the chance of weeds becoming resistant.

Cross resistance can occur when a weed not only develops resistance to a herbicide which has been used against it, but also against unrelated herbicides with different modes of action, which have never been used against the particular weed.

Rate of resistance development

The rate at which resistance develops in a weed population depends on the number of resistant individuals in the weed population, the number of generations the weed can complete in a season, the number of times a particular herbicide is used, and the type of herbicide and its mode of action.

Any weed can become resistant to herbicides. Weeds reported resistant to herbicides in other cropping industries include nutgrass, sowthistle (*Sonchus oleraceus*), Indian hedge mustard (*Sisymbrium orientale*), annual ryegrass (*Lolium rigidum*), wild oats (*Avena fatua*), wild turnip (*Brassica rapa* var. *silvestris*), silver grass (*Aristida contorta*), barley grass (*Hordeum leorinum*), climbing buckwheat (*Fagopyrum esculentum*) and summer grass.

Prevention

The most effective way of preventing resistance is to use a range of weed control measures, both chemical and non-chemical. Rotating the use of herbicides from different groups and tank mixing herbicides with different modes of action will limit resistance development. Non-chemical control measures include cultivation and trash blanketing. A fallow also can be used to break the weed cycle and to reduce weed seed numbers.

Know the herbicide groups

Understanding that herbicides work in different ways is an important step in being able to use them effectively, while minimising the risk of resistance development. Herbicides act by interfering with plant functions. For example, atrazine interferes with photosynthesis. Often, a number of herbicides inhibit the same plant function (diuron also affects photosynthesis).

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Herbicides have been placed into groups based on the plant process they affect (mode of action) and the risk of resistance development (Table 1). By knowing the group a herbicide belongs to, decisions can be made with regard to rotating herbicides and tank mixing to minimise the risk of resistance development. Many herbicides now have the mode of action group displayed on the label to assist with resistance management.

Accurate spray records will assist with early identification of resistance development and allow monitoring of herbicide groups that have been used over several seasons.

Resistance to herbicides has the potential to significantly increase the cost of weed control, but can be minimised if appropriate management strategies are adopted. Early detection is important and unexpected weed control failures should be reported to allow determination of the reasons for failure.

HERBICIDE APPLICATION

Herbicide application equipment is any apparatus used to deliver a predetermined quantity of chemical to the target. Farm chemicals can be delivered as liquids (usually as droplets), solids (dusts and granules), gases or vapours.

The early method of chemical application was by hand. Products were spread or poured on to a single weed or a patch of weeds to achieve control. The period of control or effectiveness depended on the coverage and rate of product applied. This method was time consuming, posed health risks to operators, and was suited only to small areas of treatment.

Herbicides were foliar or soil applied to give knockdown and or pre-emergent control of weeds. Liquids were commonly used, but some dusts or granules were applied and then cultivated or washed in by rain. Various machines were developed to spread herbicides formulated as powders and granules. Equipment to supply diluted and undiluted liquid by gravity or with pumping assistance was also developed as chemical weed control became more widely accepted. Methyl bromide gas was used to control small areas of nutgrass and Johnson grass, and the liquid was applied under a plastic sheet.

Methods of application were designed to provide an even distribution of product over a field, a given amount to a small area, or a band over the cane row. A hand-operated knapsack sprayer was commonly used to treat small patches of weeds. Powered sprayers, such as misters, were used for

Table 1. Common sugarcane herbicides and their activity group.

HIGH RISK	GROUP A	Fusilade®
	GROUP B	Sempre®
MEDIUM RISK	GROUP C	Atrazine, Ametryn, Diuron, Actril DS®, Velpar K4®, Gesapax combi®
	GROUP D	Trifluralin, Stomp®
LOW RISK	GROUP I	2,4-D, Actril DS®, Dicamba, Tordon 75D®, MCPA, Starane®
	GROUP J	Dalapon (2,2-DPA), TCA
	GROUP K	Asulox®, Daconate®, Dual®
	GROUP L	Paraquat, Gramoxone®
	GROUP M	Glyphosate, Roundup®, Touchdown®
	GROUP N	Basta®



Figure 2. *Post-emergent application of herbicide using early application equipment.*

overall coverage of the cane crop to control broadleaf weeds such as vines. Tractor-mounted boom sprayers using diaphragm, piston, gear or centrifugal pumps were adapted to cover larger areas of weeds or crop with an overall application. Early spraying equipment involved 200 L drums, gear pumps and galvanised water pipe with brass nozzles screwed into it. Equipment was coarse and prone to wear. It did, however, produce effective results with the chemicals used at the time.

