The Sugarcane Advisors Information Kit
Acknowledgements

The material covered in the Sugarcane Advisors Information Kit includes information drawn from BSES’s Manual of Canegrowing (2000). This expertise and knowledge is gratefully acknowledged.

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More information

We are committed to providing the Australian sugarcane industry with resources that will help to improve its productivity, profitability and sustainability.

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• Publications including soil guides, technical manuals and field guides
• Research papers
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• Industry alerts
• CaneClips extension videos
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## Advice for new growers

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Importance of the sugar industry

• The Australian sugar industry produces annually around 32 million tonnes of sugarcane (4.5 million tonnes of raw sugar) from approximately 370,000 ha of land.

• This contributes between $2 billion and $2.5 billion dollars to the Australian economy.

• With 80 percent of production exported and sold on the world market, sugar is Australia’s seventh largest agricultural export.

• The industry has more than 6000 cane growers involved in more than 4000 cane farm businesses, 24 sugar mills employing more than 4000 workers, and thousands of small and medium-sized businesses directly servicing cane growers and millers.

• This makes the industry hugely important, both economically and socially, to the communities built around it that spread over more than 2000 kilometres of the Australian coastline – Northern (Wet Tropics, Tablelands, Herbert); Burdekin; Central (Mackay, Proserpine); Southern (Bundaberg, Maryborough, Rocky Point); and Northern NSW (Tweed to Grafton).

Why the industry needs more production

• To improve economies of scale, iron out seasonal production imbalances and more efficiently service market needs, the industry needs to continually increase production. In 2013, the Australian Sugar Industry Alliance (ASA) set a goal of producing at least 36 million tonnes of cane per year.

• This occurs against a background of losses of some existing productive cane land to urban, industrial and other agricultural uses, and a significant decline in the number of Australian cane farm businesses. For example, from 2002 to 2009, the number of cane farm businesses dropped by 40 percent.

• While some of the increased production will come from existing cane farms expanding their crop area and improving productivity, new growers are being continually sought.

• While the ideal is new full-time growers, the crop lends itself well to part-time and lifestyle growers with appropriate land, particularly given that farm operations including land preparation, planting, weed control and harvesting, can be provided by contractors.

The pros and cons of growing sugarcane

The pros

• The industry is well established with a proven production, and a close-knit and reliable structure of growers, millers and industry agencies.

• Provided the proven production system is followed, the crop is generally profitable.

• The crop can be successfully grown on a wide range of soil types.

• High-quality information resources are readily available and each region has a good network of competent service providers and advisors.

• As contract services are available for most farm operations, sugarcane can be a good component of a mixed crop farm for full-time, part-time or lifestyle growers, providing a good source of additional income.

The cons

• Profitability is related to the price of raw sugar and that can be volatile. As 80 percent of the crop is exported, prices are exposed to the volatility of the world market and dependent on production and supply in the large competitive countries such as Brazil. In addition, the export parity price is applied to the domestic market.

• Profitability is also driven by quality of the sugarcane grown. As growers are paid on the basis of Commercial Cane Sugar (CCS), they need to pursue management practices that optimise CCS with the tonnage of cane produced. This requires some experience and precision.
• Profitability is also subject to the rising costs of inputs such as fuel, fertiliser and chemicals. This means that these need to be efficiently managed according to industry Best Practice.

• Some factors that affect productivity, such as drought and flooding, cannot be effectively predicted or managed. Extreme weather may be more frequent under changing climate conditions.

• There is increasing public awareness of environmental issues, particularly water quality and its impact on the Great Barrier Reef. This means that the sugarcane industry is under increasing public scrutiny for its environmental performance. Growers will need to adopt production systems that comply with the Reef Water Quality Protection Plan (Reef Plan) and other recognised environmental performance indicators.

What growers can expect to make

Yields

• Plant crop yields in many districts can be in the range of 100 to 120 tonnes per hectare. Under good management in good seasons, yields of up to 150 tonnes per hectare are possible, but conversely, under poor management and in unfavourable seasons, yields can be as low as 50 tonnes per hectare. Higher yields are more predictable in the Burdekin region as a result of more favourable growing conditions, including plentiful irrigation.

• Ratoon crop yields are less than those achieved for the plant crop but are generally in the range from 80 to 100 tonnes per hectare.

• For the whole of industry, average CCS generally ranges from 13 to 15 percent. The long-term average is 13.5 percent.

Prices

• Although raw sugar prices over the last 10 years have ranged from $230 to $450 per tonne, the five-year average from 2005 to 2009 was $350/tonne (see Graph 1 and 2). To relate this to the price of cane delivered by the grower to the mill, a cane payment formula is used, which varies from mill to mill depending on locally agreed and negotiated arrangements.

In general, the formula is:

\[
\text{Cane price} = \text{Sugar price} \times (\text{CCS} - 4) \times 0.009 + \text{local increment}
\]

• The four-unit reduction in the CCS reflects the contribution to the miller to cover milling and other production costs.

• Based on the formula with a sugar price of $350 per tonne, a CCS of 13.5 percent (before deducting the four points) and a local increment of 0.5, the cane price to the grower would be about $30 per tonne of cane supplied.

Graph 1: The world average raw price of sugar has averaged 18.22 US cents/pound (1980-81 to 2016-17).

Source: ABARES. Price is the average International Sugar Agreement (ISA) price for raw sugar for the marketing year (October to September). Prices deflated using US CPI. Base year = 2017-18.

Graph 2: The indicative average Australian price per tonne of sugar between 1985-86 and 2016-17 is $505.60/tonne.

Source: ABARES. Price is the average International Sugar Agreement (ISA) price for raw sugar for the marketing year (October to September) in equivalent Australian dollars and deflated using AUS CPI. Base year = 2017-18.
### Costs

**Cash costs**

- An ABARES report on the financial performance of sugarcane farms in 2013/14 reported that the total cash costs (excluding finance) for the industry were $2490 per hectare. For the Burdekin, where there are higher costs associated with irrigation, the cost was $3220/ha, while the lowest cost was in NSW at $2040/ha.

- Cash costs include those incurred for such things as land preparation, planting, fertilising, weed control, pest and disease control, and harvesting. These figures do not include finance.

- For ratoon crops, variable costs are about two-thirds of those for the plant crop.

### Returns

- According to the ABARES report, in 2013/14, 27 percent of sugarcane farm businesses had negative farm income that year, and was estimated to increase to 39 percent in 2014-15, although the two subsequent seasons saw improved yields and prices.

  > For 2013/14, the bottom 25 percent of sugarcane farms had a rate of return (excluding capital appreciation) of -9.2 percent. Some of these farms were significantly affected by flooding in previous years.

  > The top 25 percent of business had an average rate of return (excluding capital appreciation) of 4.5 percent.

  > Top performing farms typically operate larger sugarcane enterprises and achieve higher yields. They account for 25 percent of the population, but account for about 47 percent of the total area planted to sugarcane.

  > In contrast, the bottom performing 25 percent account for 6 percent of total sugarcane production.

  > The gross margins in sugarcane (income less variable costs) ranges from about $500 to $1500 per hectare per year, to a range of about $1500 to $2500 per hectare per year in the Burdekin.

  - A good gross margin rule of thumb is about $10 per tonne of cane produced.

  - Note that gross margins may be significantly reduced under unfavourable conditions.

  - Previous studies indicated a return on investment ranging from 5 percent to 8.7 percent, the higher figure relating to the Burdekin.

**Capital for machinery**

- As mentioned earlier, the crop can be grown with minimal on-farm capital, by using contractors for all land preparation, planting, cultivation, fertilising, weed spraying and harvesting.

- Depending on location, some minor capital expenditure may be required for overhead irrigation equipment, which is not normally available from contractors. This may be necessary to supplement rainfall in dry periods in order to maximise productivity.

#### Important tip

**FEAT (Farm Economic Analysis Tool)** is a computer program for evaluating cane farm enterprises. The tool can provide a whole-of-farm economic analysis and/or compare economics of various components of the farming system, including assessing the impact of changed practices on profitability.

### The farm needs

- Sugarcane can be grown in most soils provided they are not saline, sodic or significantly waterlogged.

- Nutritional status is generally not a limitation as most nutrient levels can generally be adjusted appropriately with liming materials and fertilisers. Similarly, inadequate drainage can be improved with surface drainage systems, although at some cost.

- However, the better the nutritional status and the better the drainage, the easier it is to manage productivity.

- Because growth declines significantly at temperatures above 34°C, areas where long-term monthly mean temperatures exceed 34°C should be avoided. This will rarely be a problem in coastal areas of Queensland or NSW but may be a problem in inland areas.

- Because cool nights and early mornings (below 14°C in winter) reduce growth, avoid colder inland areas.

- Frost damage can occur in low-landscape positions of inland areas, particularly in southern Queensland and NSW. While minor frosts can be tolerated, areas with continuous periods of frost risk should be avoided.

- Within the main existing production areas, climate issues can generally be managed adequately through a combination of timely operations and good management practices.
**Water availability**

- While crops in the Wet Tropics coastal areas of the Northern region can have their water needs met totally from rainfall, supplementary irrigation is beneficial in all other regions, and essential in the drier regions such as the Burdekin and the Tableland (Mareeba–Dimbulah) area of the Northern region.

- In regions where crops rely totally on rain for growth, productivity will be dependent on the quantity and distribution of the rainfall.

**Important tip**

While sugarcane is adaptable to many soils and climates, it is best to avoid growing it in marginal areas, as savings in land cost are outweighed by higher production costs and likely productivity losses.

**Management needs**

- If contractors are used, labour needs are minimal. Harvesting on most farms is done by harvesting contractors, who operate independently of growers and millers, and get paid per tonne of cane delivered to the mill.

  In 2013, harvesting costs ranged from $7 to $8 per tonne (without GPS guidance systems) and up to $9 per tonne with GPS. Rates are generally less (from $6.50 to $7.50) in the Burdekin because of higher-yielding crops.

  Contract planting generally costs $360 to $400 per hectare depending on GPS use, and slightly higher in the Burdekin. Contract spraying for weeds generally costs about $30 per hectare.

- Skills are needed in sourcing and using technical information and advisory services to more effectively grow the crop and maintain productivity.

- As the industry operates under strict quarantine measures to minimise the spread of pests and diseases, growers need to be aware of and observe all quarantine restrictions.

**Operating environment**

**R&D**

- Sugar Research Australia (SRA) is a new agency formed in 2013 from the former BSES, Sugar Research and Development Corporation (SRDC) and activities of Sugar Research Limited. It is an industry-owned company funded by a statutory levy paid by growers and millers.

  SRA performs a variety of functions including:

  > Managing and commissioning a portfolio of research, development and extension projects through the Research Funding Unit
  > Providing a conduit for research findings to growers, millers and the sugar advisory community
  > Running a large sugarcane plant breeding and biosecurity program through the SRA Technology group
  > Providing a range of online tools, publications and analytical services.

**Millers**

- In 2017, there were eight millers operating within the industry:

  > Wilmar Sugar Australia
    - Herbert – Macknade and Victoria
    - Burdekin – Invicta, Kalamia, Pioneer and Inkerman
    - Central – Proserpine and Plane Creek
  > MSF Sugar Ltd (Mitr Pohl)
    - Northern – Mulgrave, South Johnstone and Tableland
    - Southern – Maryborough
  > Tully Sugar Limited (Cofco)
    - Northern – Tully
  > Mackay Sugar Limited
    - Central – Farleigh, Racecourse and Marian
    - Northern – Mossman
  > Bundaberg Sugar Limited (Finasucre)
    - Southern – Millaquin and Bingera
  > Isis Central Sugar Mill Company Limited
    - Southern – Isis
  > Sunshine Sugar
    - NSW – Harwood, Condong and Broadwater
  > WH Heck and Sons Pty Ltd
    - Southern – Rocky Point

- The Australian Sugar Milling Council (ASMC) is the peak body for sugar millers. It provides information to members and facilitates forums for collaboration between growers, millers, government and other agencies.

**Grower organisations**

- CANEGROWERS Australia is the peak body for Australian growers. Membership is voluntary. It provides industry leadership, representation to government, and a range of grower services including insurance, financial planning, cane testing, grower conferences and information services. It publishes the *Australian Canegrower* magazine.
• Australian Cane Farmers Association (ACFA) is a voluntary membership organisation providing services to members, including farm and crop insurance, financial planning, conferences and information.

Cane productivity services

• Local industry-owned productivity services organisations provide a range of services at the local level, including planting material, inspections, research and grower advice. Agencies exist in all regions.

Environmental matters

• The Australian sugar industry stretches along the eastern coast of Queensland and northern New South Wales, adjacent to the Great Barrier Reef (GBR). Parts of the GBR are under pressure from climate change, land-based run-off, coastal land use change and some aspects of the direct use of the reef.

• Movement of nutrients and pesticides, from agricultural lands have been linked to a reduction in the resilience of the Great Barrier Reef. While a reduction of coral cover on the GBR has been largely attributed to storms and cyclones, crown-of-thorns starfish and coral bleaching, improvements to water quality will increase the Great Barrier Reef’s resilience to these threats. Elevated nutrient and sediment loads have also been linked to outbreaks of unusually high numbers of crown-of-thorns starfish, due to an abundance of food available at the larval stage.

• In 2009 the Queensland Government introduced the Great Barrier Reef Amendment Act, which mandated nutrient applications based on the SIX EASY STEPS nutrient management program, record keeping and also targeted a number of agricultural chemicals (PSII herbicides – diuron, atrazine, ametryn and hexazinone).

• In 2013 the Queensland Government and sugarcane industry agreed to introduce self-regulation through a voluntary best management practice program known as Smartcane BMP. As of 2015, the reef regulations were reinvigorated, to include a combination of regulation and Smartcane BMP with revisions being undertaken and due for completion in 2017/2018.

• There is a need to stress that practices recommended are not only about environmental protection. Good nutrient and pesticide management will maximise productivity and profitability, minimise off-site nutrient and pesticide losses, and minimise impacts on water quality.

• Input use efficiency, whether it be nutrient or chemical, and environmental stewardship are entirely compatible.

• See Nutrition section for an overview of the SIX EASY STEPS nutrient management program and reducing off-site impacts.

• See Chemical sections for reducing off-site impacts.

References


Publications for further information

Reef 2050 Long-Term Sustainability Plan
Reef Plan 2018 and 2020
Smartcane booklets
A Review of Nitrogen Use Efficiency in Sugarcane
### Understanding the sugarcane plant

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Understanding the sugarcane plant

Understanding the science

The sugarcane plant

Stalk (stem)

- Sugarcane is commonly propagated vegetatively by stem (stalk) cuttings containing one or more buds. On germination, the bud produces a primary stalk. Each stalk (or sett) is composed of nodes, with a bud, one or more rows of root buds (root primordia) and a growth ring (intercalary meristem), separated by intermodal storage tissue.

- Internodes are the sugar-storage organs of the plant and vary in length from less than 10 mm to over 300 mm according to age and growing conditions. Sugarcane stalks normally reach up to 3 m in height in the normal growing season.

Above: Sugarcane is a grass in which the stalks are composed of internodes. When planted, new plants can grow from the bud on each internode.

Leaf

- Leaves are attached to the nodes and form two alternate ranks on either side of the stalk. They consist of two parts, a blade and a sheath, separated by a blade joint. Leaf size and number increase from germination and about 10 leaves per stalk remain at maturity.

- Canopy structure varies with variety, but the two youngest leaves are usually vertical, with the older leaves becoming progressively more horizontal.

Above: Schematic of a section through a leaf.
The importance of stalk growth in sugar production

- The final yield of sugar is a function of stalk growth to provide a large storage volume, and ripening to fill this volume with sugar. Five phases occur in the growth of sugarcane:
  1. Germination – plant established and tillers initiated.
  2. Early growth – leaf canopy established and maximum growth or elongation of the stalk.
  3. Maturation – stalk elongation slows down and sugar storage or ripening dominates.
  4. Flowering – vegetative growth ceases and arrow produced.
  5. Ratooning – stalks harvested and crop regrowth occurs from underground buds on the severed stalks.

- Note that some of these phases overlap considerably and basal internodes of the stalk can fill with sugar while the top of the stalk is still actively growing. Sugar is a stored fuel for the cane plant, so that both storage and mobilisation of sucrose occur continually as the plant responds to periods of active growth and growth constraint.

1. Germination and stool establishment

- The key factor in germination is temperature. In general, germination will be very slow when soil temperatures drop below about 18°C and will be increasingly faster as temperatures approach 35°C. Germination rarely occurs at temperatures below about 11°C and, even between 11°C and 18°C, the rate may be too slow to avoid the death of setts from attack by soil pathogens.
During the initial stages of germination, the root primordia around the nodes produce a flush of sett roots. These roots are transitory in terms of plant growth. They are not directly connected to the primary shoot, but they are important in maintaining the moisture level in the sett while the shoot elongates through the soil into the sunlight. Although the sett contains the food and water required for germination of the primary shoot, the levels are totally inadequate to support ongoing shoot and root growth. The emerging shoot must quickly become independent of the sett by producing leaves that can photosynthesise and produce the sugars needed to support its growth and development.

Once through the soil and in the light, the shoot grows rapidly, produces leaves and develops a series of short internodes under the ground as the stalk begins to elongate. Each node carries a new bud and new root primordia which are the basis for stool establishment and growth. The root primordia germinate and produce the shoot roots that will support the plant for the rest of the plant crop cycle.

These roots are an integral part of the vascular plumbing of the new plant and will harvest water and nutrients from the soil solution to support growth. The shoot is now independent of the original sett. At the same time, the new buds below ground produce the first flush of tillers or secondary shoots and the new stool is well on the way to being established.

2. Early growth

Rapid and sustained early growth of the stool is important for laying down the maximum volume of stalk for subsequent sugar storage and ripening. During this phase, the plant initiates a number of tillers, and the leaf canopy expands to capture the available light. Production of each new tiller requires a diversion of photosynthate from the primary stalk and older tillers. Growth of existing stalks slows or ceases for a short period until the new surge of tillers has produced leaves and is able to exist on its own photosynthate. Many of the younger tillers are subsequently lost when the canopy closes in and robs them of light. The cane plant increases the size of the remaining stalks to compensate. In a well-grown crop, yield loss does not occur through loss of these tillers.

Stalk elongation during this phase is very sensitive to both temperature and soil moisture. Under field conditions, too much water after heavy rain or irrigation will slow or stop elongation due to waterlogging in the root zone. After soil drainage has occurred, the elongation rates will recover but then progressively decline until the next rainfall or irrigation. Temperature provides an over-riding effect in that good growth at suitable temperatures is dependent upon adequate soil moisture. As the average temperature declines, growth also declines, even after significant rainfall.

At the end of this phase of growth, the crop is almost fully grown in terms of cane yield but the CCS or sugar level of the crop is still relatively low, usually around 5 to 7 units.

3. Maturation and ripening

Ripening is a continuous and reversible process. During stalk growth, each internode tends to function as a single unit. While it has a leaf attached, the internode completes cell elongation and cell-wall thickening and tends to complete filling its storage volume with sugars. Hence, the internodes have generally completed their cycle by the time that the attached leaf dies, and the lower internodes are essentially ripe while the upper part of the stalk is still growing.

However, the stored sugar is still available for relocation to support tillering and/or support growth when conditions are not favourable for photosynthesis. With stalk maturation, more and more internodes reach the same condition and a progressive increase in crop CCS is observed. The laying down of fibre and sugars displaces some water from the internode volume, so that the observed moisture content in the crop begins to drop.

Generally, the ripening phase corresponds to the cooler and drier time of year. Stalk elongation is more sensitive to these conditions than is photosynthesis, so stalk elongation slows strongly, but photosynthesis continues until conditions become too cool and/or too dry for it. During this interim period, the most recently expanded internodes near the top of the stalk stop elongating, and photosynthate previously used for growth is channelled into sugar storage. The net result is an overall increase in the sugar levels in the upper portion of the stalk.

Above: Production rates of sugar and fibre during the year. It shows similar production rates until the onset of winter conditions when sugar production is greater and the upsurge in fibre production during spring.

4. Flowering

Flowering is important in the production of new varieties. The occurrence of flowering is influenced by variety and field conditions. When day length, temperature and stage of plant growth are favourable, the stalk undergoes a physiological change and initiates flowering. Flower initiation causes the apical meristem of the stalk to switch from vegetative growth to flower production.
This switchover causes stalk elongation to cease and can lead to some incremental ripening, since, for a short period after the needs of producing the flowers have been met, there is an increase in available photosynthate for channelling into sugar storage. However, the advantage is usually transitory and, since stalk growth has ceased, the potential for maintaining a continued increase in sugar yield is limited.

5. Ratooning

- When the crop is harvested (normally 12 to 18 months after planting), the next or first ratoon crop is produced from the buds remaining on the underground portions of the stalk. Germination of the buds is inhibited prior to harvest by a hormone continually produced by the apical meristem in each stalk. Harvest of the above-ground stalks removes the source of the hormone and allows the buds to germinate when soil temperature and moisture conditions are favourable.

- Ratooning is very similar to germination, but each stalk in the stool produces a ratoon stalk at the same time. Hence, the ratoon crop grows faster than the plant crop and the leaf canopy covers in much earlier. Ratoon crops tend to produce more stalks per hectare than plant crops, but the stalks are usually not as thick.

- Sugarcane can be repeatedly ratooned for many years and up to 20 ratoons have been grown commercially. However, any stool damage incurred during cultivation and harvesting operations, or caused by pests and diseases, is cumulative and causes successive ratoon-crop yields to decline until they reach a point at which further ratoons are no longer economic. With today’s production methods, it is rare to grow more than four ratoons before ploughing out the crop and replanting.

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**Important tip**

For more information on the physiology of sugarcane, refer to the recently published seminal reference on the subject by Dr Frikkie Botha: *Physiology, Biochemistry and Functional Biology of Sugarcane.*

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**Yield potential**

- It is useful to understand the concept of maximum yield potential and compare this with current commercial yields.

- Maximum yield potential can be calculated based on the efficiency of photosynthesis in converting light to biomass and the daily light and temperatures received at a given location. The calculations assume that water and nutrients are fully supplied and that weeds, pests and diseases are properly managed. The calculations also make basic assumptions about crop geometry and row spacing, commonly working with current plant spacings within and between rows.

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* Table 1 shows the modelled maximum cane yields for four locations, based on available meteorological records of light radiation and temperature, a spring (1 August) planting date, a 1.5 m row spacing and a 14-month crop production period.

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</tr>
<tr>
<td>Harwood</td>
<td>29° 26’</td>
<td>164</td>
</tr>
</tbody>
</table>

* The modelled maximum yield calculated using average daily climatic data at each site from 1957 to 1997.

** Average commercial plant crop production from 1993 to 1998 (mill records).

- Comparison of the modelled maximum and actual average commercial yields shows a 30 to 100 tonne/ha difference, which suggests that there is still appreciable scope to improve field production through breeding and better crop management.
### Climate

- **Advice for new growers**
  - Understanding the sugarcane plant

- **Drainage**
  - Planting and crop establishment
  - Variety selection
  - Nutrition
  - Diseases and disease control

- **Pest control**
  - Weed control
  - Chemical use and application
  - Harvesting and transport
  - Milling issues for the grower
Understanding the science

The four key elements of climate for sugarcane

• Rainfall
• Radiation

1. Rainfall

• The Australian sugar industry is located in five discontinuous regions, separated by areas of unreliable rainfall or unsuitable soils, along the eastern coast, between latitudes 16.49°S and 29.48°S. Climate across these zones ranges from wet tropical through to dry tropical to humid sub-tropical.

• Rainfall data (from the RAINMAN database) has been analysed for 35 sites within the five regions. For 20 of these sites, annual rainfall ranges between 1000 and 1700 mm; for 12 sites in the Wet Tropics, annual rainfall averages between 1700 and 4200 mm, while for Mareeba and Grafton, annual rainfall averages less than 1000 mm (911 and 980 mm, respectively).

• Annual rainfall is only a broad guide to adequacy of moisture for growing sugarcane. Effective rainfall, calculated from a daily water balance, provides a more useful index of rainfall available for crop growth. Effective rainfall allows for loss of water from the root zone as run-off or deep drainage of excess water, and can be calculated by computer packages such as SoilWat within APSIM-Sugar.

• Effective rainfall in sugar districts is less variable than total rainfall, and may range from 21 to 75 percent of annual rainfall under irrigated conditions and 28 to 87 percent of annual rainfall under rainfed conditions.

• Irrigation reduces the effectiveness of rainfall because irrigation before rainfall allows less storage of rainfall in the soil profile.