The next step was the use of dedicated spraying equipment. Purpose-built tanks were fed through better pumping systems into rigid spray booms. These were dry booms, in that they did not carry any spray solution. They had hosing mounted on them and the hosing fed into spray nozzles that could be changed easily. These rigid booms often would sway up and down at their ends as the tractor moved over bumps and hollows in the

paddock. This caused damage to the cane and ineffective application of the herbicide.

Droppers were attached to the spray booms to get the spray nozzles closer to the soil surface and the target weeds. This helped reduce the effects of spray drift. Boom bounce, however, still remained a problem and could at times break the spray nozzles if they hit the ground. With some contact herbicides still causing damage to the crop, a number of innovative growers made shrouds of various types that deflected the crop leaves as the boom passed through it. This allowed the spray to reach the target weeds with greatly reduced effect on the crop.

El Arish growers, the Costanzo family, developed a 'leg' that trailed behind the boom. The spray nozzles were attached to this trailing leg. The legs were built using a parallelogram system that kept the spray nozzles at a constant height above the ground. The spray was applied to the weeds

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more accurately and the spray pattern from the nozzles could be directed away from the crop leaves.

Ingham grower John Irvin further developed this principle. He used two trailing legs per interspace, and the legs were curved so they would follow the row profile and keep the nozzles positioned in the centre of the interspace. To ensure adequate spray coverage, two flood jets were used per interspace, one spraying forward and the other to the rear, operating on the horizontal plane. The Irvin leg was further modified by the addition of an adjustable T bar that enabled the nozzle height to be adjusted to cater for varying hill heights. The number, type and direction of nozzles could be adjusted or changed, but a standard bar usually featured six tapered flat-fan nozzles to cover the interspace and the hill profile on each side.

Droppers, Costanzo and Irvin legs, spraying shields and various adjustable nozzles enabled growers to apply herbicides to weeds or the soil surface and minimise herbicide contact with the cane crop.

Inter-row tractors with a variety of spraying equipment, enabled growers in the 1980s and 1990s to apply contact, translocated and pre-emergent herbicides at all stages of cane growth (Figure 2). Aerial spraying using planes or helicopters enabled large areas to be treated with pre-emergent herbicide when fields were unsuitable for ground application methods (Figure 3a). Aerial spraying has revolutionised the control of vines at the out-of-hand stage or in the mature crop particularly in the areas when extreme crop lodging occurs. Rope or wick wipers were designed to deliver diluted products such as glyphosate onto the leaves of weeds such as Guinea grass and phragmites (*Phragmites* spp.)

Modern equipment

Conventional boom-spray equipment generally consists of a tank, a pump and bypass system, pressure regulator, filtration system, spray boom and nozzles (Figure 3b). Small boom sprayers with tanks up to 900 L are usually three-point linkage mounted, whereas larger sprayers with tanks up to 3000 L are trailer mounted.



Figure 3a. Aerial application of Fusilade to Q124 at Sarina 2000.



Figure 3b. Modern equipment to apply herbicides.

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The tank should be made of a non-corrosive material, resistant to farm chemicals and easily repaired. The most common materials are fibreglass, PVC, or stainless steel. They should not have a flat bottom or square corners and must be easy to fill, drain and clean.

The main types of pumps are diaphragm, piston, centrifugal, roller and gear. In selecting a pump, the operating pressures required, types of chemicals to be applied, agitation requirements, durability and cost of the pump should be considered. A pump must be able to supply sufficient liquid to agitate the chemical mixture in a full tank, as well as the volume to be applied per hectare.

All application systems must have a method of controlling the operating pressure. The pressure regulator is essential to maintain the spray output, supply agitation, and maintain operating pressures, even when parts of the boom are turned off. The pressure gauge indicates the operating pressure and is essential for the spraying unit to be effectively calibrated. Gauges may show the pressure in bars or kilopascals (kPa), but should be a dual-pressure system to accurately display low pressures as well as operate at high pressures of 1000–2000 kPa when using a handgun for spot spraying.