• The rainfall distribution is predominantly in the summer growing season, when more than 60 percent of annual rainfall is recorded in the period November to April. This proportion declines from more than 80 percent in the tropics, where there is a greater influence from cyclonic rainfall, to 60 to 70 percent in southern districts, where summer rainfall is more reliant on storm rain associated with the eastward passage of surface and upper-atmosphere troughs.

• Irrigation is essential for production of sugarcane in the Mareeba and Burdekin areas because of low total annual rainfall. Variability of the summer and winter distributions in the Mackay-Proserpine and Bundaberg-Maryborough regions indicates a need for significant supplementary irrigation for economic production.

• In southern districts, the higher proportion of rainfall in the ripening/harvesting months of May to October (30 to 40 percent of annual rainfall compared to less than 20 percent in most tropical districts) creates particular management problems with drainage and wet weather harvesting. This is particularly so in areas such as Rocky Point and Northern NSW, where the winter distribution is also associated with higher annual rainfall than other parts of the southern region. Similar problems are created by the 25 percent of the 3000 to 4200 mm annual rainfall that falls in the Tully-Babinda area between April and October.

Important tip

The SoilWater module is a cascading water balance model. Visit SoilWat at www.apsim.info/Documentation/Model,CropandSoil/SoilModulesDocumentation/SoilWat.aspx

Left: An example of a histogram for annual rainfall (by months).
2. Radiation

- Solar radiation is the energy source for photosynthesis and evaporative loss of water from soil and leaf surfaces.

- Radiation is measured with a pyranometer or solarimeter in MJ/m²/day (megajoules/metre squared). A reading of 28 to 30 MJ/m²/day is typical of a clear sunny summer day in the tropics, with monthly averages in the range 22 to 25 MJ/m²/day. The corresponding monthly value for winter in coastal Queensland is 10 to 15 MJ/m²/day. Sugarcane accumulates dry matter at the rate of 1.7 g/MJ/m² of intercepted radiation for the rapid growth phase of plant cane, and 1.59 g/MJ/m² for ratoon cane.

- As radiation cannot be effectively managed or conserved for crop production, management of the crop is directed at optimising interception of radiation by the leaves, and minimising the fraction falling on bare earth. Relevant practices in this regard include:
  
  > Choice of planting time. Autumn-planted cane has closed its canopy by mid-late spring and, therefore, intercepts maximum solar radiation in summer. Conversely, spring-planted cane may only achieve canopy closure well into summer.

  > Row spacing. Cane planted at the 1.5 m row spacing intercepts only 60 percent of available solar radiation, whereas cane planted at closer row spacings (for example, dual rows at 1.8 m centres) achieves earlier effective canopy closure and maximum interception of available radiation. This can help contribute to potential yield increases.

  > Irrigation. As water-stressed plants are slower growing and less effective in intercepting radiation, irrigation management is important in maximising leaf growth and effective leaf area.

  > Nutrition. Similarly, adequate nutrition is important in maximising leaf growth and effective leaf area.

  > Pest and disease control. Also similarly, the crop requires protection from pests and diseases that may limit leaf growth and reduce the effective leaf area.

3. Temperature

- While radiation provides the energy for photosynthesis, temperature affects the rate of photosynthesis and other biochemical processes governing growth and development.

- In sugarcane, photosynthetic efficiency increases in a linear manner with temperature in the range from 8°C to 34°C. At the upper end, the rate of photosynthesis declines rapidly above 34°C. This is significant in that daily maximum temperatures can exceed 34°C for several days at a time in some northern districts, although long-term monthly means do not exceed 33°C in coastal Queensland. At the lower end, cool nights and early mornings (14°C in winter and 20°C in summer) will significantly inhibit photosynthesis the next day. Based on minimum temperature data for sugar-growing areas, this means that photosynthesis is reduced to some extent for up to 9 months at Harwood in NSW, up to 6 months at Mackay and Bundaberg, and up to 3 to 4 months at Ayr, compared to no reduction at Meringa near Cairns.

- Regarding the effect of temperature on shoot emergence (bud development), studies have indicated a base temperature (the temperature below which there is no activity) of 11.5°C and 11.8°C respectively for the varieties Q138 and Q141. Thermal time to emergence of 14 varieties ranged between 127.5 and 233.7 day degrees – representing a period of 9 to 16 days or 19 to 29 days for autumn and spring planting, respectively, at Bundaberg.

- Regarding the effect of temperature on leaf and stalk growth, base temperatures of 15°C (leaf) and 14°C (stalk) are generally recognised for Australian conditions, although there is a significant varietal variation. Data suggests that for varieties Q138 and Q141 at Cairns, a new leaf would be expected every 5 days in February and 11 to 21 days in June–August. By comparison, at Harwood in NSW, a new leaf would be expected every 8 to 10 days in February and no new leaves would emerge in June–August. For stalk growth, it is generally accepted that the peak growth phase is terminated by the onset of mean day temperatures less than 21°C. This is significant in that brief periods of minimum temperatures less than 21°C are common in southern regions of the east coast during February and March.

- Regarding the effect of temperature on CCS, it is well recognised that when leaf growth is constrained at temperatures less than 14 to 19°C, the available photosynthesis is partitioned to sugar accumulation rather than vegetative growth. This explains the role of lower temperature in ripening of sugarcane. Although a large range in diurnal temperatures is also known to favour sugar accumulation, research over 10 years in 10 districts did not find a significant link between the two. However, it did show a significant association between CCS and mean annual day degrees greater than 14°C. The research implied that CCS will generally be higher in tropical regions than in subtropical regions, and that CCS is enhanced by a wider range in diurnal temperatures for any given accumulation of thermal time. For example, Innisfail, Ingham and the Burdekin have similar annual thermal regimes, but CCS is ranked Burdekin > Ingham > Innisfail because of the ranking in diurnal temperature range (11.8 >10.8 >8.9°C).

**Important tip**

Day degrees are calculated by deducting the base temperature (the temperature below which there is no growth activity) from the mean daily temperature to provide an effective temperature for the day. Effective day degrees are accumulated until the relevant growth process is completed.
• **Cold chlorosis.** Low temperatures can induce a chlorotic banding pattern on leaves. This results from damage to the chlorophyll by low, but non-freezing temperatures while leaves are still elongating in the leaf roll.

• **Frost.** Frost damage is usually confined to low-lying parts of the landscape in inland areas of the Bundaberg, Isis, Maryborough, Broadwater and Harwood districts. While slight leaf damage to young autumn plant cane is relatively common, significant frost damage to millable cane occurs in some years in the Burnett Valley near Wallaville and in the inland sections of NSW. There are two types of frost:

  > Radiation frosts occur on clear, cold nights with little wind, when outgoing radiation is excessive and air temperature generally increases with height in a micro-layer near the ground.
  > Wind or advection frosts occur when wind or topography bring in cold air.

The two types of frost can occur together, with an advection frost reinforcing the effects of a radiation frost. While frost damage to the growing point begins at -2.0°C, an air temperature of at least -3.5°C is required at 1 m height outside the crop for frost damage to occur. A well-grown canopy helps to retain heat in the crop and prevent cold air from descending onto the growing point. Thus, the following management issues are important in minimising the impact of frost:

  > Appropriate nitrogen fertiliser rates to ensure good growth.
  > Avoidance of waterlogging or moisture stress.
  > Presence of a trash blanket under partially canopied cane dramatically increases susceptibility to frost damage by reducing the capacity of soil to radiate heat into the cold night air.

A light frost causes leaf scorch. A more severe frost kills the green leaf and the growing point. Frozen internodes begin to deteriorate after the thaw, causing a drop in juice pH and an increase in alcohols and dextran in juice. It is important to exclude frost-damaged material from the cane supply by lowering the topping height. Side shoots will develop from the uppermost one or two buds not killed by the frost. Severity of the frost is assessed from the number of frozen internodes. A four-stage classification is used:

1. Class I frost kills all green leaf, the growing point and all buds on the stalk; a sour rot is developing; basal stalks should be harvested immediately.

2. Class II frost kills the green leaves, the growing point and the top 3 to 10 eyes on the stalk; stalks should be topped at the side shoots.

3. Class III frost kills up to three green leaves, the growing point and buds 1 to 3 on the stalk.

4. Class IV frost causes some leaf damage, but stalks will resume normal growth. Deterioration will usually be significant within 2 to 3 weeks after the frost. Highest priority for harvest is allocated to the most severely frosted cane.

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Above: Frost damaged cane.

• **Hail damage.** Hail shreds the leaf blade and in severe cases may break some immature upper stalks. Leaf growth will resume as long as the growing point is not damaged.

• **Lightning damage.** Lightning damage is effectively a localised high temperature stress. Damage in young cane is usually restricted to small areas (30 to 60 m) in diameter, with the effect grading from severe in the centre to little or no effect on the margin. Leaves are scorched. Lightning strike can ignite trash blankets if there is little rain associated with the storm.

4. **Wind**

• While there may be slight effects of wind on transpiration and carbon dioxide uptake, the main impact of wind is mechanical (physical) damage to leaves and stems, which may inhibit photosynthesis and translocation of photosynthetic products.

  The main types of physical damage are:

  > Leaf shredding – usually associated with high winds during cyclones.

  > Wind burn (leaf desiccation) – a rapid desiccation of the spindle leaf caused by hot, dry winds during periods of rapid growth in summer. Only a few varieties are susceptible.

  > Stalk breakage – may occur in immature sections of the stalk, while brittle varieties may break at ground level.

  > Lodging – when a canopy of well-grown cane is loaded with rainfall and the stalks are blown down by wind. A response to light usually results in immature sections of most stalks re-erecting an incomplete canopy within 7 to 10 days of lodging. Lodging usually occurs in late summer or autumn in crops of more than 80 t/ha.
Varieties with higher resistance to lodging may accumulate 120 t/ha in stalk yield before lodging. Lodging can limit further accumulation of biomass and may cause loss of CCS. Some stalks may die where crops lodge heavily in one direction, rather than sprawling, which allows more general access of individual tops to radiation.

> **Stool tipping** – occurs in similar circumstances to lodging, but rigidity of stalks and limited root mass cause the whole stool and root mass to tip from the ground. Stool tipping results in reduced accumulation of biomass, increased soil and extraneous matter in mechanically harvested cane, and gaps in the subsequent ratoon crop.

### Managing for climate

There are two important considerations for growers in managing for climate:

1. Managing the timeliness of planting and harvesting operations to optimise the beneficial effects of climate and minimise the adverse impacts.
2. Making better use of climate and weather forecasting tools.

#### 1. Timeliness of planting and harvesting

- Traditional planting and harvest seasons have developed in response to the long-term appreciation of weather patterns.

- For instance, planting in the tropics usually commences in late autumn to early winter, when soils are dry enough for seedbed preparation after the wet season. **Late spring planting in the tropics is undesirable because the stool and canopy are not sufficiently established before the wet season.**

  Conversely, in the Bundaberg to Maryborough region, the climate provides a fairly even split between autumn and spring planting. In NSW, a late finish to the wet season and cold winters restrict planting to spring.

- Within each planting period, there is the opportunity for good management to improve the result. For example, investment in field drainage, fallow management, attention to quality of planting material, and recognition of the benefits of earliest planting opportunities are usually reflected in well-established plant cane. On the other hand, cane planted before, or towards the end, of the optimal period has a greater risk of germination failure from waterlogging, the onset of cold weather or attack by wireworms or fungal diseases.

- The harvest season for sugarcane has developed around suitable weather conditions to promote maturation of the crop and also to allow access to the fields. Impacts of wet weather on the cane harvest can be minimised by improved in-field and whole-farm drainage design, and the use of wider interspaces to match the track width of infield equipment combined with mound planting of dual rows.

#### 2. Climate and weather forecasting

- Weather conditions influence the timeliness and efficiency of many operations on the farm, including land preparation, planting, cultivation, weed control, irrigation and harvesting. Risk associated with such operations could be reduced with access to more reliable weather forecasts.

- In the past, the effective use of the available short-term weather forecasts was limited by the lack of probability information. However for some climatic variables, such as rainfall, this has now been addressed with seasonal forecasts for more than three months in advance based on status and trends in the Southern Oscillation Index (SOI). This enables growers with limited supplies of irrigation water to think more strategically about opportunities for the more effective and strategic use of such resources.

### Important tip

For more information on the physiology of sugarcane, refer to the recently published seminal reference on the subject by Dr Frikkie Botha: **Physiology, Biochemistry and Functional Biology of Sugarcane.**
Soil health
Soil health

Understanding the science

A healthy soil is one that can sustain long-term productivity by maintaining a desirable balance of chemical, physical and biological properties. There are 10 key physical, chemical and biological soil health features:

Physical features of healthy soils

1. Getting water into the soil with minimal run-off and erosion
   - At least 30 percent ground cover is recommended to reduce erosion to manageable levels. This cover reduces the impact of raindrops that cause surface sealing and allows more infiltration with less run-off and erosion. One caution is that heavy soil compaction will override the effect of even heavy cover levels and limit the amount of infiltration.

2. Storing plant available water in the soil
   - Plant Available Water Capacity (PAWC) is the maximum amount of water a soil can hold that is available for plants to use. PAWC is affected by:
     - Soil depth – deeper soils generally have a higher PAWC
     - Soil texture – PAWC generally increases with clay content
     - Soil structure – well-structured soils that maintain their porosity allow roots to better exploit the available water
     - Soil organic matter content – improves soil structure
     - Salinity – salts decrease PAWC by osmotic effects and toxicities that reduce root growth.

3. Maintaining a friable structure for root growth and water extraction
   - Healthy structure allows water and air to move through the surface, and permeate into the profile to support healthy roots that can absorb water and forage for nutrients. Air-filled porosity must be about 10 percent for healthy roots.

   - Good structure also provides ease for plant establishment, workability of the soil and resistance of soil to erosion.

   - Poorly structured surface soils may seal over after rain (surface crusting) and set hard when dry (hard setting). This reduces infiltration, leads to ponding of water, greater erosion, fewer opportunities for efficient and non-destructive cultivation, and problems with crop establishment.

   - Adding organic matter through pasture rotations or green manure crops is the best way to improve surface structure. Gypsum may improve soil structure on dispersing ‘sodic’ soils.

   - Subsoil structure is also important as poor subsoil structure restricts roots and reduces infiltration. Compaction from heavy machinery is a major cause of poor subsoil structure.

Above: Dual row controlled traffic farming system.

4. Remaining aerobic through wet periods
   - Waterlogging occurs when 90 percent of the total soil pore space fills with water. The plant roots are then starved of oxygen.

   - Waterlogging also affects microbial activity. For example, under anaerobic conditions, nitrate – the most available form of nitrogen – is broken down (denitrified) by microbes to obtain oxygen. This valuable nitrogen is then lost from the soil as gas and soil fertility declines.
Chemical features of healthy soils

5. Supplying nutrients in the right proportions for plant growth
• See the Nutrition section.

6. Maintaining pH that support plant growth and soil organisms
• See the Nutrition section.

7. Avoiding toxic levels of nutrients, trace metals and pesticide residues
• See the Nutrition and Pest control sections.

Biological features of healthy soils

8. Maintaining organic matter
• Organic matter includes litter, living plants, animals and microbes, and their degrading material as they decompose. About 85 percent of organic matter is made up of dead plant material, 10 percent is live plant roots and around 5 percent is soil biota.
• Organic matter provides food for soil microbes, is a store for relatively available nutrients for plants, and bonds soil particles for good structure.

9. Maintaining biological capacity for physical and chemical fertility
• Physical fertility and structure is maintained by larger soil organisms, such as earthworms and arthropods, that improve soil porosity by burrowing and transporting soil organic material deeper into the soil profile, as well as bacteria and fungi that produce organic polymers and bind soil particles into aggregates.
• Chemical fertility is maintained through the mineralisation of nutrients by the microorganisms and the subsequent release of the nutrients within the microbial biomass by the soil fauna.

10. Maintaining freedom from damaging populations of pathogens, weeds and other pests
• See the Diseases and disease control section, Pest control section and Weed control section.

Publications available on the SRA website

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<thead>
<tr>
<th>Publication</th>
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<tbody>
<tr>
<td>SmartCane Fallow and Land Management</td>
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<tr>
<td>SmartCane Principles of Best Management Practice</td>
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Particular soil health problems in sugarcane

In an era of rapid technological change and ever-increasing economic pressures, it is easy to overlook the importance of soil health. The issue is exacerbated by three particular factors of the sugarcane production system:

1. Sugarcane is grown as a long-term monoculture
• This means that any block of land is typically under cane for about five years (one plant and four ratoon crops), usually followed by either a six-month fallow or by another cane crop (plough out replant). Hence, land is under cane for at least 90 percent of the time.
• The key direct impacts from monoculture include:
  > Increased incidence of diseases such as Pachymetra, Pythium root rot and nematodes. The lack of an appropriate fallow period means there is no opportunity to break the reproductive cycle of disease pathogens.
  > Increased incidence of pests such as ground pearls. As above, the lack of an appropriate fallow period means there is no opportunity to break the reproductive cycle of soil pests.
  > Lack of effective cycling of biota and nutrients into the deeper soil layers. As sugarcane has a fibrous root system, with roots largely confined to the surface soil, monoculture concentrates biotic activity in the surface soil.
• The key indirect impacts from monoculture include:
  > Increasing soil acidification from the application of high rates of nitrogen as inorganic fertiliser because of the lack of a legume crop to fix organic nitrogen.
  > Declining soil organic matter levels from the lack of return of fallow organic material. In recent years, this has been offset somewhat by the extra organic matter returned from green cane harvesting and trash blanket retention, which provide definite improvements in soil health as indicated by increased earthworm activity and improved soil structure resulting in better water infiltration.

2. The sugarcane farming system is highly dependent on heavy machinery for harvesting and transport from the paddock
• Under the current harvesting system, each inter-row is run over at least twice by the harvester and at least once, but usually more often, by a haul-out vehicle.
• This can have two important consequences:
  > Soil compaction, particularly when the soil is wet. This reduces porosity and permeability resulting in waterlogging, run-off, and erosion; restricts root growth leading to nutrient and water stress; and produces a less favourable environment for soil biota.
> Damage to stools from cane rows being run over by indiscriminate driving of both harvester and haul-out equipment. This results in gaps in the subsequent ratoon crop and subsequent yield loss, as cane yield is very closely related to the number of stalks. Stool damage is often exacerbated by the fact that row spacings do not always match machinery wheel spacings – for example, cane is most often grown in 1.5 m rows but harvesting and haul-out equipment is generally based on 1.8 m wheel spacings.

Above: Cane harvesting.

3. Conventional sugarcane production uses extensive tillage during land preparation for the plant crop

- This involves deep tillage to break down the compacted layer developed during previous harvesting operations, incorporation (or burning) of the remains of the trash accumulated over a number of ratoons to facilitate land preparation, and repeated cultivations with equipment such as the rotary hoe.
- The direct impacts are:
  > Soil structure is significantly damaged.
  > The more tillage, the faster the breakdown of organic matter in the soil and the greater the disturbance to beneficial organisms such as earthworms, which maintain soil structure, and mycorrhizae, which benefit plant growth through aiding in nutrient uptake.
  > Without a trash blanket, the plant crop is more prone to soil erosion during heavy rainfall.

Above: Beneficial mycorrhizal networks preserved through zero or minimum tillage.

Improving soil health

1. Breaking the monoculture

- Options for breaking the monoculture include:
  > Bare fallow
  > Legume fallow grown for organic matter and Nitrogen returns (lablab, cowpeas or soybeans)
  > Legume fallow grown for annual grain cash crops (peanuts, mung or soybeans)
  > Pastures (grass or grass/legume).
- The above breaks can be applied between the plough out of the last ratoon and planting the next crop. In the case of the fallow and cash crop options, it is normally for about six months (plough out in November; replant May/June). The pasture option is obviously of a longer duration. It means a break is possible on average one year in every six (following a plant and four ratoon crops).
- Research shows that yield increases by up to 84 percent following a break, compared to plough out replant. This productivity increase appears to be associated with improvements in the biological (and in some cases, physical) conditions of the soil.
- The best break is the pasture break, which incorporates no tillage and the return of large amounts of organic matter (about 20 t/ha/year dry matter). This improves soil porosity, allowing better infiltration of water, and encourages a more diverse soil biota, suppressing pathogenic soil organisms for the subsequent cane crop.
- Limited or no improvement in soil physical properties occurs under the bare fallow or annual crop break options. This is because the bare fallow has no organic matter inputs and the annual crops require regular tillage.
- The benefits of fallowing will only be realised if the fallow is managed appropriately. This means, for the bare fallow, preventing the sugarcane from becoming a fallow weed, which negates the potential benefit of breaking the disease cycle. For the legume fallow, it means growing the fallow crop properly – using a planter to establish it; growing it on raised hills to avoid waterlogging; and controlling early weed competition. This enables more dry matter and more nitrogen to be produced.
- Soybean is generally the best choice of legume fallow as it produces more dry matter, fixes more nitrogen, and withstands wet soil conditions considerably better. Note that if soybean is grown as a grain crop, much of the nitrogen benefit is removed in the grain, with the remaining stubble returning between just 80 to 100 kg/ha of nitrogen to the soil.
2. Reducing compaction and tillage through strategic tillage and controlled traffic

- Strategic tillage is based on the premise that tillage should be carried out only when absolutely necessary. Controlled traffic is based on the premise that it is best to separate crop growth zones and traffic zones in a permanent arrangement. Together they provide a powerful tool to improve chemical, physical and biological properties in the crop growth zone by minimising the adverse effects of compaction and the degradation of organic matter that occurs with regular tillage.

- In a controlled traffic system, all traffic passes down permanent traffic lanes that are compacted while the rows are not trafficked. Removal of the old ratoon and land preparation for planting is carried out with herbicides or by cultivating only a narrow strip of row and then cultivating this area as little as possible.

- Research has indicated that substantial cost savings can be achieved by not cultivating the whole paddock and not attempting to remove the compacted interspace. More importantly, these changes can occur without loss in yield and without any obvious adverse effects on crop growth. Soil structure in the rows improves and there are indications of an improved soil biota, particularly increases in numbers of earthworms.

However, a strategic-tillage, controlled-traffic system will achieve little if equipment wheel spacing and row spacing are not matched and if plant operators do not confine their machinery to the traffic lanes.

### Table 1: Calculation of N contribution from a legume crop (Bell M. et al. 2007 – SYDJV).

<table>
<thead>
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<th>Legume crop</th>
<th>Fallow crop dry mass (t/ha)</th>
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<td>2</td>
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<td>60</td>
<td>30</td>
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</tbody>
</table>

Above: Preparing to plant cane after soybeans, bed renovator.
3. Increasing organic matter

- Organic matter is the basis of soil health and a critical factor in aiding the repair of soil physical properties damaged by soil compaction. It is also vital in maintaining the biological diversity that suppresses pests and diseases of sugarcane.

- The more organic matter is degraded, the less resilient are the biological, chemical and physical parameters of the soil and the more reliant growers are on more aggressive tillage and artificial amendments such as fertilisers and chemicals.

- While the industry has made a major move in the right direction with the widespread adoption of Green Cane Trash Blanketing (GCTB), there is evidence that intensive land preparation practices between crop cycles largely destroy much of the organic matter increase obtained during the previous crop cycle.

- Organic carbon, the main component of organic matter, is made up of a number of fractions, from a labile or available fraction to an inert or unavailable fraction such as charcoal. The burnt cane system increases the charcoal fraction at the expense of the labile fraction. Conversely, a pasture break between crops increases the labile fraction. Research has shown that in addition to measured increases in labile carbon, a pasture break increases the population and diversity of soil biota, cation exchange capacity, and aggregate stability, as well as suppressing root pathogens such as Pachymetra.

- There is now established evidence of the important relationship between tillage, organic matter and the prevalence of various insect pests such as greyback canegrub, the most important pest of sugarcane in Australia. This evidence clearly shows the adverse impact of intensive cultivation on soil organisms pathogenic to the grub (Adelina and Nosema protozoans, Metarhizium fungus, Bacillus bacteria and entomopox viruses).

Research has shown that damage by greyback canegrub can be substantially reduced, and yields substantially increased (by 20 to 30 t/ha), by using a GCTB with minimum tillage, compared with burnt and cultivated ratoons. It has been shown that grubs grow more slowly under a trash blanket and are more susceptible to the pathogenic organisms in the soil.

- Earthworms are a good indicator of soil health and depend on organic matter for their survival and activity. They play a major role in distributing organic matter throughout the soil profile, leading to increases in aggregate strength and structural stability, water-holding capacity, and microbial activity of the soil.

Earthworm burrows and casts increase the porosity of the soil, allowing better drainage and infiltration, while the casts contain high levels of plant-available nitrogen and other nutrients. Further, high populations of earthworms provide a food source for insect predators such as ground beetles and centipedes.