Filters are essential to prevent nozzle blockages. Filters are usually fitted to the tank inlet, suction line, pressure lines and sometimes nozzles.

Spray booms are made of steel, but this needs to be protected from corrosion. Aluminum and stainless steel are also used, but are less popular because of higher cost and more maintenance problems. Booms can be fixed (rigid) on small units or folding on

larger units to allow the unit to be driven between jobs and allow easier access to blocks. Spraylines should not be made of steel as they will corrode, and this material will block filters and nozzles. PVC is usually the preferred material on most spray units

Hydraulic pressure is the most common method of generating spray droplets on cane farms. Droplets are formed when liquid is forced through a nozzle under pressure. A disadvantage of hydraulic sprayers is that many droplet sizes are formed, and many of the small droplets will drift away from the target area, while the large ones will bounce off the target. Units require frequent calibration, equipment has to be operated at the correct pressure and distance from the target, and nozzles may wear quickly and or unevenly.

The main types of nozzles used are fan jets, flood jets and cones (Figure 4). Fan nozzles are the most common type used. Tapered fans are used on boom sprays to obtain overall spray coverage. Even fans are used for spraying a band or strip over the cane row. These nozzles are operated at 1.5 to 3 kPa. Low-pressure flat fans and low drift fan nozzles have been introduced to reduce spray drift. Flood jets, operated at 1.5 kPa, generally produce larger droplets than the equivalent sized fan nozzle. They are used where large water volumes are required or to reduce spray drift. One nozzle will cover 1.5 m, the width of one cane row. However, obtaining even spray coverage across the row profile can be difficult.

Cone nozzles are operated at 3-6 kPa. Two types are available—hollow and solid. The solid cone produces a complete coverage across the nozzle. Cone nozzles produce finer

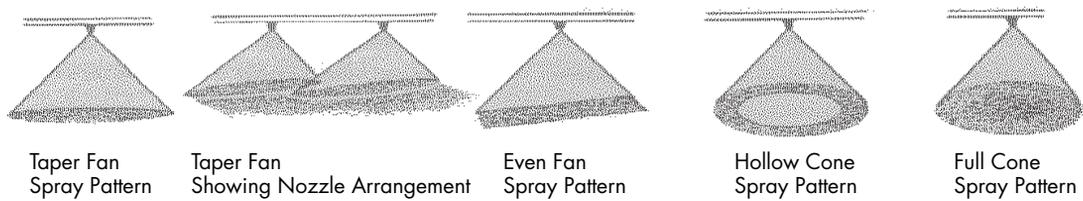


Figure 4. Spray patterns from different nozzles.

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droplets and are suited for applying insecticides and fungicides. These nozzles were fitted to the fungicide application equipment of many cane planters.

Spray nozzles are made out of many different materials. This influences their cost and durability as shown in Table 2.

Table 2. Relative durability and cost of nozzle tips made from different materials.

Type of material	Durability	Percent output increase after 50 hours use
Sintered alumina	Most durable ↓ Least durable	0
Tungsten carbide		0
Ceramic		0
Hardened stainless steel		1
Plastic		4
Stainless steel		5
Brass		18
Aluminium		27

Modern equipment can apply precise rates of chemical at the correct spray volume with the desired droplet size, to maximise the effectiveness of the chemical applied. This precise application reduces the chance of off-target effects and thus protects the environment. Controlled droplet applicators (CDAs) on airplanes, ground rigs and hand-held sprayers are examples of equipment that can produce spray coverage with the majority of droplets in the optimum size range.

Spray drift

Spray drift or vapour drift is an issue that all growers should be aware of and take precautions against. A major problem for canegrowers is the wide range of crops grown on neighbouring farms, including many small

crop, flower and orchard operations. Urban encroachment into cane areas is aggravating this problem; here, there is often nil tolerance to any form of spray drift.

Vapour drift is the movement of fine particles from a herbicide that tends to give off vapour at the time of application or afterwards. This vaporisation may occur for up to a week following spraying and increases as the temperature rises. Vaporisation reduces the effectiveness of the herbicide application and increases the danger to nearby susceptible crops. Ester formulations of herbicides are the most vaporous and amine salts the least. Table 3 shows the phenoxy herbicides which are less subject to vapour drift.

Table 3. Phenoxy type herbicides with reduced vapour drift hazard.

	Registered name
2,4-D amine	<ul style="list-style-type: none"> • 2,4-D amine 500 • Ami-weed 500 • Amicide 50 • Amicide LO-500 • D-500 • Shirweed 500 • Zephyr
2,4-D sodium	<ul style="list-style-type: none"> • Hormicide • Sodium 2,4-D
MCPA amine	<ul style="list-style-type: none"> • Agritox • MCPA 50 • MCPA 500 • MCPA Amine 500
Dicamba-amine salt	<ul style="list-style-type: none"> • Banvel 200 • Dicamba 200 • Dicamba herbicide
Fluroxypyr (methyl heptyl ester)	<ul style="list-style-type: none"> • Starane
Iso-octyl ester + ioxynil as octanoyl ester	<ul style="list-style-type: none"> • Actril DS

Canegrowers have the responsibility to keep their pesticides on their own property because pesticides can damage other crops and waste chemicals that do not reach their

intended target. This applies especially to phenoxy type herbicides such as 2,4-D and dicamba.

A number of factors can contribute to spray drift.

Droplet size

Very small spray droplets are lighter and fall more slowly than big droplets. The hydraulic spray nozzles that are used for sugarcane produce a mix of droplets in a wide range of sizes. Most of the droplets produced are large and do not drift, but there are a significant number of small droplets that will.

Pressure

Spraying at high pressure increases the proportion of small droplets that come from the same nozzles at lower pressures. In 'drift-sensitive' situations, lower spraying pressures should be used.

Spray nozzle height

The higher the spray nozzles are positioned above the target weeds, the more chance there is for spray droplets to drift away from the target. Spray nozzles should always be adjusted to their minimum working height above the target to minimise drift.

Spraying speed

When spraying at fast speeds, the spray rig creates turbulence that can swirl the small droplets away from the target. Spraying should be done at a safe speed between 6-8 km/h. This speed should be reduced further in stronger winds.

Wind speed

Stronger winds increase spray drift. Spraying at normal pressures is acceptable in light breezes so long as there are no strong gusts or changes in wind direction. As wind speed increases, spraying pressures should be reduced. When applying herbicides, growers should always be watching for any change in wind speed or direction that could cause drift problems.

Air temperature and humidity

Hot temperatures at low humidity cause droplets to evaporate quickly. This reduces the size of bigger droplets and makes them more prone to drift.

CDA equipment

Controlled droplet application (CDA) spraying equipment produces uniform-sized droplets. When set up and used correctly, there is little or no chance for drift. This type of equipment is not normally used for sugarcane because it is expensive and requires more maintenance. However, those growers who do use CDA sprayers will benefit from the uniformity of the spray droplets they produce.

Low-drift nozzles

Several years ago, some manufacturers made new ranges of nozzles that produced larger droplets even for smaller nozzle sizes. There is now a range of second-generation, drift-reducing nozzles that tend to produce larger droplets, while reducing the proportion of small drift-prone droplets.

These new spray nozzles are presently being evaluated at the Centre for Pesticide Application and Safety to confirm manufacturer claims and formulate better recommendations for the use of the nozzles.

Contact herbicides

Herbicides with a contact mode of action, such as paraquat, usually need good target coverage. This is often achieved by spraying many small droplets. In some cases, increasing droplet size might reduce the coverage and produce poorer spray results. However, this is not the case for systematic action herbicides, like 2,4-D and glyphosate.

Care and attention in the setting up, selection and use of spraying equipment should result in spray-drift reduction.

Procedures for minimising spray drift

Amine or less volatile formulations are used when it is necessary to apply phenoxy-type herbicides, such as 2,4-D and dicamba, near

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sensitive, desirable plants. The lowest pressure possible should be used to apply the herbicide. This may mean the use of floodjet or low-pressure nozzles which operate effectively at pressures less than 100 kPa. The height of nozzles is set as far below the cane canopy as possible by the use of droppers or skids.

Spraying under very still or very windy conditions should be avoided. A light breeze blowing away from susceptible plants is ideal.

It is preferable to spray when relative humidity is high. This is normally early morning or late afternoon.

If these procedures are followed, herbicide drift can be reduced significantly. However, it is not possible in a practical sense to eliminate spray drift entirely.