Research has shown that there are considerably higher populations of earthworms under GCTB systems than under burnt systems, and where pesticides are not applied. In addition, numbers of earthworms increase substantially under legume fallows.

- There is current interest in the use of pasture legumes such as pintopeanut (*Arachis pintoi*) as a permanent understory in a sugarcane farming system, providing the legume does not effectively compete with sugarcane for nutrients and water.

Pinto is a low-growing non-twinning legume that grows very well under shady conditions such as under a sugarcane canopy. It fixes nitrogen well and is a very hardy perennial legume. In rotation experiments, it has been used in combination with signal grass (*Brachiaria decumbens*) as a pasture break between the end of the ratoon crop and the start of a new plant crop. In this research, when the pasture was returned to cane, the pinto re-established itself from seed reserves in the soil and formed a dense understory. However, in some instances it had an adverse effect on the plant cane crop, while in others, it had a beneficial effect.
Above: Soil strength in the non-compacted and compacted beds at Ingham. Roots grow best in blue zones. They stopped growing beyond 1800KPa (green zone).
<table>
<thead>
<tr>
<th>Advice for new growers</th>
<th>Understanding the sugarcane plant</th>
<th>Climate</th>
<th>Soil health</th>
</tr>
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<tbody>
<tr>
<td>Drainage</td>
<td>Planting and crop establishment</td>
<td>Variety selection</td>
<td>Nutrition</td>
</tr>
<tr>
<td>Pest control</td>
<td>Weed control</td>
<td>Chemical use and application</td>
<td>Harvesting and transport</td>
</tr>
</tbody>
</table>

- **Irrigation**
Everyday advice and recommendations

Irrigation tools for advisors

- **IrrigWeb**: The aim of IrrigWeb is to provide local irrigators with current and local advice on sugarcane crop water use and development. IrrigWeb combines crop-water use estimates with user-defined irrigation system constraints and crop cycle inputs to schedule future irrigation events. Developed by SQR Software, IrrigWeb uses a scientifically tested sugarcane crop model, CANEGRO, to calculate sugarcane crop water use and yield outputs.

- **KMSI (Knowledge Management System for Irrigation)**: irrigation tool kit with a range of online tools for irrigation systems development. Includes EconCalc – a decision-support tool to evaluate the costs and benefits of a new irrigation system. Some of the KMSI tools require a login and password. More information is available on the SRA website or directly with the NCEA group at the University of Southern Queensland.

Overall comparison of irrigation systems

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Furrow</th>
<th>Winches (water gun)</th>
<th>Lateral move</th>
<th>Centre pivot</th>
<th>Boom</th>
<th>Drip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>Low – medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
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<tr>
<td>Labour</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Management needs</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
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<tr>
<td>Special requirements</td>
<td>Land levelling</td>
<td>Lanes</td>
<td>Lane</td>
<td>Suitable slopes</td>
<td>Lanes</td>
<td>Maintenance Filtration</td>
</tr>
<tr>
<td>Potential application efficiency</td>
<td>Medium</td>
<td>Medium – Low</td>
<td>Medium – High</td>
<td>Medium – High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Limitations</td>
<td>Slope, permeable soils, hard-setting soils</td>
<td>Energy cost</td>
<td>Speed of operation</td>
<td>Speed of operation</td>
<td>Speed of operation</td>
<td>Water quality</td>
</tr>
<tr>
<td>Relative cost of operation</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Key points on irrigation systems

1. Furrow irrigation

- Most widely used irrigation system for sugarcane in Queensland.
- Suitable for land with up to 3 percent slope; slopes of less than 1 percent are most often used.
- In conventionally planted young plant cane, the cane drill is sometimes used as the water furrow (often referred to as ‘watering over the top’). When the plant crop is 3 to 6 months old, furrows are formed between the cane rows, and a hill 150 to 250 mm high is formed in the cane row. Soil in the hill will settle to give a final hill height of 100 to 200 mm.
- Where pre-formed beds are used, cane is planted into the bed and irrigation is down the water furrow. Even in conventionally planted systems the cane is often watered down the furrow, rather than over the top.
- Design of furrow irrigation systems is covered in more detail in the Irrigation of Sugarcane Manual.
- Hill size and furrow shape – important for managing deep percolation – V-shaped furrows with high hills minimise losses; broad-shaped furrows and small hills maximise infiltration. The design of the furrow shape, however, is soil type dependent; with smaller infiltration rates, water tends to advance faster reducing irrigation times and total volumes applied.
- In Green Cane Trash Blanketing (GCTB) situations, correct furrow slope, cross fall and hill size in the cane row become more critical because trash slows the flow of water. This results in deeper water in the furrow. Furrow shape may need to be narrower and hills higher to compensate. Note that this change should occur in the plant crop.
- Surge (also known as “pulse”) irrigation and alternate row irrigation are variations of furrow irrigation and are commonly used as ways to improve irrigation efficiencies depending on the soil and level of automation of the application system.

Above: Furrow irrigation.

2. Water winches

- Suit all soil types.
- To avoid tracking problems, the tow path should be maintained in good condition. Tow paths should not be used as drains.
- Uneven water distribution occurs if changing wind conditions or poor design prevents the correct overlap of water application.
- Operate best on straight runs. For operation in contoured fields, a series of pegs is used to guide the tow cable.
- Capacity permitting, irrigation is best carried out at night to take advantage of still conditions and cheaper electricity.
- Find more information on design and operation in the Irrigation of Sugarcane Manual.

Information sheets available on the SRA website

Simple calculations for furrow irrigation

Other links


Above: Large hills and narrow interspaces limit water penetration (permeable soils).

Above: Small hills and broad interspaces maximise water intake (less permeable soils).
4. Lateral move irrigators

- Precise method of irrigating. Large areas can be irrigated with high application efficiency and application rates are easily varied by changing the speed of travel.
- Each grower’s operation can be customised to sprinkler packages based on crop, soils and climate conditions.
- Initial capital costs are high. Offsetting this are low labour requirements when the system is operated on a suitable layout.
- The system can be largely automated.
- Lateral move systems can irrigate up to 96 per cent of square or rectangular fields and can be towed between fields.
- Requires the field to be rectangular in shape.
- Typically gives high application uniformity.
- Usually guided by cable.
- Usually fed by open ditch with moving pump or by dragging a flexible hose.

5. Centre-pivot irrigators

- Use low operating pressure and have low labour requirements.
- Significant water, fertiliser, and operating costs savings are possible.

- The need for circular fields is a severe limitation for the system in the Australian sugar industry. However, extra end nozzles can be used to irrigate the areas in the corners of fields not covered by the droppers, though these nozzles are usually very inefficient.
- Easy automated.
- Corner systems can be expensive, can operate using buried cable; corner systems don’t irrigate the whole corner.
- Can operate on very undulating topography.
- Center pivots are ideal for allowing effective precipitation.
- Many variations; overhead and underneath sprinklers, constant sprinkler spacing, varied sprinkler spaces, hoses in circular furrow.
- Some center pivots can be moved from field to field.
- Centre pivots are well suited to large-scale farms where savings in labor are critical.

6. Boom irrigators

- Like water cannons, they need regularly spaced irrigation lanes from 60 to 80 m apart depending on the boom length.
- Because boom irrigators operate at pressures as low as 70 kPa, operating costs are much lower than for water cannons.
- Since water is applied directly from the boom, these irrigators can be used effectively under windy conditions.
- Long flexible hose with high head losses.
- Boom irrigators tend to be more suited to supplemental irrigation, for establishing plant cane or boosting young ratoons.
7. Micro-irrigation systems

- 'Trickle' and 'drip' are terms used to describe what can be generally called "micro-irrigation" systems, in which water is applied in relative precise quantities and precise times at precise locations.

- Most efficient of the irrigation systems, but has the highest management and maintenance requirements. An essential component is the filtration system, which must be adequate for the size of the system.

- Tape diameter is influenced by the volume of water that needs to move through it, the length of the field, and the emitter spacing and flow rate.

- Emitter spacing and flow rate are determined by the soil type.

- Ability to operate on steep slopes and rough terrain.

- Because of the reduced wetting zone with drip irrigation, the frequency and amount of irrigation need to be adjusted compared to other irrigation techniques to avoid deep drainage.

- Drip irrigation enables small irrigations as frequently as daily (or even a number of times per day). The water requirement will vary depending on the soil type and water-holding capacity, crop size and the daily water demand.

- Can be either a surface system, where the drip tape is laid out down the middle of the interspace or to one side of the crest of the row when the cane is near the 'out-of-hand' stage; or a sub-surface system, where the drip tape is usually placed in the soil prior to planting.

- Drip systems lend themselves well to automation and fertigation.

- Fertigation can apply fertilisers throughout the year in a readily available form for the plant to use. Fertigation is both quick and inexpensive as readily available commercial products can be used.

- Adequate filtration is essential for drip irrigation systems. Filtration is used to remove algae, dirt, iron precipitate and other suspended solids from water. Before installing drip irrigation, full water analyses (including iron and manganese) should be obtained to determine any potential problems with the water supply.

- Chlorination is needed to kill bacteria and algae associated with the water supply. This will reduce the chance of any blockages caused by these organisms. Chlorine is added to the water supply in either a liquid or solid form.

Above: Sub-surface drip irrigation.

Above: Disc filters for a drip irrigation system.

Understanding the science

The importance of irrigation

- More than 40 percent of the Queensland sugarcane crop is irrigated, accounting for more than 60 percent of the total cane production.

- Irrigation is required in areas where natural rainfall is insufficient to meet the annual crop water needs, particularly where the natural rainfall falls predominantly outside of the main growing season (supplementary irrigation).

- Given adequate growing conditions, approximately 100 mm (1 ML/ha) of water (irrigation or rainfall) is needed to be taken up by the crop to produce 10 tonnes of cane per hectare. Very efficient irrigation practices can use the same amount of water to produce up to 15 tonnes of cane per hectare.
• While irrigation for maximum growth produces high cane yields, it reduces CCS. Research in Queensland and overseas has shown that supplying approximately 85 percent of crop water requirements with irrigation is most efficient in balancing yield and CCS.

Soil, water and the crop

• When water is applied to a soil for plant survival and growth, some of it is held in the soil and is available to the plant (PAW) and some is held too tightly in the soil colloids that it becomes unavailable to the plants.

• When water is applied to a soil, it fills the pore spaces. The water can be split into two broad types: unavailable water and Plant Available Water (PAW).

• Unavailable water is made up of gravitational water (water that drains away because of gravity; a very small amount will be used by the crop) and water that the plant roots cannot physically extract.

• PAW is the water that plants can extract from the soil. When all PAW has been depleted, the soil is said to be at Permanent Wilting Point.

• Within PAW is Readily Available Water (RAW). This is water that plants can easily extract. The aim of scheduling irrigations is to replace this fraction of the water in the soil.

• In sandy soils, approximately 80 percent of PAW is readily available. In clay soils, because more of the water is held in small pores, plants have more difficulty extracting the water. Therefore, only 45 to 50 percent of the PAW is RAW. However, clay soils still have approximately twice the amount of RAW of sandy soils.

• The effective rooting depth (or effective root zone) is the depth of soil containing most of the roots actively extracting water. In irrigated deep soils (e.g. a clay loam), the effective rooting depth of sugarcane may vary from 0.9 to 1.2 m. Under rain-fed conditions, the effective rooting depth may extend to 1.8 m.

• In sodic duplex soils (generally a loamy topsoil over a sodic clay subsoil), the effective root zone is usually restricted to little more than the depth of topsoil. However, with years of the use of soil amendments (gypsum) the sodic soil layer tends to move downwards.

• The distribution of roots in the soil is affected by irrigation practices. The more frequent the irrigation, the shallower the roots. With trickle irrigation, most of the roots will be close to the emitter, and are generally confined to the wetted area.

Irrigation scheduling

Important steps

• Determine the amount of RAW in the soil. RAW is the amount of water stored in the soil between the full point and the refill point. Past the refill point is when the plant begins to suffer moisture stress. The full point is also known as ‘field capacity’. It is the maximum amount of water the soil can hold against gravity, when excess water has drained away.

Ideally, irrigation scheduling should maintain the soil moisture between the refill and the full points. RAW of most soil types has been extensively studied. This information is found in many publications. To calculate rootzone RAW, multiply the thickness of the soil layer by the RAW of that layer found in tables. If the soil is made up of different layers, then add the values for each soil layer in the rootzone to get the total rootzone RAW.

• Determine the rate of depletion of the water in the soil. The depletion will be by transpiration (water lost from the leaves) and evaporation from the soil surface. Together evaporation and transpiration are known as evapotranspiration or ‘crop water use’. The goal in irrigation scheduling is to apply enough water to replenish the water taken out of the soil within the root zone whilst minimising overwatering and then allow the soil to dry out in between irrigation events, but not so much that the plant suffers from stress.

Scheduling methods

Irrigation scheduling is the process of determining the correct frequency and duration of irrigation, that is, the “when” and “how much”. There are different methods of irrigation scheduling:

• Reference evapotranspiration rates and crop factors

Since plant water use is strongly correlated with evaporation rates, monitoring evaporation can provide a useful indicator of crop irrigation needs.

Reference evapotranspiration is the standard that is used to determine crop evapotranspiration. Reference evapotranspiration figures are published by the Australian Bureau of Meteorology – [www.bom.gov.au/watl/index.shtml](http://www.bom.gov.au/watl/index.shtml)

The relationship between the amount of water required by the crop and the evaporation rate is referred to as the crop factor. This will vary with crop size and is related to the proportion of ground covered by the crop canopy (see table below). These crop factors are for use with reference evapotranspiration.

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>Crop factor</th>
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<tbody>
<tr>
<td>Initial 0-25 percent cover</td>
<td>0.4</td>
</tr>
<tr>
<td>Crop development 25-100 percent cover</td>
<td>0.4-1.25</td>
</tr>
<tr>
<td>Crop actively growing 100 percent cover</td>
<td>1.25</td>
</tr>
<tr>
<td>Crop maturing</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Information sheets available on the SRA website

Crop water use and soil water-holding capacity
Tools used for irrigation scheduling

- **Evaporation minipans**

  These are probably the simplest and cheapest scheduling tool available, providing good accuracy and reliability once they have been calibrated. Growers can easily calibrate minipans to their individual soil. Minipans are most useful in furrow irrigation.

- **Tensiometers**

  Tensiometers measure the force that plants need to exert to obtain moisture from the soil. The higher the reading, the drier the soil. Usually, tensiometers are installed in the plant line with the ceramic cup at 600 mm except for sandy soils where the cup depth should be 300 mm. Preferably, two tensiometers should be installed at each site to improve accuracy. They need careful installation to ensure effective soil-cup contact and regular maintenance to ensure they do not run out of water. They are most useful and more commonly used for overhead and trickle irrigation systems.

- **Gypsum blocks**

  Gypsum blocks are porous blocks with embedded electrodes, placed in the soil at different depths. The electrical resistance is measured and related to soil moisture as a tension. While the blocks may last for several years under ideal conditions, under low pH or heavily leached conditions, they may deteriorate within three months.

- **GDots**

  The GDot displays soil moisture tension represented by fluorescent yellow flip dots. The more yellow dots showing, the wetter the soil is; the fewer lit yellow dots, the drier the soil. The Gdot, uses a granular matrix sensor, a type of gypsum block. Electrodes embedded into gypsum blocks are used to measure the electrical resistance between them under the presence of moisture and those signals are related to soil moisture tension, that is, how hard it is for the plant to extract water. GDots can be used in most soil types (although not recommended for use in light sands and heavy or cracking clays) and have an operational range of 0-100 kPa.

- **Capacitance probe e.g. Sentek EnviroSCAN**

  Capacitance probes use a constant in the soil to measure moisture content. Sensors are placed in the soil at several depths within a sealed PVC tube. Normally between six and eight sensors are required per probe. The probes are connected to a logger by cables. Readings are automatically taken by a logger at preset intervals which can range from once a minute to once a week. The data can be downloaded directly from the logger in the field or sent via mobile phone or radio telemetry to a computer. The probes come with software that presents the moisture data graphically. It also allows the setting of full and refill points. These can be used to schedule irrigation times and amounts.

- **Time-domain reflectometry**

  Time-domain reflectometry (TDR) sends an electromagnetic pulse into the soil via stainless steel rods called waveguides. The moisture in the soil influences how fast the electromagnetic wave travels. The TDR is primarily a research tool.

Decision Support Systems

Crop models, meteorological information, networked soil moisture sensors. Examples with varied degree of precision and reliability are: IrrigWeb, APSIM, Scheduling Irrigation Diary (USQ). IrrigWeb is the only model designed and customised for Sugarcane.
Maximum irrigation efficiency can be achieved by reducing losses of irrigation water. Irrigation losses occur through storage and transmission, evaporation from the soil surface or from the leaves of the plant, and deep drainage or run-off as tail-water.

1. Furrow irrigation
- In *freely draining alluvial soils* like those in the Burdekin Delta, the main irrigation loss is through deep drainage. Important efficiency factors include:
  > Matching water inflow rate to the soil infiltration rate
  > Matching furrow length to the infiltration rate
  > Having the correct furrow shape for the soil type
  > Reducing cultivation where it impacts on soil porosity
  > Carefully managing the duration of irrigation to avoid prolonged irrigation after water has reached the end of the furrows.
  > Practicing surge irrigation (some level of automation would be required).
- In *surface-sealing soils*, important efficiency factors include:
  > Irrigating with low inflow rates
  > Using wide U-shaped furrows to increase the total wetted surface and total infiltration
  > Using a soil ameliorant, such as gypsum, to ‘open up’ the soil surface
  > Using GCTB to increase the opportunity time for water to move into the soil.
- In *cracking clay soils*, the main irrigation loss is tail-water run-off. Efficiency therefore involves minimising tail-water.
- In *sodic soils*, the main irrigation loss is also from tail-water run-off. However, unlike cracking clays, they do not infiltrate water at high rates, and poor soakage is a common problem. To overcome the poor soakage, a wide U-shape (to maximise the area exposed to water) and low inflow rates should be used. In addition, the use of GCTB and gypsum or lime will improve soakage.

2. Overhead irrigation
- Efficiency factors include:
  > Being aware of the water-holding capacity of the soil so that irrigation can be matched to the amount of water stored in the soil and the water evapotranspirated.
  > Increasing or decreasing the speed of travel of the irrigation system.
  > Wherever possible, watering in calm conditions to avoid uneven distribution of water during wind.
  > With centre-pivot irrigation systems, taking care to ensure that the application rate at the end-spans does not exceed the infiltration rate of the soil.
  > Using GCTB where the trash blanket delays the time taken for water to reach the soil surface, allowing more time for infiltration.

3. Drip irrigation
- Efficiency factors for micro-irrigation systems include:
  > Placing the tape and the right depth. This will vary depending on soil type and the soaking pattern of the soil. The tape also needs to be deep enough to avoid mechanical damage from farming machinery.
  > Choosing tape emitter spacing to ensure that the root zone between emitters can be fully replenished at each irrigation.
  > Selecting tape size to ensure water transmission along its full length is sufficient to maintain pressure within the design criteria for uniform output from each emitter.
  > Having pressure-regulating valves to reduce mains pressure to the relatively constant-design operating pressure in the tapes. Ensuring adequate mainline and sub-main sizing to transmit the total required volume to the tapes at sufficient pressure to meet output flow rates from the emitters.
  > Being able to use fertigation for convenience and timeliness of fertiliser application.
  > Monitor for leaks and pressures along the system.
  > Check for root intrusion and rodents.
  > Follow the maintenance program recommended by the supplier.

**Above:** Surface sealing causing poor water penetration on a light-textured soil.
Most water contains many types of salts. Some are harmful to crop growth, while others have beneficial effects. For example, sodium and bicarbonate salts in the water can affect soil structure adversely, while calcium salts can improve soil structure.

Over time, soils will take on the chemical properties of the irrigation water used. Thus, without proper leaching, saline soils will result from the use of saline water. Water with a high sodium hazard will produce sodic soils.

The main indicators of water quality are:

- Salinity – the total quantity of dissolved salts (TDS) in the water, generally expressed and measured as electrical conductivity (EC)
- Sodicity hazard (sodium adsorption ratio [SAR] and residual alkali [RA] – the amount of sodium bicarbonate and sodium carbonate in the water)
- Presence of toxic ions – iron, clay or calcium carbonate – can cause blockages and shorten the effective life of trickle or spray irrigation systems
- Presence of materials that may clog or corrode irrigation systems – primarily acidic waters with a high proportion of chloride ions.

Water analysis is essential in determining the suitability of a water source for irrigation.

Managing water quality problems

Dealing with water penetration issues

1. Field management
   - Form small hills and a broad flat interspace.
   - Do not exceed a slope of 0.125 percent.
   - Use GCTB.

2. Soil ameliorants
   - Apply gypsum (up to 10 t/ha).

   - On soils with a pH of 6.5 or less, use earth lime (crushed limestone) in preference to gypsum.

   - Ideally, apply before planting. Applications to ratoon cane do not allow adequate incorporation of the product into the mound of the cane row where it is most needed.

   - Mill mud, rice hulls or other organic material will improve water penetration when incorporated into the soil. However, the effects are only temporary.

3. Improving water quality
   - Mix water containing ‘too little salt’ with water from a ‘salty’ bore. Recycled tail-water may also improve the quality of low-salinity open water.

Managing saline water

- All irrigation waters add salt to the soil. Without adequate leaching, this salt will accumulate in the soil profile.

   - Ideally, each application of water should leach away the salt left by the previous irrigation. To achieve this, apply water in excess of the crop’s needs. In most situations, rainfall can be relied on to provide adequate leaching.

   - Note that deep drainage will most likely cause groundwater to rise over time. If the groundwater is not too salty, it may be used for irrigation, and this will slow or prevent its rise. If groundwater rises to within 2 m of the soil surface, cane growth will be reduced. Sub-surface drainage and disposal of the drainage water are then necessary.
Effect of water quality on crop growth

Irrigation water is graded into seven classes:

<table>
<thead>
<tr>
<th>Class</th>
<th>Electrical conductivity (dS/m)</th>
<th>Residual alkali (meq/L)</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 1:</strong> Low salinity</td>
<td>0–0.6</td>
<td>0–0.2</td>
<td>When some light-textured soils (e.g. sandy or silty loams) are irrigated, the soil particles may disperse and form a slurry which prevents adequate water penetration.</td>
</tr>
<tr>
<td><strong>Type 2:</strong> Low salinity with residual alkali</td>
<td>0–0.6</td>
<td>0.2–2.4</td>
<td>The presence of residual alkali aggravates the penetration problem on light-textured soils.</td>
</tr>
<tr>
<td><strong>Type 3:</strong> Average salinity</td>
<td>0.6–1.5</td>
<td>0–0.6</td>
<td>Suitable for all soil types. Does not cause water penetration problems or result in excessive build-up of soluble salts as long as leaching occurs.</td>
</tr>
<tr>
<td><strong>Type 4:</strong> Average salinity with residual alkali</td>
<td>0.6–1.5</td>
<td>0.6–2.4</td>
<td>Encourages soil particles to bind together when wet and allows adequate water penetration. However, when the residual alkali content exceeds 0.6 meq/L, soil particles may disperse when wet, especially if large amounts of calcium have been removed from the soil. Poor water penetration can then result.</td>
</tr>
<tr>
<td><strong>Type 5:</strong> High salinity</td>
<td>1.5–2.2</td>
<td>0–2.4</td>
<td>On soils with poor internal drainage, use will result in a build-up of salts in the root zone. This problem occurs mostly with heavy soils or soils that have clay subsoil.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With clay soils, water with an electrical conductivity greater than 1.5 dS/m should not be used. On lighter soils, saltier waters may be used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With higher salinity waters, irrigation management is important. Slow, heavy irrigations aimed at leaching salt from the crop root zone must be carried out. Light irrigations will result in a rapid build-up of salt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deep ripping the soil may improve leaching of salts to below the root zone.</td>
</tr>
<tr>
<td><strong>Type 6:</strong> Very high salinity</td>
<td>2.2–3.2</td>
<td>0–2.4</td>
<td>Can be used only on free-draining sandy soils without causing a serious build-up of salt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water with conductivity greater than 3.0 dS/m should be used only in extreme circumstances.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Where Type 6 waters are used, more frequent, heavy irrigations are necessary to leach excess salts from the root zone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Where a build-up of salts is evident, the soil should not be allowed to completely dry out. Drying concentrates salt in the soil solution.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>During irrigation with these waters, soils should be wet to a depth of at least 1 metre.</td>
</tr>
<tr>
<td><strong>Type 7:</strong> Unsuitable for irrigation</td>
<td>&gt; 3.2</td>
<td>&gt; 2.4</td>
<td>Not suitable for routine irrigation due to the extreme levels of salt or residual alkali.</td>
</tr>
</tbody>
</table>
Drainage

Advice for new growers
Understanding the sugarcane plant
Climate
Soil health
Irrigation

Planting and crop establishment
Variety selection
Nutrition
Diseases and disease control

Pest control
Weed control
Chemical use and application
Harvesting and transport
Milling issues for the grower
Drainage

High-intensity summer rainfall is a characteristic of all cane-growing districts; therefore most farms require good surface drainage. This is particularly critical in the Mackay and Ingham districts where relatively flat land is combined with duplex soils (Mackay) and heavy-textured soils (Ingham), both of which have poor sub-surface drainage.