Extremely low amounts of some herbicides are damaging to sensitive crops. Therefore, extreme care must be taken when spraying near sensitive crops and it may be possible that herbicides should not be used in extremely sensitive situations.

Records

A record should be kept of each and every application of farm chemical.

The Queensland CANEGROWERS in conjunction with Crop Care have produced an excellent 'Farm Chemicals Record Book'. All canegrowers can acquire this booklet from their local CANEGROWERS Office to record all their chemical applications. This booklet summarises why records should be kept:

'The Rural Chemicals Code for the use of chemicals on farms was released in January 1994.

'This Code provides you with the flexibility to continue to use agricultural chemicals in a safe and reasonable manner without undue bureaucratic regulation. It also gives the general public the legislation they have been seeking to assure them that chemicals are being used safely.

'The Workplace Health and Safety Act, under which the Code was written, says that in going about your business you must do what is 'reasonable' to protect the health and safety

of yourself, your workers and the general public. Deciding what is reasonable is the sort of thing that you do all the time.

'When using agricultural chemicals, the local environment, the weather and the chemicals being used are all part of your decision whether or not to spray and the manner in which spraying takes place.

'The Rural Chemicals Code contains guidelines to determine what is reasonable. But in the end it is the decision that you make by which it will be judged if your actions are reasonable or not.

'This is where records come in. If you record your spraying decisions at the time you are making them it will be a lot easier, if there is a problem later on, to explain what you did and why you believed it was a reasonable course of action at the time.

'Keeping records of chemical applications may not be the most pleasant job on the farm, but if there is a complaint about the use of chemicals you will be very glad you have a set of records which are complete, were filled out at the time of application, and which demonstrate that you thought carefully about the job before you started spraying.

'Of course a good set of records is always an invaluable aid to memory too.

'There is a space on the form to include details of the effect of the spray as this can assist in chemical selection in the future'.

Good records are growers' insurance that reasonable precautions were taken at the time of any application. Without any written record, growers are particularly vulnerable to litigation. It is wise to get into the habit of recording details about all chemical usage in this CANEGROWERS booklet.

Biological control

In recent times when lower reliance on chemical weed control has become desirable, biological control of some problem weeds is being investigated. One example in sugarcane is the control of giant sensitive plant (*Mimosa invisa* Mart.) with an introduced sap-sucking insect called a psyllid. Insects have been released and populations have built up on the weed plants. While they

might not give total control of the weed, they do have a significant effect on colonies of the weed, and reduce reliance on herbicide control measures.

Environmental considerations

Good weed management is an important aspect of caring for the natural resources of farms. Weed management strategies, which control weeds around the farm and take care to minimise adverse impacts, will improve environmental quality.

Controlling weeds in cane

Both chemical and mechanical weed control methods have the potential to affect the downstream environment. For example, seagrass appears to be highly sensitive to diuron, even at low concentrations. Careful weed management strategies will help to minimise any risk of harm. Herbicides may move to non-target areas through run-off, leaching, spray drift, attached to eroded sediments, or from chemical spills. These concerns are taken into consideration in the chemical registration process and are incorporated into label recommendations. Herbicides should always be applied in accordance with the label. Very soluble herbicides can also leach through the soil profile and have the potential to enter the groundwater.

Mechanical weed control methods reduce chemical usage, but still require careful management, as cultivation leaves soils more prone to erosion. Soil loss from unprotected soils leaves rills and washouts in blocks. Eroded sediments make waters turbid, silt up waterways and transport nutrients and chemicals. The retention of green-cane trash has the double benefits of protecting soil from erosion and suppressing weed growth.

Choosing the best practice to suit the situation will help to minimise risk of harm to the environment. For example, a spray-out fallow will use more herbicide but will likely have less environmental impact as soils are better protected from erosion.

Headlands and drains

Wherever possible, headlands and drains should be well grassed and slashed. Research has found that these grass filter strips can trap considerable levels of silt from runoff water and protect headlands from erosion. Shallow, spoon-shaped, grassed drains are the most stable and can double as headlands where appropriate.

Control rat-harbourage areas

Rats rely on high-protein feed from grass and weed seeds to be able to breed. Reducing weed and grass growth around the farm by slashing, spraying or shading out with vegetation will minimise both this food source and harbourage areas.