A drainage problem is caused by an excess of water either on the surface of the soil or in the root zone beneath it. If the water stands on the surface of the soil the issue is most likely one of surface drainage.

The most common practices are land levelling, the provision of surface drains and mounding of rows. Headland drainage also requires special attention.

Another type of drainage problems concerns water that occurs beneath the surface of the soil; that is, a high water table is present.

The presence of a high water table is not normally evident from an inspection of the soils surface. In many instances, the soil surface may appear to be dry, although waterlogged soils at depths of 50 cm or more beneath the surface may be causing serious damage to the cane's roots. Methods of investigating such problem form an important part of the design of a drainage system.

1. Land levelling

- Land levelling to fill small depressions and to provide a continuous slope of the soil surface is one of the most effective surface drainage techniques.
- It is generally achieved with GPS- or laser-controlled scoops which provide the most precise results. Conventional land planes and graders may be used where less precision is required.
- Land levelling is best directed by computer-based programs, which calculate cuts and fills in relation to farm or block contours. Loss of top soil may occur when the leveling works are not done properly. A well designed land leveling plan, a cut/fill map needs to be overlaid on the map of the depth of the top soil to minimise problems from shallow soils after leveling.
• In areas such as the Burdekin, where there may be a relatively shallow topsoil overlying a sodic subsoil, bulldozers remove the topsoil. Then the subsoil is levelled and the topsoil put back on top of it. This avoids exposing the sodic subsoil in cut areas.

• Land levelling is usually combined with shallow, grassed, headland waterways to collect run-off water and convey it into either natural drainage channels or deeper open drains. Waterways should have a gradual side slope of 4:1 to 5:1 (horizontal: vertical) where they will be slashed, and no steeper than 9:1 where they will be crossed by harvesters and tractors.

2. Surface drains

There are five types of surface drainage:

• Bedding systems
• Ditch systems
• Interception systems
• Diversion-ditch systems
• Field-ditch systems

Some of the factors that influence the choice of a system are:

• Soil type
• Topography
• Farmer preference

• In-field cross ditches are used in some districts to connect larger depressions to drainage outlets and to minimise earthworks. The ditches should be kept shallow enough to be crossed by cultivating and harvesting equipment, but they still usually restrict machinery operations.

• Deep open drains serve a dual function of surface and sub-surface drainage. They should have sufficient capacity to remove surface water from the crop within 72 hours for a 1-in-3-year rainfall event.

Above: Shallow cross field drain.

Above: A deep open drain.

• Formulas for designing drains are given in the Drain design formulas section. They tend to use average rather than peak run-off because sugarcane can withstand some short-term inundation without adverse effects.

• The water velocity in drains needs to be greater than 0.3 m/s to prevent siltation but not so high that it causes scouring. For loams and silts, velocity should be less than 0.6 m/s; for clays and gravels it should be less than 1.2 m/s.

• Most drains require a minimum side slope of 1:1 to prevent the collapse of sidewalls and facilitate cleaning. Less stable soils require side slopes of 2:1 to 3:1, but deep open drains are not practical in unstable sands. Both deep and shallow open drains require drop structures to slow the water flow in situations where following the natural slope of the land will cause erosion.

• Where drains are being constructed in areas with acid-sulfate subsoil, care is required in the disposal of spoil from the drains. Acid-sulfate material becomes extremely acidic on exposure to air and, if spread, it will be toxic to cane unless adequate lime is applied. If field peroxide soil tests indicate acid-sulfate subsoil along the proposed drainage line, leave these soils undisturbed if at all possible by either finding a new location for the drain, or using only shallow drains which do not expose the acid-sulfate subsoil.

• Regular maintenance of deep open drains is essential, including spraying to control problem weeds such as Brachiara mutica (para grass) and regular desilting with a backhoe or excavator. Grass cover should be maintained on the sides of the drain to prevent erosion and slippage of the sides.

For more information regarding acid sulfate soils

Queensland Acid Sulfate Soil Technical Manual V3.8

NSW Information

Sugarcane Advisors Information Kit →
3. Mounding of rows

- Cane rows should be hilled up to provide a suitable profile for harvesting. Where inundation or flooding is likely to be a problem, these hills should be higher than normal to provide better drainage.

- A mound allows water to drain into the furrow and minimises waterlogging in the hill.

- There are three options:
  
  > Forming a bed before the wet season and then planting into the bed. A legume fallow can be planted over the wet season to provide ground cover. The legume stubble can then be retained and cane planted with a minimal disturbance planter.
  
  > Conventional furrow planting and subsequent mound formation at filling-in.
  
  > Placing the billet on the surface of a tilled block and covering and mounding up in one pass using tines or discs.

Above: Mounding of rows.

4. Headland drainage

- With any of the drainage improvement options listed above, attention should be given to headlands to ensure surface flow from the crop is appropriately managed.

- Headlands should be lower than the block to prevent water backing up into the rows. A shallow spoon shape and grass cover will direct the water flow while minimising erosion.

5. Crop management

- Drainage issues can also be partially addressed through good crop management practices. These include:
  
  > Early planting – to get the crop more advanced before the wet season commences, which will reduce the impact of flooding
  
  > Using varieties that are more tolerant of flooding and waterlogging – visit QCANESelect – a variety decision-support tool available on the SRA website.

> Good agronomic practices – any practice that improves the health of the crop (nutrition, weed control, pest and disease management etc.) will help offset drainage problems.

- On poorly drained flood plains that have limited outfall and are subject to periodic shallow inundation, it is recommended to form a higher hill than normal during hilling-up operations or to plant into a pre-formed bed.

Sub-surface drainage

- Subsurface drains are designed to maintain the water table below the root zone for most of the growing season. It may take the form of a simple system to drain seepage areas or a whole-field/whole-farm drainage scheme in low-lying areas.

- The aim of sub-surface drainage is to maintain the watertable at least 0.6 m below the soil surface.

- In saline seepage areas or tidal areas, the risk of salinisation due to a shallow saline watertable has to be taken into account in designing the sub-surface system. Where this risk exists, it is necessary to lower the watertable to a depth of one or two metres, depending on soil texture.

- A decision on whether to install sub-surface drainage will depend on the average number of days for which the crop is waterlogged each year and the cost of installation.

Seepage areas

- To drain a spring or seepage area effectively, dig test holes to locate the source of water. An interception pipe or a branched underground pipe system can then be located correctly to remove the seepage water.

- For saline seeps, pipes generally need to be installed at a depth of 1 m to 2 m, depending on soil texture, to prevent capillary rise of salt water.

- Check with the Queensland Government about requirements for the disposal of saline seepage water.

Whole-field/whole-farm drainage

- A total field drainage system may be justified in heavy-textured soils, on flat flood plains, or in former swamp or tidal areas. The most common method used in sugarcane areas is deep open drains, which serve a dual purpose of disposing of surface water run-off and deep drainage water. However, there are a few examples of whole-field sub-surface drainage pipe systems throughout the industry.
**Options for sub-surface drainage**

1. **Mole drains**
   - Mole drains are a special case of subsurface drainage; they comprise relatively short-lived soil-channels formed in a clay subsoil using a mole plow. The life of a mole drain depends on a number of factors.
   - Most suitable for clay soils with a clay content between 30 and 50 percent. Sodic soils are not suitable as they disperse when wet and the mole drains collapse.
   - Less expensive than sub-surface pipes.
   - Can provide drainage through the headland barrier and reduce ponding at the lower end of blocks.
   - Should have a regular gradient to prevent water lying in low spots and causing the collapse of the drain.
   - Maximum recommended length is about 200 m, but longer mole drains can be effective if there is adequate slope (above 0.1 percent) and a stable soil.
   - Common spacings range from 1.5 m to 7.5 m. Closer spacings allow for the failure of a proportion of the drains.
   - Generally need to be reinstalled each crop cycle.
   - Information on construction is available in the *Irrigation of Sugarcane Manual*.

2. **Sub-surface drainage pipe**
   - Drainage pipelines comprise a network or grid of perforated pipes buried at a target depth. These drains discharge into deep open surface drains or ditches.
   - Most commonly used for draining seepage areas.
   - Mainly corrugated, slotted plastic pipe 100 mm in diameter and designed to dispose of 5 to 8 mm of water per day.
   - Pipe is generally installed at a minimum slope of 0.1 percent, but a slope greater than 0.2 percent is desirable to ensure that there is self-cleaning of silt from the pipes.
   - Specialised equipment to reduce the costs of laying sub-surface pipe is available in some districts. This includes laser-controlled machines that can cut the trench and backfill with gravel in the same operation. This system is versatile and can be used for a range of trench depths.
   - Trenching can also be carried out with a backhoe or excavator, but chain trench diggers are usually faster and less expensive if pipe can be installed in relatively dry conditions. The problem with backhoes and excavators is ensuring an even slope for the pipe.
   - Pipe should be installed on a 50 to 100 mm bed of coarse sand or graded aggregate (3 to 10 mm) and covered with an additional 200 mm of this filter material.
   - The depth of pipe installation is usually dependent on the available slope to the outlet. In general it should be at least 1 m in non-saline areas or 1.5 m in saline seeps. The aim is to keep the water table below 0.5 m.
   - Where there is no natural outlet for underground pipes, a sump is constructed and a pump is used to lift water to the surface for disposal.
   - High-pressure drain cleaners are available in most districts, and a system of Y-pieces installed every 100 m with a 100 mm diameter branch to the soil surface facilitates insertion of the drain-cleaning nozzle. The outlet is protected with a short length of concrete pipe. Cleaning should commence at the outlet and work upslope using clean water in a spray tank to avoid damage to the high-pressure pump.

**Publications available on the SRA website**

*Irrigation of Sugarcane Manual*

**Understanding the science**

- Sugarcane performance can be affected by inundation and shallow water tables which lead to oxygen depletion and high carbon dioxide concentrations. Inundation also leads to chemical reduction reactions in the soil, denitrification, and a build-up of methane and ethylene gases in the soil solution. The capacity of soils to carry machinery falls steadily as the soil moisture content increases and, at moisture levels above field capacity, soils can only bear light loads without being damaged. Access to lands is impaired and field operations cease.
- Waterlogging caused by poor drainage can have a significant impact on production.
- Drainage problems commonly occur where:
  - Agricultural development has extended into former wetlands where natural drainage is inadequate to prevent waterlogging
  - Watertables have been raised by the clearing of natural vegetation or over-irrigation
  - Farming operations have interfered with natural drainage pathways
- These situations are more acute in the high-rainfall districts on flood plains.
• Successful production in these situations needs improved drainage to promote better disposal of both surface run-off water and sub-surface drainage water.

• Where drainage is improved, it is imperative to consider the potential impact on the off-farm environment.

Causes of drainage problems

1. Low-lying swamp or flood-plain country with limited natural drainage

• These areas have persistent high watertables or soil wetness in the summer wet season.

• Typical examples are northern NSW, Rocky Point, Ingham, Tully and Babinda districts.

2. Relatively flat land with poor surface drainage and restricted internal drainage

• The restricted internal drainage is from either heavy surface soil texture or clay subsoil.

• These areas suffer from temporary perched watertables or general waterlogging during the wet season.

• The most obvious example is the Mackay district, where there are extensive areas of duplex soils with clay subsoils of low permeability and areas of heavy clay 'gluepot' soils.

• Good surface drainage is critical in these areas, and areas of local ponding and waterlogging will occur in any depressions.

3. Local wet areas towards the bottom of slopes due to seepage from higher areas

• The clearing of trees from the upper slopes or irrigation of these areas generally accentuates seepage.

• Where soils overlie old marine sediments, seepage water is salty and local salt scald areas may develop at the bottom of slopes.

• Some wet areas also occur at the boundary of freely drained soil and relatively impermeable clay subsoil, rock dykes or other natural impediments to free drainage.

4. Artificial impediments to surface or sub-surface drainage

• These include compacted soil in headlands, roads or mill tramlines across natural drainage channels, filling in of natural drainage lines during farm re-design; and seepage derived from application of excess irrigation water.

• Within cane fields, surface soil ruts smearing created during wet harvests, and subsoil compaction from cultivating and harvesting equipment, also contribute to drainage problems.

Above: Surface soil ruts caused by harvesting in the wet.

Indicators of poor drainage

These include:

• Before clearing, dominance of water-loving species such as Banksia robur (swamp banksia) and Melaleuca spp. (paperbarks).

• Prolonged soil wetness.

• General yellowing of foliage, poor stooling and gaps in the stand.

• In salt seepage areas, scorching of cane leaves, particularly towards the tips; in severe salt cases, plant death.

• Slow germination of plant and ratoon cane.

• Prolific growth of wetland weeds such as sedges. In salt-affected areas, Rhodes grass or other species adapted to saline conditions.

• Soil indicators:
  > Dark-coloured or peaty surface soil
  > Presence of a bleached layer below the dark surface layer
  > Mottling or dull grey to blue subsoil
  > In salt-affected areas, a crust of salt on the soil surface and a hard-pan appearance due to loss of soil structure.

Impacts of poor drainage on crop growth

Roots

• The root system is shallower, and growth is reduced as a result of poor aeration (lower oxygen and higher carbon dioxide levels).

• As a result, the crop wilts in hot weather because of the reduced capacity of roots to take up water.

• Use of applied fertiliser is less efficient because of the lower functioning roots.
Leaves

- There is general yellowing of the leaves as a result of waterlogging reducing the supply of nitrogen to the crop. This results from reduced mineralisation of organic matter and increased denitrification of nitrate from applied fertiliser (nitrogen lost as gas to the air). Waterlogging also reduces the availability of some other nutrients such as phosphorus and molybdenum.

- In severe cases of prolonged waterlogging, cane may die.

Above: Prolonged waterlogging causes cane to die.

- Chlorotic streak disease, which causes irregular chlorotic streaks on the leaves, is spread by drainage water and may cause significant yield loss in wet areas.

Setts

- Bud germination will be slower in both plant and ratoon cane. This occurs because temperatures in wet soil are up to 4°C lower, relative to drier well-drained soil.

- When germination is slow, the risk of attack from diseases rises. For example, pineapple disease (*Ceratocystis paradoxa*), is worse in colder, wetter soil.

- Wireworms are more frequent in poorly drained areas where they are a common cause of poor germination.

Overall impact

- Many cane production areas are based on flood plains subject to intermittent and temporary inundation. While this generally has a minimal effect on yield, research shows that a yield loss of about 0.5 tonnes per day could be expected while the watertable remains shallower than 500 mm. Since, in some years, soils may remain waterlogged for 100 days, yield losses of up to 50 tonnes per hectare could be expected. The impact is compounded where the watertable is also salty. However in practical terms, it is generally accepted that cane can remain inundated for up to 3 days without suffering appreciable damage or yield loss.

Benefits of good drainage

Apart from addressing the above impacts, good drainage has a number of other more indirect benefits:

- Drainage promotes beneficial soil bacteria activity and improves soil tilth.

- There is less surface runoff and soil erosion on drained land.

- Rapid drying out of soil is important to facilitate harvesting operations – allowing an earlier start after wet weather; reducing damage to fields by harvesting and cane transport equipment; and minimising the risk of being forced to leave burnt cane in the field after wet weather interruptions.

- Good drainage allows greater flexibility in timing of planting, and will speed up ratoon growth. The latter is a particularly important issue in trash-blanketed fields.

- In wetter districts, good drainage will allow the growth of other crops during the fallow period, with all of the benefits that this provides (supplying nitrogen to the plant crop, maintaining soil structure, minimising erosion, and helping to control weeds and volunteer cane stools).

- Good drainage allows more timely cultivation and/or herbicide application for weed control. Cultivation of the soil at the correct moisture content reduces compaction and loss of soil structure.

- Due to difficult access, weeds often get out of hand in poorly drained blocks, contributing to yield loss as well as providing harbourage for rats.

Filter strips

- Filter strips are areas of dense vegetation located between runoff pollutant sources and receiving water bodies. Filter strips are constructed of turf, grasses, or other vegetation such as landscape plantings. Filter strips act to impede the velocity of stormwater runoff and allowing sediment to settle out. Filter strips slow the rate of runoff, reduce peak flows, and allow for infiltration to a lesser extent.

Drainage in flood-prone and tidal areas

- Protection of cane in low lying areas from inundation by tidal or flood waters is achieved in many situations by a combination of levee banks and floodgates.

- A properly built levee bank and floodgate system stops tidal and floodwater entering farms and allows water to flow out at low tide or when floodwater recedes. In tidal areas, floodgates also act to minimise salt entry into cane land while allowing leaching of salt from reclaimed land within the levee.
• Much of the northern NSW sugar-producing area is protected by floodgates and levees supplemented by low-lift, high-capacity pumps to speed up the removal of floodwater. Axial-flow or propeller-type pumps give high output and pumping efficiency at low heads. They are usually powered by a tractor PTO system.

### Environmental issues

Public concern about water quality and its potential impact on the Great Barrier Reef has increased in recent years. Growers need to ensure they put in place drainage practices that least impact the environment. A good farm drainage is one that:

- Prevents inundation
- Prevents waterlogging
- Reduces sediment losses
- Reduces nutrient and pesticide losses
- Controls the direction and velocity of the flow of water to reduce erosion and disposes it in an environmentally friendly way.

Drainage of cane may have significant environmental impacts, including:

- Acid export from acid-sulfate soils following drainage and aeration of drainage spoil
- Movement of suspended sediments, nutrients from fertiliser, and chemicals (herbicides, insecticides, fungicides) in drainage water into streams, wetlands, estuaries and marine areas
- Peak water discharges that may increase downstream flooding.

Industry Codes of Practice to minimise environmental impacts need to be followed. These may include, among other things:

- Silt traps to retain soil on the farm
- Rock baffles to aerate low-oxygen waters for improving fish survival
- Culvert design to reduce water velocity and aid fish passage
- Revegetation schemes to reduce the incursion of exotic weeds and improve fish habitat.

Note that the clearing of trees from natural drainage lines and riverbanks to establish drainage works, including the clearing of mangroves in tidal areas, is limited by regulations and require environmental permits.

### Drain design formulas

These equations can be used to estimate the volume of run-off from a given area and the capacity of the drain needed to drain that area.

To determine the drain size and shape, it is best to consult an agricultural, civil or environmental hydrological engineer. The slope, soil characteristics and water velocity will all affect the drain design.

**Volume of run-off from a field**

\[ V = KRA \div 100 \]

Where:

- \( V \) = volume of run-off (ML)
- \( K \) = volumetric run-off coefficient; for most soils, this is 0.6–0.7
- \( R \) = rainfall (mm) in a 72-hour period (from Table 1)*
- \( A \) = area drained (ha)

* the accepted rainfall design intensity for sugarcane in the Wet Tropics is the 1-in-3-year event.

**Required drain capacity**

\[ Q = V \div 3.6T \]

Where:

- \( Q \) = drain capacity (m³/s)
- \( V \) = volume of run-off (ML)
- \( T \) = period of inundation (usually 72 h)

### Filter strips design principles

- Calculation of the required width of the grassed filter strip based on soil loss (t/ha/y) and strip slope.
- Requirement of a minimal grassed filter strip with (5-10m) for most cane paddocks with low slope and using green cane trash blanket (GCTB).
- Selection of a dense medium height native grass species.
- Planting taller native grass species up against riparian vegetation to assist in shading out invasive weeds.
- Maintaining the grass at a height at least 20-15 cm. If kept too short, the grassed filter strip will be much less effective in trapping sediment containing nutrients and pesticides.
- Mowing of grass filter strips may be required for cane rat control, and there is little benefit to sediment trapping in allowing grasses to grow higher than 20 cm.

### Publications available on the SRA website

- SmartCane Riparian and Wetland Areas on Cane Farms
- Practical Farm Drainage
Planting and crop establishment
Planting and crop establishment

Everyday advice and recommendations

Land preparation for planting

When the final ratoon is harvested, a grower has three options for land preparation and crop rotation:

- Plough out replant – not recommended
- Fallow plant (bare or weed fallow) – recommended
- Fallow plant (legume crop fallow) – highly recommended.

1. Plough out replant – not recommended

This strategy is based on a rapid turnaround between the harvest of the final ratoon and re-planting the new crop. Hence, the final ratoon must be harvested early in the crushing season (June–July), the land prepared quickly, and the new crop planted by early spring (September).

These time restrictions mean that the old stool must be removed quickly. The option of using herbicides to remove the stool cannot be used as there is insufficient time to allow the stool to grow to provide enough foliage for herbicides to be effective. Further, compaction from the previous cropping cycle must be removed quickly to facilitate establishment of the next crop.

Thus, removal of the old stool and removal of compaction can only be done within the short time available by frequent aggressive tillage involving ploughing/discing, ripping and rotary hoeing. This has a significant negative impact on soil tilth, structure and biology.

In addition, the aggressive cultivation works most effectively if the trash from the previous harvest is burnt and not incorporated, thus loss of valuable organic matter.

2. Fallow plant (bare or weed fallow) – recommended

This strategy involves the harvest of the final ratoon towards the end of the crushing period (October–November), and its removal through either cultivation or herbicide. For the following wet season or summer period, the paddock is left as a bare or weedy fallow.

Conventional or zonal tillage is then used for land preparation and planting during the following autumn–winter period.

The grower has the choice of removing the stool through less aggressive tillage or herbicides, as timeliness is not as critical compared with the plough out replant system. If using herbicides, the old stools are sprayed when they are 200 to 500 mm high and actively growing, generally the wet season. Herbicides can then also used to remove any weeds or volunteer cane during the fallow and land preparation stage. This process significantly reduces soil erosion.

3. Fallow plant (legume crop fallow) – highly recommended

This strategy involves the same process as option 2, without a bare or weedy fallow, a legume crop is grown.

The traditional practice was to broadcast seed onto the soil surface and incorporate it with a disc implement or rotary hoe, with little or no further management.

However, by machine planting on raised beds to avoid wet season waterlogging and using a herbicide to control weeds, the growth of the legume is greatly enhanced. Beds also facilitate irrigation, if required.

Sowing seeds with a planter ensure good germination, because planting rate and depth are controlled, particularly if ground speed is slow enough to minimize tine and seed bounce that result in variable planting depth. Broadcasting seed sometimes leads to poor germination, as planting depth is uncontrolled.

For both green manure and grain legumes, it is important to plant into moist soil, although cowpea and lablab are more tolerant of dryer conditions.

In addition, a change in species from the traditional cowpea to soybean is providing improved benefits, particularly in terms of increased nitrogen input. Appropriate inoculants must be used for successful nodulation.

At the end of the crop, the legume is either sprayed out with herbicide or incorporated by either shallow discing, not by rotary hoeing.

Allow fallow crops (grown for grain or green manure) with large biomass residue to break down before incorporating (more so on heavier soils) to prevent N draw down on following cane crop and possible allelopathic effect.
Advantages of the fallow plant options

- Soil properties are improved, particularly with the legume fallow. These include an improvement in structure and a reduction in compaction from a non-grass crop being included in the system.

- Root diseases can be better managed through an extended break from sugarcane.

- Organic nitrogen can be incorporated into the system for the next plant crop.

- The zonal tillage and controlled traffic concept can be accommodated – the old ratoon can be sprayed out, the legume direct seeded into the old mounds and then incorporated using a narrow zone of tillage prior to sugarcane planting.

- The main disadvantage is that there is a year when no cane is harvested from part of the farm. However, this is more than offset by the higher yields following the fallow options in both the plant and at least the early ratoon crops. When planting a legume fallow crop for grain (Soy, mung, peanut) further financial offset can be expected.
1. Conventional (full) tillage – not recommended

- Conventional tillage is where the full area, both row and inter-space, are cultivated or tilled. This normally involves several passes with various implements, often including ploughs, tines, discs and rotary hoes. Cultivation may be used in combination with spray-out to ensure an effective kill of the old cane stools.

- Excessive tillage damages soil structure, and seriously affects soil health (kills beneficial soil biota and enhances degradation of organic matter). There is also increased potential for soil erosion and off-site movement of nutrients and pesticides because all the soil has been cultivated. Thus it is important that these risks are minimised by planting a legume crop as soon as possible to provide cover and bind the soil with the roots.

- Conventional or full tillage is still necessary under certain circumstances:
  - Widening row spacing and forming raised beds to implement controlled traffic
  - Land grading to improve drainage or irrigation
  - Altering blocks by changing row direction and/or amalgamating areas
  - Assisting in the control of problem weeds
  - Applying mill mud or lime.

- Some benefits of conventional tillage include breaking up row compaction accumulated over the previous crop cycle and ‘diluting’ the levels of the soil fungus Pachymetra within the paddock. However, these two factors should not be seen as sufficient reasons in themselves to adopt full cultivation.

- In summary, full cultivation should involve just enough mechanical operations to achieve an adequate soil tilth. The soil should never be pulverised to a powder with a rotary hoe.

2. Zonal tillage – recommended

- Zonal tillage is when only the row area is cultivated and the inter-row area remains undisturbed. It is primarily used in the fallow to alleviate compaction, particularly on heavy-textured soils and to provide a better seedbed for legume growth.

- This system improves the efficacy of pre-emergent herbicides due to the absence of a GCTB. It therefore results in better control of problem weeds.

- Zonal tillage provides farmers with a number of benefits over conventional (full) tillage and is a compromise to address some of the problems that may occur with the spray-out system. The most immediate and obvious benefit is the very significant reduction in farm input costs and time compared with conventional cultivation. Soil erosion, off-site movement of nutrients and pesticides and deleterious effects of cultivation on soil health are less than with conventional cultivation.

- Most growers implementing the zonal tillage system use combinations of rippers and rotary hoes. Purpose-built machines are now available. These usually include rippers, discs and a roller, but omit the rotary hoe, which is an aggressive cultivation tool that destroys soil structure if used excessively.

Above: Preparing to plant cane after soybeans, bed renovator.

Information sheets available on the SRA website

Cane and grain legumes = Better returns, healthier paddocks

Publications available on the SRA website

SmartCane Harvesting and Ratoon Management

SmartCane Fallow and Land Management

Above: Conventional cultivation.
Planting

Planting time

- Selection of planting time is influenced by three factors:
  a) Climatic conditions – moisture levels and soil temperature
  b) Variety
  c) Crop rotation – whether the grower is going to use the plough out replant strategy (not recommended) or one of the fallow plant options (recommended).

Planting material

- Planting material needs to meet the following criteria for optimum performance:
  > **Free from disease and insect damage:** primarily RSD, chlorotic streak, eye damage from soil insects, and weevil borer damage causing red rots in stalks. Disease problems are reduced by using approved seed cane for planting material and maintaining farm hygiene to prevent re-infection. Sterilisation of harvesters and other equipment used for cutting planting material is particularly important. Planting material should be inspected prior to planting for pest and disease status.
  > **Erectness:** lodged cane is prone to side shooting, prominent eyes (which are easily damaged), and stalk cracks (which allow the entry of red rot affecting germination). Lodged cane is difficult to cut for whole-stalk plants and may be twisted, making feeding of the planter difficult. While it can be cut by chopper harvesters for billet planting, it is more prone to eye and sett damage.
  > **Relatively short internodes.**
  > **Adequate nutritional status:** *The seed source should show no signs of nutrient deficiency* as the germinating shoot initially obtains nutrients from the cane sett, and vigor is reduced if the plant source suffers nutrient deficiency.
  > **Billet damage:** *Seed source inspection and minimal sett damage* are critical. Inspect varieties for piping before planting. Piping is the site where rot can occur once the stalk is planted in the soil.

Reduce billet damage with all planting techniques but particularly for billet planting where some damage will occur during harvesting and within the billet planter itself. Planters and harvesters should be prepared to minimise billet damage. Sharp basecutter blades, sharp chopper knives, and rubber-coated rollers (or at least well-worn feed rollers without sharp edges) are essential for producing quality billets.

> **Most suitable variety for soil type/condition:** Pachymetra root rot reduces crop yield, therefore at least 25% of the selected farm varieties should be Pachymetra resistant and rotated with other varieties. Some varieties are suited to early, mid-season or late harvest, while others may be suitable for harvest over the entire season. When deciding which variety to plant in a paddock, consider the following:
  - Usual time of harvesting of the block
  - Is the paddock a fallow or plough out and replant?
  - Previous variety grown – consider variety rotations
  - Soil type
  - Drainage
  - Other environment and pest factors.

Above: Good quality billets cut with rubber coated rollers.

Planting machinery

Planting machinery falls into two groups – billet and whole stalk.

Whole-stalk planters that have a cutting mechanism to cut the stalk into manageable lengths of seed cane which are laid end to end by the planter. Whole-stalk planters generally produce better germination than billet planters, however are more labour intensive.

Billet planters can produce inferior results due to harvesting damage to billets. Best results with billet planting are achieved using harvesters that have been modified to cut plants. Modifications normally increase the billet length to about 300 mm and reduce feed roller damage by using worn or rubber-coated rollers. Extra care should also be taken to keep basecutter blades and chopper knives sharp to avoid splitting billets.
Planting operation

Planters combine several operations in the one pass: furrow forming, fertiliser application, placement of billets in the furrow, fungicide and pesticide application, closing of furrow and pressing of soil onto the cane sett.

- **Furrow forming:** the optimum planting depth varies with soil type and drainage conditions. Deep planting in sandy soils can lead to excessive cover if the furrow walls subsequently collapse after rain or irrigation. Similarly, deep planting can cause excessive waterlogging in poorly drained soils.

- **Fertiliser application:** Nitrogen and Phosphorous are required by the plant in the early stages of growth (Potassium tends to damage the billets and therefore should be avoided in planting blends). Fertiliser is applied through adequately calibrated planters.

- **Billet placement:** With either whole stalk or billets, the planting material should be placed end to end in the furrow with minimal gaps.

- **Fungicide and pesticide application:** it is usual to apply a fungicide to cane setts at planting to manage pineapple disease, and to apply an insecticide for wireworm and symphyla control. For fungicides to be effective, cut ends should be covered with fungicide. Ensure good coverage of setts when either applying fungicides or insecticides using spray or dip treatment methods. See the Diseases and disease control section and Pest control section.

- **Furrow closure and rolling:** the amount of soil cover required over cane setts varies with soil conditions. Moist conditions require minimal cover, whereas in dry planting conditions more cover is necessary. Rolling of the furrow after planting to improve contact between the sett and soil is beneficial in many soil types and particularly where the soil tilth is not ideal for planting.

Subsequent cultivation (filling in and hilling up)

- Cultivation of plant cane has the dual purpose of weed control and gradual filling in of the furrow. For green-cane harvesting and trash blanketing, plant cane should be slightly hilled up (100 to 120 mm height) to give a satisfactory stool profile in ratoons where there is usually no hilling up operation. Some adaptation of existing equipment may be necessary to achieve a good filling in operation.

- For furrow irrigation systems, plant cane should be hilled up to allow water movement and penetration.

Row spacing and controlled traffic

Row spacing for sugarcane production has evolved as a compromise between crop agronomy and machinery track width.

The current row spacing traditionally used in the industry is single rows spaced between 1.50 m and 1.65 m apart.

- Unfortunately, the track width of most harvesting and haul-out equipment is 1.8 m. Therefore, at 1.5 m row spacing, the machinery compacts 90 per cent of the total area in a block.

If the row spacing is less than 1.45 m, the harvester wheel or track is on the side of the stool and knocks down and squashes cane before it is cut. Where soil is moist, this also causes soil compaction in the stool area. All of these traffic issues greatly reduce the potential yield of later ratoons.

Additionally, growers do not always ensure that their row spacing is consistent. Quite often the spacing of rows within a field can vary from 1.35 m to 1.65 m, unless managed under a GPS system. Such variation increases the potential for stool damage.

- The improved farming controlled traffic system is matching the row spacing to machinery on GPS guidance systems. This can either be 1.8m single wide rows, 1.8 or 2 m dual row systems.

There are differing systems, however the important point is matching row spacing to both farming and harvesting machinery. This ensures compaction is confined to the interspaces (traffic zone), thus minimizing stool damage in cultivated zone.

- For this system to be fully effective, all machinery used in both the farming and harvesting operations must be fitted with GPS guidance.

- The fallow period presents the opportunity to establish a controlled traffic system.
• The controlled traffic system is improved if the row areas are formed as raised beds or mounds. Forming the beds at the beginning of the fallow allows them to consolidate over the wet season.

There have been germination problems in beds formed pre-planting due to lack of moisture from dry soil being used to form the raised bed. Mounding reduces soil moisture in upper parts of the root zone by 4 to 6 per cent. This reduces water movement through the fertiliser band and nitrogen losses in drainage water. The reduction in soil moisture around the fertiliser band should reduce denitrification. It also clearly defines the row area and therefore assists with the prevention of machinery traffic on the row.

Above: Conventional plant cane 1.5 m spacing.

Above: Dual row controlled traffic farming system.

Above: Dual row controlled traffic farming system diagram.

Above: Compaction resulting from harvesting.

Above: What not to do – tractor wheel on cane row not controlled traffic.

Information sheets available on the SRA website

Simple GPS data collection and mapping
Ratooning

There are two main practices used in the industry today, either burnt cane or green trash blanket.

1. Burnt cane – not recommended

Main operations

- Burning the trash off the crop prior to harvest.
- After harvest cultivation of the interspace using a ripper tine, grubber tines, ratoon discs or some combination of these.
- A single pass to apply fertiliser sub-surface beside the stool.
- For weed control: either subsequent cultivations with grubber tines (interspace), scratcher tines (row) or multi-weeders (entire row) up to the out-of-hand stage; or spray with post-emergent herbicides one or more times to control small weeds; or application of a pre-emergent herbicide.

Above: Burnt cane trash blanket.

2. Green cane trash blanket – recommended

Green-cane trash blanketing offers the combined benefits of minimum or zero tillage and good weed control.

Main operations:

- Harvest the crop green
- A single pass with a fertiliser applicator
- Spraying with post-emergent herbicide, if required.

Publications available on the SRA website

*SmartCane Plant Cane Establishment and Management*

Above: Green cane harvesting.
### Variety selection

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<th>Understanding the sugarcane plant</th>
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<tr>
<td>Drainage</td>
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<td>Pest control</td>
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<td>Harvesting and transport</td>
<td>Milling issues for the grower</td>
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</table>
Variety selection

Everyday advice and recommendations

**QCANESelect®**

- Each season cane growers are faced with a key decision on what variety or varieties to plant. They will need to consider, among other things:
  - Whether that variety should be cut early or late
  - What potential cane and sugar yield is likely to be produced from a variety
  - Whether the variety is performing above or below the mill average
  - The status of the variety in relation to the various diseases and pests present in the region.

- To help growers find answers to these questions, QCANESelect® – an easy-to-use online tool – provides up-to-date information on all available varieties. This free tool is available on the SRA website www.sugarresearch.com.au

- The Variety Information section provides detailed information on all current varieties recommended for planting in each region. The information includes:
  - Parentage
  - Appearance
  - Features
  - Harvesting time
  - Sugar season (early, mid or late)
  - Productivity (cane yield and CCS)
  - Speed of germination
  - Reliability of germination
  - Ratooning
  - Lodging tolerance
  - Reaction to stress (waterlogging, flood)
  - Reaction to diseases
  - Cane grub tolerance
  - Herbicide reaction
  - Crop management issues.

- The user can develop reports for each region that:
  - Compare selected varieties across the range of characteristics listed above
  - Compare the suggested harvesting period for all recommended varieties
  - List the disease resistance of all varieties grown in the region, including varieties not recommended for planting.

- To generate a recommendation for which variety to plant in a block on the basis of relevant disease resistance (for all important diseases in each region), and other important management issues, visit the Block Recommendations section.

- The Whole-of-Farm Planning section allows you to work with the grower to develop a variety plan for the farm, taking into account grower-defined risk management issues.

- The Regional Reporting section contains current and historical mill data so the user can compare the commercial performance of varieties in each region.

**Important tip**

As well as the information contained in QCANESelect®, you can also gather information about varieties from the local trials conducted by productivity services groups and extension agronomists.
We publish regional variety guides annually using data and information sourced from QCANESelect®.

These guides are issued to all growers throughout Queensland and NSW and are available on our website.

Variety guides contain the following information:
- Which new varieties are available and how they performed in regional trials
- Disease ratings for each variety
- When each variety should be harvested
- Which varieties are most suited to the environment of the farm
- Which varieties have performed well over recent seasons.

The use of clean (disease-free) seed cane is vital for all varieties.

Important diseases such as ratoon stunting disease, leaf scald, smut, Fiji leaf gall and mosaic can be introduced in planting material and once present in a block can then spread quickly.

There are two sources of clean planting material – approved seed cane and tissue culture plantlets. SRA manages the supply of both sources in conjunction with productivity services groups following strict protocols to ensure disease-free seed of varieties that are true-to-type.

**Approved seed cane**

Supply and distribution of approved seed cane is managed by your local productivity services group.

Approved seed cane is produced through the following process:

1. Selected stalks are cold-soaked, long hot-water treated and planted into mother plots. These plots are closely inspected for diseases such as smut, chlorotic streak, mosaic and Fiji leaf gall, which cannot be eliminated by hot-water treatment.
2. Plant material from the mother plots is treated again and planted into approved seed plots where they are again closely inspected for diseases, and the variety identity checked by DNA fingerprinting.
3. Plant material from the approved seed plots becomes the approved seed cane supplied to cane growers.

Growers need some approved seed cane every year in order to maintain a continual supply of on-farm disease-free planting material for their commercial blocks.

Plant the approved seed cane into fallow areas to prevent disease contamination from diseased volunteer cane plants. When planting the approved seed cane, it is very important that the planter is sterilised beforehand.

Use only plant or first ratoon material from approved seed cane for commercial block planting material.

When cutting and planting commercial block planting material, ensure all implements are sterilised thoroughly.

**Tissue culture plantlets**

- Tissue culture plantlets are produced from disease-free stock and multiplied in a tissue culture laboratory.
- Tissue culture provides a rapid mass production of disease-free planting material in an easily transportable form. This provides a much faster pathway to commercialisation for new varieties.
- Tissue culture also reduces the need for large hot-water treatment facilities as well as approved seed cane farms.
- However, field management requirements are more intensive than for conventional seed cane planting material.
- Tissue culture plantlets of all approved varieties for each region are available for order from productivity service groups.

**Information sheets available on the SRA website**

Tissue culture plantlets
The Plant Breeding Program involves three core activities:

1. Creating new genetic variation (crossing program).
2. Discriminating amongst this variation (selection program).
3. Continuous improvement of the germplasm/parent population through rapid recycling of elite clones from SRA and international selection programs.

- The parent selection and crossing program is based centrally at our Meringa facility, while the selection programs are conducted in the Northern, Herbert, Burdekin, Central, Southern and Northern NSW regions.

- Variety selection is a lengthy and complex process. An example of the Northern Program timeline:

<table>
<thead>
<tr>
<th>Stage:</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: Progeny Assessment Trials (PAT’s)</td>
<td>1</td>
</tr>
<tr>
<td>Stage 2: Clonal Assessment Trials (CATs)</td>
<td>4</td>
</tr>
<tr>
<td>Stage 3: Final Assessment Trials (FATs)</td>
<td>7</td>
</tr>
<tr>
<td>New commercial variety</td>
<td>12+</td>
</tr>
</tbody>
</table>

- Traits selected for include productivity (TCH, CCS and percent fibre) harvestability and appearance grade (lodging, suckering, side shooting & arrowing) and disease resistance.

- The regional economic and genetic worth of each variety is evaluated using SRA’s selection index rEGV (relative Economic Genetic Value).

  > Varieties with rEGV >10 are likely to have a greater economic return (to whole-of-industry) than those <10.

- New varieties released commercially from the Breeding Program are protected under the *Plant Breeder’s Rights Act 1994* (PBR).
### Nutrition

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<tr>
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</tr>
</thead>
</table>

- **Nutrition**
Nutrition

**Everyday advice and recommendations**

**The SIX EASY STEPS program**

The SIX EASY STEPS program is an integrated nutrient management tool that enables the adoption of best practice nutrient management on-farm. It consists of:

1. Knowing and understanding your soils.
2. Understanding and managing nutrient processes and losses.
3. Regular soil testing.
5. Checking the adequacy of nutrient inputs (for example, leaf analysis).
6. Keeping good records to modify nutrient inputs when and where necessary.

The SIX EASY STEPS program is available to industry through a grower-orientated short course entitled *Accelerating the adoption of best-practice nutrient management*.

The overall objective of the program is to provide guidelines on how to implement balanced nutrition on-farm with the ultimate aim of optimising productivity and profitability, without adversely influencing soil fertility or causing off-farm effects. It is also aimed at giving growers the required skills to develop nutrient management plans for their farms.

**Information sheets and publications available on the SRA website**

Best practice nutrient management SIX EASY STEPS program

**General practice**

With cane grown predominately in monoculture, the general practice is:

- Annual applications of N P K fertiliser
- Application of calcium, magnesium and silicon amendments as required
- Application of trace elements as required
- Irregular use of mill by-products such as mill mud or ash
- Concentrated use of mill by-products within a small radius around the mill
- Routine use of dunder products in the Central region
- Use of soil analysis to determine all fertiliser use. The exceptions are copper, iron, manganese and boron where soil analysis results are unreliable and of limited value.

**Understanding the science**

**STEP 1: Knowing and understanding your soils**

**Physical properties**

Soils are made up of three primary particles sizes, sand, silt and clay. The formation of a soil depends on its parent material, the climate and the soils position in the landscape.

- The **colour** of a soil can give an indication of soil properties and characteristics. Black or dark coloured soils indicate high organic matter, light or bleached colours indicate a highly leached soil, while mottled colours indicate periodic waterlogging and a fluctuating watertable and blue coloured soils indicate prolonged waterlogging.
- The **texture** of a soil can be determined by the relative proportion of sand, silt and clay. Texture influences the structural behaviour of soil. Sands are freely drained and nutrients are easily leached, whereas clays can be more fertile but can waterlog more easily.
- The **structure** of a soil influences the movement of water, gases, seedling emergence and root penetration. Structure describes how the primary particles aggregate into peds or clods.

> See ‘Physical features of healthy soils’ in the Soil Health section.
Chemical properties

• **Cation Exchange Capacity (CEC)** is a soil characteristic that greatly influences nutrient availability. Positively charged nutrients (cations) are attracted to the negatively-charged clay particles and become bound. The CEC of different soils vary depending on organic matter and clay content and it is difficult to change the CEC of a soil.

• **Phosphorus sorption (P-sorption)** is the process of phosphorus binding to the soil particle surfaces and becomes chemically inactive and unavailable to the plant. P-sorption is measured by the Phosphorus Buffer Index (PBI). The PBI of different soils can vary greatly, from weakly bound phosphorus in sandy soils to strongly bound phosphorus in volcanic or peat soils.

• **Soil pH** strongly influences nutrient availability in a soil. Under extremely acid conditions, the macro-elements are largely unavailable, or ‘locked up’ in the soil, while some of the micro-elements (particularly iron and manganese) may be available in excess. The ideal theoretical pH range for the availability of all essential nutrients is 5.5 to 7.0. However, sugarcane is very tolerant of acid soils which is the natural condition on much of the Australian industry.

> See ‘Chemical and Biological features of healthy soils’ in the Soil Health section.

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Information sheets and publications available on the SRA website

Soil-specific nutrient management guidelines for sugarcane production are available for Bundaberg, the Johnstone catchment, New South Wales, Plane Creek, the Proserpine district and other regions.

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Above: Nutrient availability determined by soil pH
STEP 2: Understanding and managing nutrient processes and losses

Essential nutrients for sugarcane

- **Carbon (C)**
- **Hydrogen (H)**
- **Oxygen (O)**
  - (Non-mineral nutrients)

### 6 Macro Nutrients
- **Nitrogen (N)**
- **Phosphorus (P)**
- **Potassium (K)**
  - (Primary nutrients)
- **Calcium (Ca)**
- **Magnesium (Mg)**
- **Sulfur (S)**
  - (Secondary nutrients)
- **Silicon (Si)**
  - (Beneficial element)

### 7 Micro Nutrients
- **Zinc (Zn)**
- **Copper (Cu)**
- **Iron (Fe)**
- **Manganese (Mn)**
- **Molybdenum (Mo)**
- **Boron (B)**
- **Chlorine (Cl)**
  - (Trace elements)

**Nutrient loss pathways**

### Leaching
- Leaching is the movement of water downwards through the soil profile, taking nutrients with it past the root zone.
- Nutrients such as nitrogen (in the nitrate form) and potassium can be lost by leaching.
- Sandy and well-drained soils are most prone to losses from leaching.

### Runoff and erosion
- Runoff and erosion involves the movement of surface waters off a block that takes nutrients and soil with it.
- Most nutrients can be lost by runoff or erosion.
- Sub-surface application of fertilisers is the best option to minimise losses from runoff and erosion.

### Gaseous losses
- Volatilisation is the loss to the atmosphere of nitrogen from urea and urea-based fertilisers as ammonia gas.
- Urea + moisture > dissolved urea + enzyme (urease) > ammonia + carbon dioxide.
- Subsurface application of fertilisers is the best option to minimise losses from volatilisation, or if surface applied, follow the application with more than 15mm of irrigation to wash the urea into the soil without causing runoff.
- Denitrification is the loss of nitrogen from the soil as nitrous oxides and nitrogen gas under waterlogged conditions.
- Nitrogen fertiliser + waterlogging > nitrous oxide gas + nitrogen gas.
- Good surface drainage, splitting nitrogen applications and/or using mounded rows with fertiliser placement higher in the soil profile are options to minimise losses from denitrification.

### Mining
- The sugarcane crop takes up nutrients from the soil. When the crop is harvested, some of these nutrients are returned to the soil from the breakdown of trash and other discarded crop biomass. The nutrients that are present in the cane that is sent to the mill is exported from the block and is therefore lost or mined from the soil.
## Placement of fertilisers

<table>
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<tr>
<th>Situation</th>
<th>Fertiliser placement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant cane</strong></td>
<td>Near but apart from the sett at planting. Top dressing in the drill after germination, before or at fill-in stage.</td>
<td></td>
</tr>
<tr>
<td><strong>Ratoons that are mechanically cultivated after burnt harvest</strong></td>
<td>Either split stool subsurface application</td>
<td>• Both of these are the safest options for N fertiliser applications.</td>
</tr>
<tr>
<td></td>
<td>Or side-banded subsurface application</td>
<td>• Soil moisture should be considered when choosing which subsurface application method to use.</td>
</tr>
<tr>
<td><strong>GCTB ratoon</strong></td>
<td>Either split stool subsurface application</td>
<td>• Not recommended for furrow-irrigated blocks.</td>
</tr>
<tr>
<td></td>
<td>Or delayed surface application, banded along row when canopy is approximately 0.5m high</td>
<td>• Quick and inexpensive, but volatilisation losses may be significant.</td>
</tr>
<tr>
<td></td>
<td>Or surface application soon after harvest</td>
<td>• Can be risky for cane harvest late in the season – if summer rains set in, application may not be possible for an unacceptably long period.</td>
</tr>
<tr>
<td><strong>Burnt cane trash blanketed ratoons (BCTB)</strong></td>
<td>Either side-banded subsurface application behind a coulter/ripper but followed by a crumble roller to break up clods and seal in the fertiliser</td>
<td>• Commercial coulter rippers may bring up large clods in the interspace if moisture conditions are not ideal, leaving a rough surface for next year’s harvesting.</td>
</tr>
<tr>
<td></td>
<td>Or delayed surface application, banded along row when canopy is approximately 0.5m high</td>
<td>• Poor sealing after cultivation allows nitrogen gas to escape to the atmosphere.</td>
</tr>
<tr>
<td></td>
<td>Or delayed surface application, banded along row when canopy is approximately 0.5m high</td>
<td>• Not recommended for furrow-irrigated blocks.</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>Or delayed surface application, banded along row when canopy is approximately 0.5m high</td>
<td>• Can be risky for cane harvest late in the season – if summer rains set in, application may not be possible for an unacceptably long period.</td>
</tr>
</tbody>
</table>
Timing of fertiliser application

Plant cane

- For plant cane, some of the nitrogen and potassium fertiliser and all the phosphorus for the crop are normally applied at planting. The remainder of the nitrogen and potassium is usually applied as a side-dressing at the out-of-hand or hill-up/fill-in stage.

> See the Planting and crop establishment section for more information.

Ratoon cane

- In ratoons, N, P and K are sometimes applied immediately post-harvest as a single application subsurface, but this is not generally recommended. To reduce volatilisation losses from surface applications, it is recommended that these be delayed, if practical, until the crop is at least 50 to 70 cm tall.