Controlling weeds in waterways

Weeds in waterways can considerably degrade stream quality. Flow capacity is also reduced by weeds. In particular, para grass, guinea grass and hymenachne will trap silt and impede flow. This can cause damage in floods if banks break and can in turn lead to bed widening as water is forced to erode banks to find a flow path. Fish habitat is degraded as water weeds reduce dissolved oxygen levels and smother habitat. Long-term control of weeds is most effectively achieved by encouraging or replanting native vegetation to shade out weeds.

Marine plants are protected under legislation. Control of weed growth in tidal drains should be carried out in accordance with QDPI Fisheries/CANEGROWERS Fish Habitat Code of Practice or with an individual permit. All other watercourses in Queensland are protected under the *Water Resources Act 1989*. In Queensland, farmers should contact the Department of Natural Resources for a permit where required.

FUTURE DIRECTIONS

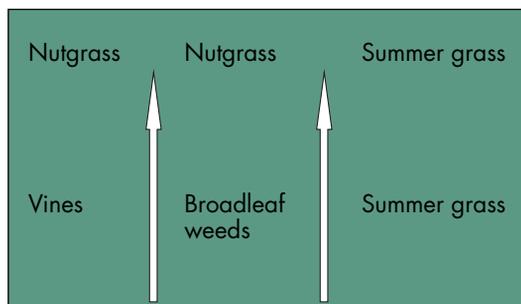
Precision agriculture

Precision agriculture is changing the way farmers conduct their routine activities. With

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the use of Global Positioning Systems (GPS) and appropriate technology, growers are now able to accurately locate items of interest and place products accurately.

With the technology now available, some growers can log into a control box in the tractor the exact position of problem weeds, such as guinea grass, during cultural operations, and return to exactly the same position at a later date and control the patch of weeds. It may also be possible during cultural operations to locate different species mix of weeds within a field and then, by using GPS and a technologically advanced spraying applicator, deliver different product mixes to control different weed species. For example, if a field had a mixture of weeds as outlined below, then a mixture of products could be used to control nutgrass, and different mixtures of products to control each of the grasses, vines and broadleaf weeds.



With development of smart applicators, these different applications could be made in one pass of the field. Precision agriculture with variable rate applicators is currently being used to vary nutrient applications across a field based on soil nutrient status or yield maps. Such advances in technology will soon influence the way products are applied to control weeds in sugarcane fields.

Organic sugar production

Organic sugar production is only a very small component of the world market and there are only limited amounts produced and sold in Australia. Production of organic food is based on the principles of 'producing optimal

quantities of food of high nutritional quality without the use of artificial fertilisers or synthetic chemicals'. Producers and processors of organic sugar have to be certified by an organic organisation accredited by the Department of Agriculture, Fisheries and Forestry Australia through the Australian Quarantine and Inspection Service (AQIS). All certifying organisations have production standards that conform with the minimum national standards. These minimum standards were developed by the Organic Produce Advisory Committee and endorsed by the Department of Agriculture, Fisheries and Forestry Australia.

One of the difficulties of producing organic sugar is the control of weeds within the crop. Under an organic farming system, weed control may use a combination of the following techniques: biological weed control, crop rotations, soil solarisation, mechanical weed control, residue retention or mulching, grazing animals, flame or steam control. Most producers of organic sugar in Australia use mechanical weed control methods. As can be seen, control of weeds in an organic sugar farming system will be more expensive and less effective than the current conventional systems. However, the tools are available to the producers of organic sugar in Australia to effectively control weeds under their farming system.

SUMMARY

Weed control has changed dramatically over the life of the Australian sugar industry.

Initially, weeds were controlled by manual labour and horse-drawn implements.

The industry progressed to weed control using tractor-drawn implements and then to the use of residue retention and herbicides.

The adoption of these new technologies has enabled the industry to reduce the cost of production and provide more effective weed control.

However, there are currently several challenges facing the weed control practices

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of the industry such as offsite impacts, herbicide resistance, consumer acceptance of chemicals and operator safety.

Weed control of the future sugar industry will involve integrated weed management strategies, precision agriculture and less reliance on pesticides.

FURTHER READING

Anon. 1989. Weeds in Australian Cane Fields. BSES Bulletin, No 28.

Anon. 1996. Farm Chemicals Record Book. CANEGROWERS publication.



An example of excellent weed control.