- Similarly, high losses by denitrification/leaching have been measured where heavy rain falls soon after fertiliser is applied. Split application of fertiliser may be preferable in poorly drained blocks.

Other

- Ameliorants such as lime, calcium-magnesium blends and dolomite are best applied in the fallow to allow mixing in the soil and time for reaction.

- Mill mud can be applied either in the fallow or to existing crops.

STEP 3: Regular soil testing

Soil analysis

Soil analysis involves taking a sample of the soil and sending it to a laboratory for analysis. The sampling process is as follows.

- Obtain soil sample bags from a consultant or fertiliser reseller.

- Use an ungalvanised auger, soil tube or spade to take the samples.

- Take samples to a depth of about 200 mm. However, if salinity and/or sodicity are suspected, take samples at 200 mm intervals to a depth of at least 800 mm.

- Ensure samples are representative of the area to be tested by avoiding unusual areas such as old drain lines, windbreaks, near trees, regularly used tacks etc. Also avoid old fertiliser bands, areas of different crop growth, different soil types, and areas where different drainage or management practices (liming, fertilising, mill mud application) have been recently applied. Sample these areas separately if the constitute a significant proportion of the block or if the purpose of sampling is to diagnose potential nutritional problems in these areas.

- Sample the area on a grid or by using a zig zag pattern to obtain at least 15-20 subsamples. The most common mistake is taking too few subsamples to adequately represent the area being tested. Electrical conductivity mapping (EC mapping) can be used to determine differences in soils and indicate where areas should be tested separately. Following this sampling procedure allows for a precision agriculture (PA) approach to nutrient applications.

- Mix the subsamples thoroughly in a clean plastic bucket or on a clean plastic sheet, and fill the soil sample bag/s with 0.5 to 1.0 kg of soil. Discard the remaining soil.
• Dispatch the samples to the laboratory immediately after collection, as changes in available nutrient status can occur over time. If the samples have to be kept for later dispatch, store them in a refrigerator.

• Choose a laboratory that is familiar with the sugar industry’s critical values.

Important tip

Cleanliness is essential throughout the sampling procedure. Potential sources of contamination are fertiliser or chemicals in buckets, sample bags or sampling gear, sunscreen, and ash from cigarettes. If testing for zinc, avoid galvanised augers or spades or wire handles on buckets (where possible) as these may contaminate the sample.

Above: Electrical conductivity (EC) map showing soil sampling locations.

Information sheets and publications available on the SRA website

Soil sampling

STEP 4: Adopting soil-specific nutrient management guidelines

Soil analysis results and interpretation

Depending on the laboratory and type of soil test, the soil analysis results will include assessments for pH, organic carbon, phosphorus buffer index (PBI), nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, copper, zinc, iron, manganese, boron and silicon.

By Queensland law, soil tests used in the Australian sugar industry require results for organic carbon, PBI and P(BSES). The results may also include determinations for electrical conductivity, sodium percentage cations and aluminium saturation percentage.

Soil analysis results are not reliable or of much value for copper, iron, manganese and boron. The main focus is on the results for phosphorus, potassium, calcium, magnesium, sulfur, and organic carbon (as a guide for nitrogen). Buffer pH, conductivity, sodium and percentage cations are used to identify other soil problems and define nutrient balances.

Results for the above ‘key’ nutrients are assessed against critical values established from experiments conducted by SRA and other researchers. Different laboratories that service the sugar industry may have slightly different critical values due to different laboratory methodologies, but the differences are generally minor. Regular exchanges of samples between laboratories ensure relativity of analyses.

Comparing the soil analysis results against the critical values enable a determination to be made on the amount of nutrient (fertiliser) required.

Nitrogen (N)

• Determine nitrogen fertiliser needs by using the relevant regional SIX EASY STEPS interpretation chart.

• Optimum fertiliser rate for the most economic return depends on a number of factors including crop class, whether a legume has been grown, soil type, whether mill by-products have been used, rainfall, length of time green cane trash blanketing (GCTB) has been practised, and irrigation.

• The organic carbon result in a soil test report is used to determine nitrogen rates in all soil types.

• If there is too much nitrogen (from excessive applications of nitrogen fertiliser), the levels of amino acids, particularly asparagine, are very high, resulting in prolonged growing conditions, lower CCS and reduced juice purity. Amino acids react with reducing sugars (glucose and fructose) during milling to produce high molecular weight colourants that colour sugar crystals and reduce sugar quality.

• Too much nitrogen also increases the probability of crop lodging and stimulates suckering.

• Nitrogen rates are reduced for a plant crop after a fallow period due to soil mineralisation of N.

• Nitrogen rates for plant cane can be reduced following a heavy legume crop.

• Do not exceed recommended rates based on SIX EASY STEPS, as this is illegal under Government legislation.

Phosphorus (P)

• Determine phosphorus fertiliser needs by using the relevant regional SIX EASY STEPS interpretation chart.

• Because phosphorus is generally applied along with nitrogen and other nutrients, and to reduce the risk of surface runoff, apply it subsurface with a stool splitter or a side-banded applicator.

• Many Australian cane-growing soils now have moderate to high levels of available phosphorus because of the long-term use of rates above crop and soil requirements prior to 1983. As a result, phosphorus can sometimes by omitted from at least one ratoon crop with no effect on yield, provided soil test results indicate adequate levels.
• Do not exceed recommended rates based on SIX EASY STEPS, as this is illegal under Government legislation.

• Two tests are required from a soil analysis report to determine phosphorus applications rates.
  > Phosphorus Buffer Index (PBI) + P \(_{BSES}\)

Potassium (K)

• Determine potassium fertiliser needs by using the relevant regional SIX EASY STEPS interpretation chart.

• Because potassium is generally applied along with nitrogen and other nutrients, and to reduce the risk of surface runoff, apply it subsurface with a stool splitter or a side-banded applicator.

• Do not exceed recommended rates based on SIX EASY STEPS, as the crop will luxury feed on any excess potassium.
  > This will not improve CCS or yield, but will cause manufacturing problems in the raw sugar mill and refinery due to the increased ash content of the juice.

• In plant cane, potassium fertiliser may cause fertiliser burn which affects root and shoot development if it contacts the sett at planting. The damage is caused by osmotic desiccation of plant cells and is effectively a salting injury. The result is delayed or failed germination of some of the eyes of the sett and root stubbing. To avoid this problem, the fertiliser must be placed so it does not come in direct contact with the sett. Some growers prefer to plant with a N and P mixture such as DAP (di-ammonium phosphate) and then apply the rest of the crop’s nitrogen as well as its potassium requirements at the filling-in stage when the crop is well established.

• Two tests are required from a soil test report to determine potassium applications rates.
  > Exchangeable or available potassium (amm. acet.)
  > Reserve potassium (Nitric K)

Calcium (Ca)

• Determine calcium needs by using the relevant regional SIX EASY STEPS interpretation chart. This facilitates a choice of lime or lime/magnesium blends to provide the required rate of calcium.

• In most instances, a lime application should last approximately five to six years. Rather than applying the full quantity of a liming product at the end of the crop cycle, smaller but more frequent liming product applications will reduce marked changes in the soil calcium values and may help with on-farm cash flow. A soil test at the end of each crop cycle will assist with this decision.

• Liming may induce zinc and copper deficiency symptoms if the levels of those nutrients are already low. It does not mean that the liming should not have been carried out.

Lime application is always necessary if soil calcium levels are low. Ensure the low zinc and copper levels are also rectified in accordance with the soil test results.

• Broadcast agricultural lime and calcium/magnesium blends to the fallow block at least one month, but preferably up to three months, before planting.

• After application, incorporate into the soil. This practice will allow the slow-acting product time to react with the soil, making some calcium available to the young cane plant. If the calcium-depleted block is not fallowed, apply prior to replant. However, the following crop may gain limited benefit from the calcium as it is only slowly available for crop growth.

• Calcium deficiency is now more common in sugarcane as most cane land no longer receives regular applications of the calcium contained in the superphosphate widely used in low-analysis fertiliser mixtures before 1970. Today’s high-analysis mixtures are based on DAP or MAP, which contain no calcium.

Magnesium (Mg)

• Determine magnesium needs by using the relevant regional SIX EASY STEPS interpretation chart.

• Calcium and magnesium deficiencies often occur together. In that case, a calcium-magnesium blend is recommended.

• For calcium-magnesium blended products, an application of magnesium should last at least one crop cycle. Rather than applying the full quantity of a magnesium product at the end of the crop cycle, smaller but more frequent applications will reduce marked changes in the soil magnesium values and may help with on-farm cash flow. A soil test at the end of each crop cycle will assist with this decision.

• As with liming, broadcast calcium/magnesium blends to the fallow block at least one month, but preferably up to three months, before planting.

• If the magnesium-depleted block is not fallowed, apply prior to replant. However, a fast-acting magnesium source may be preferable so the replant crop can access sufficient magnesium to benefit the crop growth.

Zinc (Zn)

• Determine zinc needs by using the relevant regional SIX EASY STEPS interpretation chart.

• One application of a zinc product will last several crop cycles.

• A soil test at the end of each crop cycle will assist with this decision.
**Sulfur (S)**

- Determine sulfur needs by using the relevant regional SIX EASY STEPS interpretation chart.
- The most convenient forms of sulfur fertilisers are the sulfur-fortified mixtures or sulfate of ammonia that can be applied at planting or when fertilising the ratoon crop.
- Low-soluble sulfur sources should be spread over the fallow block and incorporated into the soil before planting. For replant blocks, a soluble form of sulfur is recommended.
- Sulfur deficiency in Australian sugarcane is increasing.
- Sulfate accumulation in subsoil in the form of pyrite (iron sulfide) under anaerobic (waterlogged) conditions causes no damage. However, if this material is exposed to the atmosphere as drainage spoil, there is a rapid oxidation resulting in the formation of sulfuric acid which causes a drastic reduction of soil pH and the toxic release of aluminium. This is called acid-sulfate subsoil toxicity. Yield loss will occur if this material is spread on the block.

**Sodium (Na)**

- High soil sodium levels cause the breakdown of the soil structure which affects both aeration and water penetration. Some soils are extremely sensitive to sodium. Exchangeable sodium levels of 5 to 15 per cent of exchangeable cations may cause some breakdown of soil structure. A figure in excess of 15 per cent indicates severe structural deterioration in most soils.
- Salinity is caused by an excess of soluble salts in the soil. The most common salt in problem areas in the sugar belt is sodium chloride (table salt). Salinity induces water stress which is evident in cane by premature wilting and scorching of the leaves, restriction in growth, and in severe cases, death of the plant. Sugarcane is regarded as a relatively salt sensitive plant, but there are varietal differences in salt tolerance.
- Excess sodium can cause soils to be saline, sodic or a combination of both known as saline-sodic.

> In saline soils, excessive levels of salt are found in the soil water which restricts plant growth. The salt is soluble and can be leached with water through the soil profile. Saline soils are generally more friable than sodic soils. Saline soils are usually associated with salt water intrusion of low-lying lands along the coast, either by inundation by sea water or a rise in the watertable.

> In sodic soils, the clay particles are dispersed by the presence of high levels of sodium attached to them. Sodium in this form is referred to as exchangeable sodium, high levels of which cause the breakdown of the soil structure, giving rise to areas call soda patches. The soil water is not saline as in saline soils. Sodic soils are poorly aerated and nutrient uptake is restricted.

---

**Reclamation of saline and sodic soils**

<table>
<thead>
<tr>
<th>Saline soils</th>
<th>Sodic soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ensure the salinity of irrigation water is within the recommended levels.</td>
<td>• Improve surface and subsurface drainage to promote leaching of displaced sodium salts from the soil profile.</td>
</tr>
<tr>
<td>• Improve surface and subsurface drainage to promote leaching of accumulated salts.</td>
<td>• Ensure that the sodium and/or bicarbonate levels in the irrigation water do not exceed the recommended standards.</td>
</tr>
<tr>
<td>• An application of gypsum may be beneficial once drainage has been improved.</td>
<td>• Apply gypsum or mill ash to promote replacement of sodium on the clay particles by calcium, and to improve soil structure.</td>
</tr>
</tbody>
</table>

*Saline soils are usually associated with salt water intrusion. Affected areas can be reclaimed by providing adequate surface and subsurface drainage, preventing salt water intrusion, and leaching the accumulated salt through the soil profile. Sodium is found in plant tissues in trace quantities but is not considered essential for plant growth. Severe salinity causes death of cane. The high concentration of sodium in the soil adversely affects root and top growth.*
Other nutrients (Cu, Si, Mn, Mo, B)

- Determine other nutrient needs by using the relevant regional SIX EASY STEPS interpretation chart.
- Take care not to apply too much copper fertiliser when treating copper-deficient areas. Copper toxicity is very easy to induce if recommended application rates are exceeded, but can be overcome by liming the soil.
- Toxicities are very easy to induce for boron, molybdenum and manganese. Sugarcane crops require very small amounts of these nutrients which are naturally available in the soil. Applications of these nutrients in not recommended as deficiencies have not been reported in Australian sugarcane growing soils.

Fertiliser types

Solid fertilisers

- Available as straight or mixed fertilisers. Mixed fertilisers may take the form of either low-analysis or high-analysis NPK mixtures. Mixtures may be fortified with sulfur, copper or zinc to correct specific deficiencies. Calcium and magnesium deficiencies are corrected by lime, Ca-Mg blends or dolomite applications.

Liquid fertilisers

- Liquid fertilisers are being increasingly used as an alternative to solid granulated formulations. The most common liquid fertiliser is granulated urea dissolved in water. Soluble forms of phosphorus, potassium and sulfur are often added. On some occasions, growers use a mixture of dissolved urea and dunder. Some liquid products have added trace elements and ‘microbes’, but there is as yet little scientific evidence to back up the benefits that these products claim to deliver.

- The benefits of using liquid fertilisers include:
  > Consistent application rates
  > More even distribution of the product throughout a block than with bagged, prilled product
  > Reduced occupational health and safety risks
  > Logistically easier to use than bagged fertiliser.

- Some companies provide an application service, which is attractive to many growers. If used correctly and at rates that apply the same amount of nutrients as granular fertilisers, the only disadvantage of liquid fertiliser is likely to be the cost. Liquid fertilisers are composed mostly of the water the nutrients are dissolved in, and there are costs associated with mixing and transportation.

- Growers should calculate and compare the real cost of nutrients obtained from both the liquid and solid forms, based on the amount of nutrients per hectare.

- Even where the liquid form may be more expensive, the advantages mentioned above may outweigh that extra cost for some growers.

- The safest and best-value method of applying liquid fertilisers is subsurface application. This is because foliar application may severely burn the leaves, and surface application on the soil or trash blanket risks the same nitrogen volatilisation losses as surface application of any urea-based product.

- Sugarcane can only take up limited amounts of nutrients through its leaves, so foliar application is only suitable for applications at very low rates.

Mill by-products (mill mud, mill ash and mud-ash mixtures)

- The by-products of raw sugar manufacture (filter mud, ash, mud-ash mixtures and molasses) and of ethanol production (liquid dunder and biostil dunder) are valuable fertiliser sources.

- Mill by-products are available in most mill areas and are economic to use within a limited radius around the mill.

- These products supply an almost complete nutrient mixture and are useful for rejuvenating poor patches in blocks.

- However, because of the organic nature of mill mud, molasses and dunder and the fused condition of ash, precise information on the rate of release of nutrients for use by the cane plant is not known.

Legumes

- While legumes are not technically a fertiliser, they can provide a significant quantity of nitrogen for the following plant crop, as well as organic matter if grown and managed well.

- Nitrogen rates for plant cane can be reduced by at least 50 to 60 kg/ha following a well-grown legume crop.

Information sheets and publications available on the SRA website

SIX EASY STEPS Nutrient Guidelines for WET TROPICS
SIX EASY STEPS Nutrient Guidelines for TABLELANDS
SIX EASY STEPS Nutrient Guidelines for HERBERT
SIX EASY STEPS Nutrient Guidelines for BURDEKIN
SIX EASY STEPS Nutrient Guidelines for PROSERPINE
SIX EASY STEPS Nutrient Guidelines for MACKAY
SIX EASY STEPS Nutrient Guidelines for PLANE CREEK
SIX EASY STEPS Nutrient Guidelines for SOUTHERN DISTRICTS
SIX EASY STEPS Nutrient Guidelines for NSW
STEP 5: Checking the adequacy of nutrient inputs

Leaf analysis

Leaf analysis is a useful supplement to soil testing for evaluating the fertility status of the crop and assessing the adequacy of fertiliser recommendations. Caution is needed when interpreting the results, since many factors, apart from nutrient availability, can influence nutrient levels in a plant. These factors include the age of the plant, the cane variety, environment issues such as water stress, and interactions between nutrients.

Procedure for leaf sampling

- Ensure the crop to be analysed is actively growing and is three to seven months old.
- Ensure the crop is not affected by some other factor such as disease, insect damage or abnormal climatic factors such as waterlogging or drought.
- Take samples between November and April in Queensland, and between December and March in NSW when moisture stress is usually not a problem.
- Ensure at least six weeks have passed since any fertiliser application.
- Select stalks of average height and take only the 200 mm mid-sections from the third leaf, with the mid-rib removed and discarded. The first leaf that is more than half-unrolled is counted as the first leaf.
- Collect a total of at least 20 leaves for each sample. Place samples in a clean paper bag and store in a polystyrene cooler prior to laboratory drying at 70°C. Once the sample is dry, include relevant information about the sample and send it to the laboratory for analysis.
- As with the collection of soil samples, cleanliness is essential. Ensure that samples do not become contaminated by soil, fertiliser, dust, agricultural chemicals and galvanised coatings.

<table>
<thead>
<tr>
<th>Third leaf assay</th>
<th>Unit</th>
<th>Critical level of assay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>%</td>
<td>November to mid-January: 1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mid-January to February: 1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>March to May: 1.7</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>%</td>
<td>0.19</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>%</td>
<td>1.1</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>%</td>
<td>0.20</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>%</td>
<td>0.08</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>%</td>
<td>0.13</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>mg/kg</td>
<td>2</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>mg/kg</td>
<td>15</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>mg/kg</td>
<td>15</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>mg/kg</td>
<td>1</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>mg/kg</td>
<td>0.08</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>%</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Information sheets and publications available on the SRA website

Leaf sampling

On-farm trials

It is important to check the adequacy of nutrient inputs by comparing to other (usually higher, but sometimes lower) rates.

For growers to do this, commercial sized replicated strip trials are recommended. It is important to only change one nutrient at a time when conducting these trials. It is also important to ensure that each strip is big enough to provide a CCS sample at the mill. Advice from a trusted source is recommended before setting up an on-farm trial.
Record keeping is an important practice to undertake. While it is now regulated that nutrient inputs be recorded, it is also important to understand the usefulness of records and how they are vital for success. Records can be used to monitor production trends, check the adequacy of fertiliser inputs – as with STEP 5 – and record the results of any product or management changes to determine their impact.

**Information sheets and publications available on the SRA website**

<table>
<thead>
<tr>
<th>NutriCalc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding the fertiliser that best suits your needs</td>
</tr>
<tr>
<td>CaneClip: How to use FertFinder</td>
</tr>
</tbody>
</table>
Diseases and disease control
Everyday advice and recommendations

Disease control basics

A disease control program consists of six key elements:

1. Plant resistant varieties approved for each district.
2. Use approved seed cane or its progeny.
3. Disinfect equipment.
4. Apply good cultural management.
5. Use chemicals for treating planting setts for pineapple disease, and in certain situations to control nematodes and smut.
6. Observe quarantine restrictions on moving sugarcane and machinery between quarantine areas.

1. Plant resistant and intermediate varieties approved for each district

- All new varieties are screened for resistance to eight diseases before they are released to industry. These diseases are Fiji leaf gall, leaf scald, mosaic, red rot, Pachymetra root rot, smut and chlorotic streak. Observations on the resistance of varieties to other diseases such as yellow spot, ratoon stunting disease (RSD), orange rust and common rust are also noted. As a result, varieties that are resistant or intermediate resistant to most of the major diseases are now available. Use these wherever possible, particularly where there is a high risk of a particular disease.

- Information on the resistance of all available varieties is on QCANESelect® – a variety decision-support tool available on the SRA website.

- Check that varieties are recommended for planting in your district. The list of recommended varieties for each district is also on QCANESelect®.

Above: Billet planter in the field.

2. Use approved seed cane or its progeny

- As many of the major diseases can be transmitted in planting materials, use approved seed cane or planting material derived from approved seed cane for each new planting.

- Approved seed is produced under strict quality assurance guidelines that reduce the risk of diseases being present. It is hot-water treated and checked for RSD, Fiji leaf gall, smut, leaf scald, chlorotic streak, mosaic and other major diseases.

- On-farm multiplication of planting material from approved seed must be done in a field where there is minimal disease present and where the previous crop has been completely destroyed. To avoid volunteer plants carrying any diseases into the approved seed, do not plant approved seed after plough out replant.

- In some areas where insect-vectored diseases such as Fiji leaf gall and mosaic are active, it may be necessary to inspect the first and second progeny from approved seed. Productivity service groups offer an inspection service in most areas.

- Where farmers may not have sufficient quantities of first or second progeny of approved seed to plant their fields, other plant sources should be used only after inspection by an experienced productivity service inspector, who would look for visual symptoms of diseases and take samples for testing for RSD.
• All cane planted into seed plots for multiplication that has not come from an approved plot should be from the cleanest source on the farm, test negative for RSD, and be of good quality for planting. It should then be treated as required, as follows, for:
  > RSD: long hot-water treatment (LHWT) for 3 hours at 50°C
  > leaf scald: cold-soak, long hot-water treatment (CSLHWT), for 40 hours in cold water, followed by hot water at 50°C for 3 hours, within 6 hours of being removed from the cold soak
  > chlorotic streak: short hot-water treatment (SHWT) for 30 minutes at 50°C.
• Hot-water treatment facilities are operated by some productivity service groups.
• Tissue culture is another way of obtaining approved seed. See the Variety selection section.

Above: Whole stick cane being prepared for hot water treatment.

Important tip
RSD is a highly transmissible disease. Planting one infected stalk in a trash planter may lead to infection of the next 100 stools of cane through the transfer of infected juice on the blades of the planter. A cane harvester can also spread the disease.

3. Disinfect equipment
• A number of diseases such as RSD and leaf scald can be transmitted on cutting implements and general machinery. These include cane knives, chain saws, plant cutters, planters, toppers, bins used to transport billets for planting, harvesters and juice samplers.
• All such equipment should be regularly disinfected with methylated spirits diluted to 70 percent with water (cane knives and secateurs) or a commercial, registered sterilising agent containing 0.1 percent benzalkonium chloride or didecyldimethyl ammonium chloride (plant cutters, trash strippers, toppers, harvesters, haul-out vehicles). Keep the equipment wet with the product for at least five minutes.
• Before sterilising, thoroughly clean the equipment by removing all soil and plant material with water and detergent under high pressure.
• It is important that a number of parts of the cane harvester are treated to prevent disease transmission, including the base-cutter blades, chopper box and extractors.
• Discard steriliser solution when dirty or not fresh, according to label instructions.
• In planting machines it is essential to flush and disinfect recirculating fungicide spray systems because they can harbour RSD and leaf scald bacteria.

4. Apply good cultural management
• Minimise the incidence of other disease hosts around cane crops. These include guinea grass (Panicum maximum), corn (Zea mays) and elephant grass (Pennisetum purpureum).
• Destroy diseased cane crops as soon as possible to prevent them acting as reservoirs for spread into neighbouring crops. This is particularly important for Fiji leaf gall disease.
• Improve drainage of low-lying wet areas to reduce the risk of chlorotic streak, bacterial mottle and Sclerophthora diseases. Recycling irrigation drainage water can spread chlorotic streak from one field to another.
• Fallow periods and/or alternative break crops provide an opportunity to remove all volunteers from the previous crop, which may be harbouring diseases, and to reduce the populations of some soil pathogens such as nematodes. Plough out replant can lead to a build-up of diseases.

Above: A fallow crop of peanuts.
5. Use chemicals for pineapple disease (sett rot) and in certain situations, nematodes and smut

Pineapple disease

- There is only one disease for which chemicals are routinely used – pineapple disease. The fungicide protects the setts or billets at planting to prevent the pineapple disease fungus from entering the cut ends, growth cracks or injuries.

- The fungicide is applied during planting by spray nozzles or dips mounted on planting machines. Complete coverage of the whole sett or billet is critical. Vegetable dyes can be used to gauge the effectiveness of spray coverage.

- As some diseases can be spread in the fungicide treatment system, it is important to empty and sterilise the system between plant sources. Also change the fungicide at regular intervals according to the label to ensure freshness and activity.

- Currently registered fungicides are shown in Table 1.

![Spray boom applying fungicides to billets at planting.](image)

**Table 1**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Registered products</th>
<th>Rate of use</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 g/L propiconazole</td>
<td>Tilt® 250ec, Bumper® 250ec, Throttle®</td>
<td>20 mL/100 L water</td>
<td>Ensure thorough coverage of the cut ends of sugarcane setts.</td>
</tr>
<tr>
<td>500 g/L propiconazole</td>
<td>Tyrant® 500</td>
<td>10 mL/100 L water</td>
<td>Ensure thorough coverage of the cut ends of sugarcane setts.</td>
</tr>
</tbody>
</table>

**Continued:**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Registered products</th>
<th>Rate of use</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayfidan® 250ec</td>
<td>250 g/L triadimenol</td>
<td>20 mL/100 L water</td>
<td>Apply to setts by dipping or spraying. Ensure thorough wetting of cut ends.</td>
</tr>
<tr>
<td>450 g/L prochloraz</td>
<td>Sportac®</td>
<td>40 mL/200 L water</td>
<td>Apply as a dip or spray to setts at planting. Ensure thorough coverage of all cut ends.</td>
</tr>
<tr>
<td>120 g/L mercury (Hg) present as methoxy ethyl mercuric chloride</td>
<td>Shirtan®</td>
<td>250 mL/200 L water</td>
<td>See below.</td>
</tr>
<tr>
<td>500 g/L flutriafol</td>
<td>Sinker®</td>
<td>500 mL/ha or 7.5 mL/100 m row*</td>
<td>See below.</td>
</tr>
<tr>
<td>500 g/L propiconazole</td>
<td>Tilt® 250ec, Bumper® 250ec, Throttle®</td>
<td>20 mL/100 L water</td>
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</tr>
<tr>
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<td>Tyrant® 500</td>
<td>10 mL/100 L water</td>
<td>Ensure thorough coverage of the cut ends of sugarcane setts.</td>
</tr>
</tbody>
</table>

* The rate is based on single row cane with a 1.5 m row spacing. If row spacing varies from 1.5 m then apply at the use rate according to mL/100 m of row.
**Nematodes**

- The use of chemicals for nematodes is generally restricted to light, sandy soils. They may be economical only when sugar prices are high and if monitoring indicates many root-knot nematodes are present.
- Chemicals will kill some natural enemies and will reduce nematode populations only for a few months.
- To reduce nematode numbers, plant nematode-resistant legumes in the fallow.
- Currently registered nematicides Rugby100G®, Nemacur100G® (granules) and Nemacur 400® (liquid).

**Smut**

- A chemical treatment to prevent reinfection by sugarcane smut for up to six months in plant cane is available. This is shown in Table 2. This chemical also controls pineapple disease.

### Table 2

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Registered products</th>
<th>Rate of use</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 g/L flutriafol</td>
<td>Sinker®</td>
<td>500 mL/ha or 7.5 mL/100 m row*</td>
<td>See below.</td>
</tr>
</tbody>
</table>

Apply as a spray onto setts in the planting chute. The spray should be applied with a minimum of 4 nozzles arranged in the planting chute to give thorough coverage of all surfaces of the setts before they are planted in the furrow.

Apply in a minimum water volume of 350 L/ha and calibrate the planter prior to application and planting to give the correct rate of fungicide (500 mL/ha or 7.5 mL/100 m row).

The use of a non-ionic wetting agent at recommended rates will enhance coverage of the fungicide on the planting material.

* The rate is based on single row cane with a 1.5 m row spacing. If row spacing varies from 1.5 m then apply at the use rate according to mL/100 m of row.

---

### 6. Observe quarantine restrictions on moving sugarcane and machinery between quarantine areas

- Quarantine aims to restrict the spread of unwanted pests and diseases by controlling the movement of plants, soil, contaminated machinery and other contaminated items. Effective quarantine is vital for the continued competitiveness of the Australian sugarcane industry.
- Those involved in the industry should be aware of the importance of quarantine.

### International quarantine

- International quarantine is managed by Australian Government laws administered by the Department of Agriculture. Sugarcane can be imported into Australia only under permit from DA. The conditions for importing sugarcane can be found on the DA website – apps.daff.gov.au/icon32/asp/ex_querycontent.asp
- SRA has a DA-approved post-entry quarantine facility in Brisbane. Cane imported by SRA is maintained in the facility for two years and undergoes intensive visual inspections and tests for diseases of quarantine concern before release.
- The *Sugar Industry Biosecurity Plan* is a detailed document which outlines key threats to the industry, risk mitigation plans, identification and categorisation of exotic pests and contingency plans. This document has been prepared by Plant Health Australia in cooperation with industry and state and federal governments and can be found on the Plant Health Australia website www.planthealthaustralia.com.au/industries/sugarcane/
- The *Emergency Plant Pest Response Deed* is an agreement between federal and state governments and industry on the funding of a response to an incursion of an exotic pest or disease. Details of the Deed and how it relates to sugarcane are outlined in the Sugar Industry Biosecurity Plan.
- Researchers who travel overseas should be aware of the risk of carrying spores of some fungi and insects on their clothes, notebooks, cameras and any other equipment they may be carrying. Spores of some exotic diseases, such as leaf scorch, and small insects such as thrips and aphids can be easily carried on clothing. All travellers who walk through cane fields should launder their clothing in hot water before returning to Australia or immediately on return. Shoes should be cleaned thoroughly by scrubbing with a hot water and detergent mixture or swabbing with 70 percent methylated spirits. Other equipment should be cleaned and disinfected where possible, with particular care to remove all sugarcane residues.

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**Important**

- Nematicides are dangerous poisons. Always read and follow label safety directions.
Important diseases

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Main management strategies for important diseases

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<td>• Fiji leaf gall</td>
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</table>
1. Ratoon stunting disease (RSD)

Cause

- The bacterium *Leifsonia xylii* subsp. *xylii*.

Occurrence

- Found in all districts in eastern Australia, but not yet in Western Australia.
- More severe in older ratoon crops under dry conditions.

Symptoms

- Produces no external symptoms other than stunting. Diseased fields often have an ‘up-and-down’ appearance due to differing levels of stunting in adjacent stools.
- The only visual symptoms are red-orange dots or ‘commas’ in the vascular traces in the nodal tissue, which can be seen when stalks are sliced open with a sharp knife, and a faint pink discolouration of the growing point of young plants. However, these symptoms are not always present and some varieties can show similar symptoms when not infected.
- Commonly causes losses of 20 to 30 percent but may cause yield losses of up to 60 percent in susceptible varieties suffering moisture stress.

Spread

- There are three main ways it spreads:
  > Diseased planting material
  > Juice from infected plants on cane knives, plant cutters, trash strippers, toppers, planters, harvesters and haul-out vehicles
  > The recirculating fungicide spray system on planting machines.
- The bacteria can survive for up to seven days on cutting implements.
- Not known to naturally infect any other plant species.
- New crops can become infected during the first harvest, if diseased volunteer plants from the previous crop are present. The ‘plough out replant’ practice could sharply increase the disease, because without a fallow period it is almost impossible to prevent the growth of potentially infected volunteer plants.
- Once a field is infected, it is virtually impossible to prevent spread within that field.

Control

- Plant approved seed cane into fallow plant blocks.
- To prevent spread between blocks, disinfect all cutting equipment by first removing all soil and plant material with water and detergent under high pressure, then spraying with a registered product containing 0.1 percent benzalkonium chloride (Cane Knife Steriliser) or didecyldimethyl ammonium chloride (Steri-maX). Leave the disinfectant in contact with the equipment for five minutes before rinsing or using it.
- Harvest known infected blocks late in a rotation and sterilise harvester after harvest.
- Some commonly used varieties have partial resistance but many highly productive varieties are highly susceptible and may lose substantial yield.

Below: Comparison of infected and healthy cane (diseased on left, healthy on right).

Above: Internal stalk symptom showing the red-orange dots or commas in the vascular tissues of the nodes in top stalk compared to healthy stalk below.
2. Chlorotic streak disease (CSD)

Cause

- Unknown.

Occurrence

- Occurs in all regions, often associated with wet and poorly drained fields. Drier regions generally have a lower incidence of the disease.

Symptoms

- Irregular, yellowish to whitish streaks with wavy or ill-defined margins on the leaf blade and to a lesser extent, on the midrib and leaf sheath. The streaks follow the general direction of the vascular bundles, varying in length and width.

- Streaks may become partly necrotic, with the necrosis characteristically occurring in the centre of the streak. This is different to leaf scald, where the death of tissue starts at the edge of the leaf and extends down the leaf streak.

- Internally diseased stalks often show one to several reddened vascular bundles through the nodes.

- Wilting of the plant (even when soil moisture is adequate).

- Reduced and weakened germination and ratooning. Yield loss of up to 70 percent is possible in susceptible varieties.

Spread

- The disease is spread through the soil by water and is common in flood-prone and waterlogged soils.

- Transmission is favoured by ratooning cane when the soil has high moisture content.

- The practice of recycling irrigation tail waters to irrigate fields has led to an increase in the incidence of the disease in these blocks.

Above: Leaf symptoms of chlorotic streak.

Control

- Plant only approved seed cane.

- Improve soil drainage in low-lying wetter areas.

- Avoid highly susceptible varieties. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on susceptible varieties.

Information sheets available on the SRA website

Chlorotic streak

Publications available on the SRA website

Diseases of Australian Sugarcane Field Guide

Diseases managed primarily by use of resistant varieties

1. Brown and orange rust diseases

Cause

- Brown rust – Puccinia melanocephala.
- Orange rust – Puccinia kuehnii.

Occurrence

- Brown rust is regularly seen in all districts.
- Orange rust was considered a relatively minor disease until 2000 when it infected areas in all districts planted with the popular variety Q124. It is now found in all districts.
Symptoms

**Brown rust**

- First appears as small, elongated, chlorotic spots on the younger leaves.
- These soon develop into red-brown to brown, elongated, narrow lesions.
- The fungus ruptures the lower leaf surface to cause pustules from which the spores are released. Rubbing a hand along the leaf surface leaves a brown dusty colouration on the fingers as the spores adhere to the skin.
- Very little green leaf tissue remains in severely diseased crops. The ruptured leaves allow water to escape, leading to moisture stress and reduction in growth.

**Orange rust**

- Distinguished from brown rust by the fact that lesions are an orange colour, they tend to occur in clusters, and they are not evenly spaced over the leaf blade.

Spread

- Brown rust is favoured by warm, dry days and cool nights with dew. It is usually more severe in late spring and early summer (September–December) and tends to disappear with the onset of summer rains. Favourable conditions later may lead to further disease development. Older crops are more resistant than younger crops.
- Orange rust is favoured by high humidity and high temperatures, typical during the wet season.
- Wind-blown spores spread both diseases. Because they are small, rust spores may travel great distances. When brown rust entered Australia in 1978, the disease spread from Cairns to NSW in one season.

Control

- Plant resistant varieties. Visit QCANESSelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.

2. **Yellow spot disease**

Cause

- The fungus *Mycovellosiella koepkei*.

Occurrence

- A disease of the wet tropics it is favoured by warm wet conditions.
- It is regularly severe between Tully and Gordonvale but under the right conditions it can occur in most districts.

Symptoms

- Irregular-shaped, yellow spotting of the leaf surface. Symptoms first appear on younger leaves.
- As the leaf matures, reddening increases to a general rusty yellow with most of the green area destroyed, and the leaves die prematurely.
• In some varieties, leaves turn bright red in severe cases.

• Severe damage causes premature leaf death and reduces yield and CCS.

• The onset of cool and dry conditions in winter usually signals the end of the disease epidemic.

• A downy growth of the fungus may be present on the underside of the affected leaves.

Spread

• Spores of the fungus are spread by rain and wind during periods of wet humid weather.

• Humidity is the key factor in the spread of the disease.

Control

• Plant resistant varieties. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.

• If possible, harvest badly infected fields mid to late season to allow the opportunity for some recovery of CCS.

3. Sugarcane smut

Cause

• The fungus Sporisorium scitamineum.

Occurrence

• Smut is a serious disease of sugarcane in almost all sugarcane-producing countries.

• Discovered for the first time in Australia in 1998 in the Ord River region of Western Australia.

• First occurrence in eastern Australia in 2006.

• Has since established itself in all sugarcane-growing regions.

Symptoms

• Easily identified by the black whip-like structure that forms from the growing point of the plant. This whip replaces the spindle leaf.

• The whip has a thin membrane that breaks to release the mass of black spores.

• When all spores are blown or fall from the whip, the straw-coloured core of the whip remains.

• Abnormal whips that contain some flower parts can sometimes be formed.

• Before the whip forms there is some shortening and crinkling of the youngest leaves.

• Infected plants are usually stunted and individual stalks are thin with a grass-like appearance.

• In ratoon crops, many of the infected stools will die and leave large gaps in the crop. In most cases, these crops quickly become unviable and need to be ploughed out.

• Yield loss can be 30 percent or more.
Recommended thresholds for plough out (susceptible and intermediate-susceptible varieties)

| Young crops inspected from November to January | Immediately plough out any blocks with 5 percent infected plants. If there is an average of 1 to 4 percent infected plants, inspect the crop again after March. |
| Crops inspected after January | Plough out after harvest if more than 5 percent of plants are infected. |

**Important tip**

How to inspect a block of susceptible or intermediate-susceptible varieties to determine smut threshold:

- Select a 50 m section of row within the block.
- Record the number of infected plants (assume 2 plants [stools] per metre).
- Repeat this 5 times in different parts of the block.
- Divide the total number of infected plants in the 5 sections of 50 m by 5 and this is your estimate of the percent infected plants in the block.

**Spread**

- Each smut whip can produce billions of microscopic spores that are blown in the wind to infect other crops. The majority of spores usually spread only a short distance such as 10 to 15 metres, but in gale-force winds or cyclones, spores can travel many kilometres.
- Spores can also be carried on clothes, vehicles and machinery.
- The disease can also be spread by planting infected or contaminated cane cuttings.
- Only affects sugarcane and some closely related grasses.

**Control**

- Plant resistant varieties. Visit QCANESSelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.
- Plant only approved seed cane that has been hot-water treated.
- A fungicide flutriafol (Sinker®) can be used to protect seed cane from reinfection.
- Remove heavily infested blocks to lessen the risk of spread to surrounding blocks. It is recommended that growers inspect their blocks of intermediate-susceptible and susceptible varieties and plough out blocks if they exceed suggested thresholds.
4. Striate mosaic

Cause

• The sugarcane striate mosaic-associated virus.

Occurrence

• Found only in the Burdekin district.

Symptoms

• Short, fine striations on the leaves (approximately 0.5 mm wide and 0.5 to 2.0 mm long) – the striations can be seen by the naked eye.

• Striations vary in number from a few to many where the greater part of the leaf blade is covered. Younger leaves may show a marked striping effect or a yellowing to the entire top.

• Striations are a lighter green than the normal blade and show first on the youngest exposed leaf.

• Less conspicuous during periods of slow growth, and they are difficult to find when temperatures exceed 30°C.

• In varieties with reddish stalks, striations can be clearly seen on the rind of the stalk.

• In highly susceptible varieties the stalk may develop a marked restriction around the node giving the internodes a bulbous appearance.

Above: Leaf symptoms of striate mosaic.

Spread

• Transmitted in planting material.

• Usually associated with poorer growth areas resulting from excessive sand, shallow soil, reclaimed watercourses and uneven irrigation.

Control

• Plant resistant varieties. Visit QCANESel ect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.

Publications available on the SRA website

Diseases of Australian Sugarcane Field Guide

5. Pachymetra root rot

Cause

• The oomycete Pachymetra chaunorhiza.

Occurrence

• First discovered in North Queensland in the early 1980s.

• Now present in all sugarcane-growing regions in eastern Australia.

• Unique to Australia – not found in any other sugarcane-growing countries.

Symptoms

• Soft, flaccid rot of the larger roots. Some root reddening may be evident in the early stages. As the disease advances only the epidermis or skin of the root may be left.

• Affected roots filled with the relatively large (30 to 65 µm) fungal spores, which have large conical projections.

• Root systems on affected plants are much smaller than those on healthy plants.

• The reduced root mass and rotted roots cause a loss of stool anchorage which leads to lodging and stool tipping. When harvesting a crop with extensive stool tipping, excessive soil and roots (‘extraneous matter’) are harvested and sent to the mill.

• In susceptible varieties, yield losses of up to 40 percent may occur.

Spread

- Spread occurs through soil on vehicles and machinery or where the base of stalks carrying spore-infested soil is used as planting material.
- Movement in water is likely to be minimal, except when there is heavy water erosion of soil.

Control

- Plant resistant varieties, particularly where spore counts exceed 50,000 to 100,000 spores/kg of soil (see Table 3). A soil assay service is available from SRA. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.
- Rotate with resistant varieties to minimise buildup of spores in the soil.

Table 3

<table>
<thead>
<tr>
<th>Soil assay for Pachymetra root rot</th>
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<tbody>
<tr>
<td>• Take samples from 0 to 25 cm depth in the soil profile, within the cane row (not from the inter-row space).</td>
</tr>
<tr>
<td>• Take 8 to 10 samples within a field to ensure representative results are obtained.</td>
</tr>
<tr>
<td>• Send samples to SRA for analysis.</td>
</tr>
<tr>
<td>• Where counts are greater than 30,000 spores/kg of soil in fallow fields, and greater than 50,000 spores/kg of soil in a standing crop, use the more resistant varieties.</td>
</tr>
</tbody>
</table>

6. Eye spot

Cause

- The fungus *Bipolaris sacchari*.

Occurrence

- Occurs in all regions causing sporadic epidemics.

Symptoms

- Initial symptoms are very tiny water-soaked spots on the young leaves.
- These develop into small reddish-brown lesions that soon grow in size and elongate.
- The pathogen produces a toxin causing a halo to develop around the growing lesions.
- As lesions reach their final size (0.5 to 4.0 mm long, 0.5 to 2.0 mm wide) movement of water along the leaf carries the toxin in a stream toward the leaf margin.
- This gives rise to reddish-brown 'runners', with the affected leaf tissue dying. The runners are unique to the disease and are very useful for diagnosis.
- The presence of many lesions and runners leads to extensive leaf tissue death (firing) and reduced yield.
- Froghoppers, an insect, inject a toxin into the leaf of sugarcane and cause a similar runner on leaves, but there is no lesion at the base of the runner.

Spread

- Spores are produced in large numbers on leaf lesions and are dispersed by wind or rain.
- The disease is favoured by cool and humid conditions.

Control

- Plant resistant varieties. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.
7. Sugarcane mosaic

Cause

- The sugarcane mosaic virus (SCMV).

Occurrence

- Has been recorded in all regions but currently restricted to the Bundaberg–Childers district of the Southern region.
- Only strain A of sugarcane mosaic (a relatively mild form of the SCMV virus) has been recorded in Australia.

Symptoms

- On leaves a mosaic or mottled pattern of contrasting shades of green, or islands of normal green surrounded by paler green or yellowish chlorotic areas.
- The symptoms are most evident in the young rapidly growing leaves and can often be seen in the spindle.
- Older leaves can appear more normal as the chlorotic areas tend to become a more normal green colour with age.
- The proportion of the leaf blade that becomes chlorotic varies greatly between varieties, sometimes resulting in the appearance of scattered elongated yellowish stripes. Usually the chlorotic patches dominate and are relatively uniformly distributed over the leaf blade.
- The mosaic pattern may also be present on the leaf sheath and stalk but this is uncommon in current varieties.
- Affected plants are stunted, and yield losses of 20 to 30 percent can occur.
- Germination and ratooning ability are also impaired.

Spread

- The virus is transmitted either by infected planting material or by aphids.
- The main aphid vector is the corn leaf aphid (*Rhopalosiphum maidis*) although other aphids, including the rusty plum aphid and the ambrosia aphid, can also transmit the virus.
- The virus can infect a range of grasses and can be carried from these into the cane crop.

Control

- Plant resistant varieties. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.
- Plant only approved seed cane.

Publications available on the SRA website

*Diseases of Australian Sugarcane Field Guide*
8. Red rot

Cause

• The fungus *Glomerella tucumanensis*.

Occurrence

• Occurs in all cane-growing areas, but is generally more common from Mackay south.

Symptoms

• Infection begins in the standing stalk via a leaf scar, stalk growth ring, growth crack, bud, wound or insect puncture.

• An internal, spreading, red discolouration then develops about the point of entry often without any obvious external symptoms.

• As the disease develops, the tissues turn a dull red with occasional dark-red spots and whitish bands, elongated transversely across the stalk. These bands are specific for the disease and should be looked for whenever red rot is suspected. The white bands may be inconspicuous in resistant varieties but in susceptible varieties may be so numerous as to give the tissues a mottled appearance.

• Reddened vascular bundles extend into the healthy tissues and frequently pass through the nodes into adjoining internodes.

• Infected tissues have a characteristic starchy odour, which may be slightly acid. There is little smell of fermentation as there is with pineapple disease.

• The tops of severely affected stalks become yellow and eventually die.

• The fungus also commonly infects the mid-rib of leaves leading to a bright red lesion. Infection usually occurs where sugarcane planthoppers (*Perkinsiella saccharicida*) have laid eggs. These lesions have little effect on cane growth although they may provide an inoculum source for the infection of stalks.

• In a few cases, red rot will also infect setts of planting material and ratoon stubble.

9. Leaf scald

Cause

• The bacterium *Xanthomonas albilineans*.

Occurrence

• Found in most districts.

Symptoms

• The disease has three phases of development:

  1. **Latent phase:** The disease can remain latent in some varieties for long periods (more than 12 months) while showing no symptoms. Stress can then trigger the infected plant to pass from the latent phase into the chronic or acute phases.
2. **Chronic phase**: the most typical symptom is the presence on the leaves of a ‘white pencil’ streak about 1 to 2 mm wide. The streak follows the leaf veins and extends to the edge of the leaf. The leaf tissue at the point where the pencil line meets the edge of the leaf dies. Some patches of chlorotic tissue (bleached white) are commonly associated with the chronic phase of the disease.

3. **Acute phase**: sudden wilting and death of mature stalks, often with no previous symptoms. The leaves appear scalded and turn inwards. Side shoots may form at the base of stalks. Internally, infected stalks show red discolouration of the vascular bundles at the nodes. The reddening extends up to 10 mm either side of the nodes unlike RSD, which only forms a red dot or comma at the nodes.

### Spread
- There are three main ways it spreads:
  1. Diseased planting material.
  2. Juice from infected plants on cane knives, plant cutters, trash strippers, toppers, planters, harvesters and haul-out vehicles.
  3. Wind-blown rain, particularly during extreme weather such as cyclones.
- Can be spread into cane from infected grass species *Paspalum* spp., *Brachiaria piligera*, *Imperata cylindrica* (blady grass), *Pennisetum purpureum*, *Panicum maximum* (Guinea grass), *Rottboellia cochinchinensis* (itch grass) and *Zea mays* (corn) growing in or adjacent to the cane paddock.

### Control
- Plant only approved seed cane that has been treated using the cold-soak, long hot-water treatment (cold water for 48 hours, followed by hot water for 3 hours at 50°C), which eliminates the disease.
- Plant resistant varieties. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties.
- To prevent spread between blocks, disinfect all cutting equipment by first removing all soil and plant material with water and detergent under high pressure, then spraying with a registered product containing 0.1 percent benzalkonium chloride (Cane Knife Steriliser) or didecyldimethyl ammonium chloride (Steri-max). Leave the disinfectant in contact with the equipment for 5 minutes before rinsing or using it.

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**10. Fiji leaf gall** (formerly known as Fiji disease)

### Cause
- The Fiji disease virus (FDV), a member of the Fiji virus group of the plant reoviruses.

### Occurrence
- Has never been recorded north of Proserpine, despite the planthopper insect vector (*Perkinsiella saccharicida*) being present throughout north Queensland.

### Symptoms
- Present in Papua New Guinea, Fiji and a number of Pacific islands.

- The definitive symptom is raised whitish galls on the underside of the leaf blade and midrib. The galls normally occur longitudinally in the large vascular bundles and vary considerably in size – from those visible only with magnification to some up to 50 cm long. The colour can vary from creamy white to green, while the surface of the galls is usually but not always smooth and unbroken. Galls are solid when pressed with a fingernail.
• If the epidermis is ruptured, the appearance of the galls is brown and granular. Galls usually remain evident on dead leaves, allowing the identification of diseased plants after they have died.

• As the disease progresses, stalk development slows down and successive leaves become shorter, harsher and stiffer. The whole top develops a fanlike appearance and, in more severe cases, the leaves have a ragged edge, looking like an animal has bitten them.

• Diseased leaves are usually darker green than normal and this, together with the stunted top, is often the first sign to attract the attention of the inspector who then looks for the confirmatory galls.

• Plants are severely stunted with multiple tillers and they often die out in ratoon crops.

• When diseased stools are ratooned or when setts from a diseased stalk are planted, the resultant plants will exhibit varying degrees of stunting from a grass-like stool of stiff dark leaves to one which may produce some millable cane, depending on the variety concerned.

• Note that ‘pseudo-galls’, similar in appearance to Fiji leaf galls, may sometimes be found on sugarcane leaves. These are usually small, the gall surface is not as smooth as for Fiji galls, and they are more triangular in cross-section. The pseudo-galls also lack the white core of Fiji leaf galls, and collapse when pressed with a fingernail.

Spread

• Transmitted either by planting diseased setts or by the feeding of infected planthoppers (*Perkinsiella saccharicida*).

• Both male and female planthopper adults and nymphs can transmit the virus.

Control

• Strict quarantine regulations are in place to reduce the risk of spread from affected areas to areas where the disease has never been found or has been absent for many years. Do not carry sugarcane between quarantine areas without an inspector’s approval.

• Plant only approved seed cane.

• Plant resistant varieties. Visit QCANESelect® – a variety decision-support tool available on the SRA website – for further information on resistant varieties. Varieties that are highly susceptible to Fiji leaf gall are not approved for districts where the disease is active.

• When just a few diseased plants have been detected, roguing diseased stools can be effective. If there is a high incidence of the disease in a field it should be destroyed to prevent spread to surrounding fields.
Above: Internal stalk symptoms.

1. Pineapple disease (sett rot)

Cause
- The fungus *Ceratocystis paradoxa*.

Occurrence
- Occurs in all Australian growing regions.

Symptoms
- Rotting of cane setts in the ground with poor or no germination.
- The rot is associated with a smell typical of rotting pineapples, which is released when affected setts are split open.
- Infection also leads to a reddening of internal stalk tissues.
- In advanced stages, abundant black spores are produced in the rotting setts.
- The pathogen produces a toxin that may kill the growing shoot, particularly when the shoot is reliant on the sett for nutrients and moisture.

Spread
- The fungus is present in the soil where it can live on any organic matter such as stubble and billets left over from the previous crop. The fungus enters through the cut ends of the sett or through any wounds to the stalk surface.
- The disease is most severe when the soil temperature is below 18°C or when the soil is either very wet or excessively dry, and where poor soil preparation causes poor soil-sett contact.

Control
- Treat setts with fungicide at planting, ensuring that there is effective cover on the cut ends. For details of fungicides, see the Everyday Advice and Recommendations section. Run a suitable vegetable dye through the sprays on the planter to assess spray coverage. Re-direct or replace nozzles to ensure good coverage. Check spray coverage each year before planting begins. If using fungicide dip-type planters, clean the dip tank regularly to reduce contamination of the fungicide with dirt.
- Select well-grown planting material without growth cracks, internal pipes and other stalk damage. Use two- or three-bud, rather than one-bud, setts for better germination.
- If possible, plant when weather conditions favour rapid germination and soil temperatures are above 18°C.
- Ensure that blades on whole-stalk planters are sharp and well adjusted.
- Similarly, ensure that basecutter and chopper box blades on harvesters cutting billets are sharp to give a clean cut and prevent cracking of setts. Rubber coating and synchronising feed-rollers will reduce damage to the rind of setts.
- Ensure soil has a good tilth and that there is good soil-sett contact – use press rollers to compact the drill after planting.
- Bare fallow will reduce the concentration of the fungus in the soil.

Information sheets available on the SRA website
- Sett rot diseases and fungicides

Publications available on the SRA website
- Diseases of Australian Sugarcane Field Guide
2. Nematodes

Cause

- The root-knot nematode (*Meloidogyne* spp.) and the root-lesion nematode (*Pratylenchus zeae*) are important pests of sugarcane in Australia.

- Other nematodes such as the stunt nematode (*Tylenchorhynchus annulatus*), dagger nematode (*Xiphinema* spp.) and stubby root nematode (*Paratrichodorus minor*) may also cause economic damage. Reniform nematode (*Rotylenchulus* spp.) and spiral nematode (*Helicotylenchus dihetera*) only cause economic damage when populations are high. All these nematodes are known as Plant Parasitic Nematodes (PPNs).

Occurrence

- Occur in all regions with the abundance and proportion of species varying with soil type, climate and crop history.

- Root-knot nematodes are mainly found in the lighter, sandy soils, where nutrients are more limited and moisture stress is more likely, so the crop is more sensitive to root damage. These nematodes cause the most severe economic damage.

- Although lesion nematodes cause more subtle damage, they are important pests because they occur in every soil type. The economic damage from lesion nematodes is often underestimated because above-ground symptoms are not always obvious.

Symptoms

- Root-knot nematodes and lesion nematodes enter the root tips, while most other nematodes feed on the outer surface of the roots.

- Damage to the roots depends on the species present. Typical symptoms include short, thickened and blackened primary roots with very few fine secondary or tertiary roots. With lesion nematodes many red lesions are present on the root tips. Excessive branching of primary roots may also be evident.

- Swollen galls on the roots may be observed if root-knot nematodes are present.

- Root systems damaged by nematodes may be exposed to further attack by bacterial and fungal organisms.

- The damaged root system limits the ability of the plant to access moisture and nutrients, resulting in slower stalk growth and reduced crop yield. Yield losses are thought to be 10–20 percent or more.

- As nematodes are small (most are less than 1 mm long) and transparent, they are invisible to the naked eye.

Their presence must be determined by microscopic analysis of a soil sample.

- To prepare a soil sample, using a shovel or probe, take at least 10 samples of soil and roots from against a stool, at a depth of between 50 and 250 mm. Bulk the soil together in a bucket and mix. Take a one-litre sub-sample together with contained roots and place in a plastic bag or other suitable container. Keep the sample cool and dispatch to an analysis laboratory.

Spread

- Nematode life cycles are short, as little as 4 to 5 weeks in warm conditions, so populations can build up quickly.

- Adult females lay several hundred eggs, either in the soil, in the roots (in the case of lesion nematodes) or on the root surface (in the case of root-knot nematodes).

- Juveniles hatch and undergo a series of four moults before attaining adult stage.

- Adults move slowly through the soil, attracted to the natural secretions of host plant roots. PPNs require a food source in the form of living plant roots to complete their life cycle, although eggs may remain dormant in the soil for a few months.

Control

- Monitor crops regularly to determine whether nematode populations are high enough to cause economic damage. Check plant roots for symptoms in fallow crops and before the 3- to 5-leaf stage (plant and ratoon cane). Do a soil test if symptoms indicate a potential problem (see above).

- Avoid plough out replant where possible.

- Include a legume rotation in the crop cycle. Soybean and peanut crops can reduce PPNs numbers by 80 to 90 percent. Peanuts give better suppression of root-knot nematodes than soybeans.

- Harvest plough out blocks early to maximise the break before planting legume crops.

- Make sure fallow crops are kept free of weeds, especially volunteer cane.

- Use the Green Cane Trash Blanket (GCTB) method. High populations of PPNs can quickly re-establish if a trash cover is not maintained. GCTB provides a better environment for beneficial organisms such as Free living Nematodes and predators of plant-parasitic nematodes.

- Minimise tillage as tillage operations kill beneficial nematodes, allowing PPNs to quickly re-establish.
• Use nematicides where appropriate. For details of nematicides, see the Everyday Advice and Recommendations section. Their use is generally restricted to light, sandy soils and may only be economical when sugar prices are high and if monitoring indicates a high population of root-knot nematodes is present. Nematicides will kill some natural enemies of the PPNs and will only reduce nematode populations for a few months. Pay attention to timing and application methods, especially watering in. Note that nematicides have high mammalian toxicity and care is required in their use to protect the user and prevent contamination of the environment.

Above: Symptoms of root-knot nematode.

Information sheets available on the SRA website
Nematodes
Nematode-resistant legumes

Publications available on the SRA website
Diseases of Australian Sugarcane Field Guide

Above: Symptoms of lesion nematode.

Other diseases

All other diseases that may occur in Australian sugarcane crops are generally of minor importance. They rarely, if ever, require specialised treatment.

Diseases not present in Australia

Diseases not yet present in Australia include:

• Downy mildew
• Ramu stunt
• Grassy shoot
• Green grassy shoot
• White leaf disease
• Gumming
• Brown spot
• Leaf scorch
• Target blotch
• Veneer blotch
• White speck
• Zonate leaf spot.

For further information on these diseases, refer to the Growing Cane section and the information sheets on the SRA website, and the Diseases of Australian Sugarcane Field Guide.
### Pest control

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## Pest control

### Everyday advice and recommendations

#### Pest troubleshooting

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<td>Yellowing, poor growth and death in young cane</td>
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<td>Yellowing and death of semi-mature or mature cane</td>
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<td>Damage to roots</td>
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Current pest management recommendations for major pests

Canegrubs

- There are 20 species of canegrub that occur across the Queensland and NSW sugar districts. Distribution and pest status varies by species and location. Lifecycles may be either one-year or two-year, depending on the species and sometimes on seasonal conditions.

- **Use of chemicals is the main method of control.** A number of chemicals are registered for the major canegrub species. Check the label as product registrations are species-specific. The timing of application may vary with specific product registration details, product formulation and canegrub pressure. Current registered chemicals are shown in Table 1 and Table 2:

Table 1: Plant cane.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Formulation</th>
<th>Important information</th>
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</table>
| Imidacloprid (systemic activity) | suSCon maxi Intel® (granular controlled release formulation) – provides three to four years control, depending on canegrub species | Now used almost exclusively  
Soil pH has no effect on efficacy  
Liquid formulations are marketed under many product names |
|                           | Nuprid® 700WG, Senator® 700WG and Confidor® Guard (liquid formulations) – provides control for one year |                                                                                       |
| Chlorpyrifos (contact activity) | suSCon® Blue (granular formulation) – provides one to three years control depending on canegrub species and application rate | Now largely superseded by imidacloprid  
Prone to accelerated degradation under alkaline soil conditions |
| Cadusafos (contact activity)    | Rugby® (granular formulation) – provides knockdown control of grubs that are present at the time of application | Very limited registration for some canegrub species |
| Clothianidin (systemic activity) | Shield™ (liquid formulation) – provides control for one year | Registered for greyback canegrub only |

Note: Correct application, particularly adequate soil coverage, is critical. Follow the label directions closely.

Table 2: Ratoon cane.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Formulation</th>
<th>Important information</th>
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</table>
| Imidacloprid (systemic activity) | Nuprid® 700WG, Senator® 700WG and Confidor® Guard plus a range of other brands (liquid formulations) – provides control for 1 year | Now used almost exclusively  
Soil pH has no effect on efficacy |
| Cadusafos (contact activity)    | Rugby® (granular formulation) – provides knockdown control of grubs present at time of application | Very limited registration for some canegrub species |
| Clothianidin (systemic activity) | Shield™ (liquid formulation) – provides 1 year control | Registered for greyback and Childers canegrubs only |

Note: Correct application, particularly adequate soil coverage, is critical. Follow label directions closely.
Non-chemical control measures

- BioCane™ which contains the fungus *Metarhizium anisopliae* is a biological agent with a variable control period dependent on canegrub numbers and environmental conditions. It is currently out of production due to low demand. It is registered only for greyback canegrub.

- Monitor crops to determine the need for control measures. Region-specific thresholds have been established for key canegrub species.

- As beetles of one or both sexes of many canegrub species (for example, Greyback, Childers, Southern 1-year, Rhopaea, Nambour, Bundaberg) are attracted to lights, light traps offer a means of monitoring beetle flights and anticipating next season’s grub pressure. Light traps are not an effective control.

- Use Green Cane Trash Blanketing (GCTB) as this creates a favourable environment for soil-living canegrub pathogens such as *Metarhizium*, *Adelina* and *Paenibacillus populiae* (Milky disease).

- Reduce tillage as much as possible as cultivation harms the beneficial pathogens and does not reliably reduce canegrub larvae or pupae enough to avoid treatment of the next crop with insecticide.

- Trap crops can be used to concentrate beetle egg-laying. A trap crop is a block or section of a block that has been designed to attract egg-laying greyback beetles away from the main crop. This block can then be either sacrificed or protected more intensively with insecticide. The mechanism is that egg-laying beetles are attracted to blocks or strips that are significantly taller than surrounding cane. This can be in the form of early-harvested seed-cane strips or similar. A minimum of 8 rows is required at a frequency of 150 to 400 metres of cane crop.

Symphylans

- Rapid germination and root growth make spring plantings less susceptible to damage than earlier plantings. A slightly later planting date also allows more time for rotting vegetation to decay and symphylan populations to decline.

- Always check that plants are not being restricted by factors such as poor nutrient balance before diagnosing symphylan damage as the cause of poor-growth symptoms. Even though symphylan-affected plants may not have stooled, hilling-up generally improves growth as root buds from nodes higher up the stems are stimulated to germinate. Natural plant compensation usually evens out yields over the different portions of the field. Do not compromise the effectiveness of fill-in and weed-control operations by delaying these operations to allow for the ‘slow’ symphylan-affected portions to stool-out.

- In some cases, planting furrows (drills) that have been ‘rolled’ after planting show less damage, probably because symphylan movement is restricted in the compacted soil around the setts.

- Chlorpyrifos (500 g/L) is registered for use against symphylans, with application onto the billet or sett and adjacent soil at planting.
Wireworms

- In plant cane, apply either chlorpyrifos (Lorsban® 500EC, Chlorpyrifos 500EC, and Strike-Out® 500EC) or bifenthrin (Talstar® 250EC, Astral® 100EC, Bifenthrin 100EC and Kenso Agcare Tal-Ken 100) in a low-pressure spray unit over the setts at planting.
- An alternative chemical is fipronil (Nufarm Regent 200SC).
- There is no recommended control measure for wireworms in ratoons.

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Rats

- Because the rats that affect sugarcane are native species, strict guidelines apply when managing them.
- Effective rat management requires an integrated approach including the following measures:

  > Manage weeds in the crop and surrounding areas, particularly during the breeding season (November–March). This makes it difficult for the rats to obtain the nutrition required to maintain breeding. Control in-crop weeds with herbicides and trash blanketing. Rats may still be present in well-managed blocks as they will feed on young cane shoots, however their breeding potential will be significantly reduced.

  > Mow or graze grasslands heavily in the June-to-January period to make them unsuitable for use as between-crop refuges. Remember that small grassy areas can support large colonies of rats.

  > Revegetate areas along drains and creeks adjacent to crops to reduce habitat areas. The aim is to produce a closed canopy in forests and revegetated areas.

  > Encourage owl predators into the area by installing nesting boxes. Keep remnant old eucalypt trees with hollows for natural nesting sites for owls.

  > For in-crop rat control, use registered rat baits containing zinc phosphide (Ratoff®, ZP Rat Bait) where required and appropriate. Note that baiting in Queensland is permitted only under the conditions of a Damage Mitigation Permit issued by the Queensland Government.

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Sugarcane weevil borer

- Manage harvest residues as billets, whole stalks and cane attached to tops left after harvest provide ideal harbourage for weevil borers to breed. Harvesting practices that help to reduce borer numbers include:
  > Adjusting the harvester fan speed to minimise billet loss.
  > Using a shredder topper to break up any cane attached to tops.
  > Ensuring harvester is cutting clean and low to avoid damaged stalks being left behind and to avoid shattering of stools.

- Reduce stalk damage and lodging as any stalk damage provides an easy access point for the adult female to lay her eggs. Rat damage in particular can lead to high infestation levels.

- Varieties may vary greatly in their susceptibility to attack by sugarcane weevil borer. Varieties with hard rinds and higher fibre content that are free trashing are more tolerant to weevil borers. Varieties that are prone to growth cracks and ‘piping’ suffer more damage as it is easier for the female to lay her eggs.

- In suspect blocks, monitor weevil borer activity by placing traps made from three or four split billets wrapped in black plastic. Assess and renew the billets in the traps either weekly or biweekly. Pheromone traps may also be useful in monitoring populations and suppressing breeding if used early in the season (October to December). The trap is a 20 cm diameter pot with a plastic bag inserted to hold water with pheromone lures and cane pieces held together in a plastic container suspended over the water from a square of wire mesh. An advantage of these traps is that they can be placed near the edge of cane blocks, making them easier to check. Monitoring can be useful to assess the risk for seed cane plots, as weevil borers can be easily spread in planting material.

- Chemical control may be warranted where there is a high probability of many borers. Use fipronil (Regent® 200SC). Spray when the cane has reached the first millable internode stage from December to February. Treat both sides of the stool ensuring good coverage to stalks to a height of 40 cm, and to soil and trash to 10 cm on either side of the stool. Refer to the label for full directions.

Above: Adult weevil borer.

Feral pigs

- In Queensland, feral pigs are declared pests under the Rural Lands Protection Act (1985) and it is the responsibility of landholders to control them. Local pest management committees often coordinate control programs. These committees usually include representatives from productivity services groups.

- Feral pigs are difficult to control for a number of reasons:
  > They are nocturnal, wary and camp through the day in thick inaccessible vegetation wherever possible.
  > Their reproductive potential is high, so repeated control programs are necessary before any worthwhile population control is achieved.
  > They are omnivorous, with a wide range of available food sources, making successful pre-feeding during baiting campaigns difficult.
  > Their home ranges are large – between 5 and 50 km², so control programs must be conducted over a large area to be effective.

- Control measures include:
  > Fencing – is expensive but effective; must be constructed before pigs are used to feeding in a particular paddock; pigs will charge an electric fence and unless the fence incorporates fabricated netting, they will break it.
  > Trapping – must be designed so as not to trap or injure other wildlife such as cassowaries; most successful when the pigs’ food sources are limited; pre-feeding prior to activating traps is an essential prerequisite to success.
  > Shooting and using dogs – must not be used before or during poisoning or trapping operations.
  > Poisoning – one of the few methods available which may reduce a pig population quickly. In Queensland, sodium fluoroacetate (1080) is registered for use. Care is needed to prevent accidental poisoning of non-target species. A permit is required to carry out poisoning. Pre-feeding is an important step in poisoning operations. Consult productivity services groups for further advice before proceeding.
Soldier fly

- Natural enemies, including parasitic wasps and the fungal pathogen *Metarhizium anisopliae*, attack the immature stages, and predators eat the vulnerable pupae. Natural enemies can significantly limit damage, provided the measures below are also implemented.

- Take out affected blocks early in the harvest season. This will lengthen the break from cane, and destroy the larval food while the new generation is still small and vulnerable.

- Have a grass-free break from cane, for example, a long herbicide fallow under trash after spray-out of the old ratoon, or a short fallow followed by a non-grass crop such as soybean. Larvae will eventually starve as grasses are their natural food.

- Plant the next cane crop after the flight period of the adult flies – after June.

- Plant sugarcane with minimum tillage following the herbicide fallow. Keep cultivation for the break-crop at minimal but adequate levels. Extra cultivation does not effectively kill larvae and will harm natural enemies.

- Grow varieties with strong root systems that ratoon quickly.

- Harvest plant and early ratoon crops when conditions are good for ratooning. Soldier flies will have less impact if ratoons come away quickly.

- Do not plough out and immediately re-plant infested blocks, and do not plant sugarcane early – in autumn – following an infested ratoon. Plant after the flight period – after June.

- No insecticide is registered for the control of soldier flies.

Above: Soldier fly larva.

Current pest management recommendations for minor pests

Armyworms

- Spraying is not usually required. Each field will normally receive only one major infestation in a year. One attack on a healthy crop early in spring will not reduce yield significantly. In addition, most of the damage has probably already been done by the time spraying is considered. Early spraying of the first wave of armyworms also kills natural enemies.

- However, where there is a series of attacks in early to mid-summer, particularly in damaged, weedy or weak crops, there may be enough justification to spray. In these cases, spray with either chlorpyrifos, permethrin or trichlorphon. For best results, spray late in the afternoon when temperatures are lower and insecticides degrade more slowly. This is also when night-feeders are active.

- Note that natural fungal pathogens can reduce numbers of armyworms under showery weather conditions. Diseased armyworms turn black and hang from cane leaves. There are also several species of tachinid flies and parasitic wasps that attack larval and pupal stages of armyworms. Natural enemies need at least one armyworm generation to build up to a useful level. In this instance, first assess the amount of damage and the stage of growth of the armyworm before taking action to spray.

Above: Armyworms can be either day- or night-feeders.
Ground pearls

- Only pink ground pearls cause economic damage.
- Plough out infested blocks early and fallow for 12 months. Ploughing or rotary hoeing several times during the fallow will reduce pest numbers. Use non-grass fallow crops during the break. However, care needs to be taken not to cause soil loss through erosion.
- Ensure that machinery working in areas infested with pink ground pearls is cleaned thoroughly before moving to other fields. This is especially important in spring–summer when adults, eggs and nymphs can be easily transported in moist soil stuck to implements and vehicles.
- Some cane varieties are more tolerant to pink ground pearls.

Black beetles

- If breaking up grassy country for cane, be aware that these pests could be present. Control methods include repeated ploughing and several months of fallow. Growing a legume is a good idea as legumes are not favoured hosts. Autumn planting is preferred to spring planting, because beetles are less active in autumn and the autumn-planted cane will have grown too large to be damaged by beetles when they become active in spring.
- No insecticides are registered for control of black beetles in Queensland, although chlorpyrifos (500EC) is registered for the control of both species in NSW.

Rhyparida beetles

- Generally not serious enough to warrant control. By the time damage is seen it is too late to attempt control.
Funnel ants

- No insecticide treatment is available.
- In healthy crops, yield is not affected with up to 3500 mounds per hectare (about one mound per 2 m of cane row).
- Some varieties suffer less damage than others.

Termites

- In cane fields, the only practical control is to remove logs and trees from the edge of fields.
- No insecticides are registered for termite control in sugarcane.
- Other smaller species of termites damage cane in small areas, but infestations usually do not persist.

Information sheets available on the SRA website
- Funnel ants and termites

Publications available on the SRA website
- Pests of Australian Sugarcane Field Guide

Cicadas

- No insecticide is registered.
- Since the early 1970s, damage has been controlled using a planting rotation which breaks the cycle of movement from infested fields to 'clean' ones.
- Plough out all severely infested fields and parts of fields soon after harvest, and fallow the area over the summer flight period. Plough out kills over 90 percent of nymphs in the soil and harms the survivors enough to prevent adult emergence. Fallowing means that the few survivors soon die and do not attract others into the newly planted crop.
- Manage lightly infested fields to prevent further expansion of the infested area. Do not keep infested old ratoons near younger non-infested fields, and destroy and fallow the edges of infested fields. This creates a small border which adult cicadas avoid crossing. Cultivate and fallow any areas within fields showing ratoon failure.

Information sheets available on the SRA website
- Cicadas

Publications available on the SRA website
- Pests of Australian Sugarcane Field Guide
Field crickets

- Rarely cause problems.

- Slightly more soil cover over setts reduces the risk of billet eye damage.

Mole crickets

- Damage usually occurs before any mole crickets are seen.

- Replace damaged setts.

Locusts

- Locusts are generally not worth trying to control with insecticides. The long-term damage they do to cane is usually small and infestations die out within a couple of generations.

- Because hoppers usually group together they are easier to spray than adults, and on occasions, may be worth spraying. Chlorpyrifos (500EC) and diazinon (800EC) are registered to control spur-throated locust, Australian plague locust and migratory locust in sugarcane in Queensland.

- Many eggs can be killed by cultivating the egg beds before the hoppers hatch.

Information sheets available on the SRA website

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Large moth borer

- As the large moth borer is a minor pest, control is usually not required. Natural enemies generally minimise the risk of serious attack.

- Control grass weeds which are egg-laying sites and food for young caterpillars.

Ratoon shootborer

- Generally not serious enough to warrant control. Caterpillars are well hidden and most damage has been done by the time the insect is found.

Bud moth

- Chemical control is not practical as sprays would have to be applied during the middle of the wet season.

- Stripping trash from plant sources may reduce damage to eyes.

Information sheets available on the SRA website

- Bud moth
- Large moth borer
- Ratoon shootborer

Publications available on the SRA website

Pests of Australian Sugarcane Field Guide

Aphids

- Control is generally not required as natural enemies exercise effective control.

Right: Aphids.
**Sugarcane planthopper**

- Control is generally not warranted as natural enemies help reduce planthopper numbers in summer.
- Use resistant varieties for the control of Fiji leaf gall.

**Froghopper**

- Control is generally not required as natural enemies exercise effective control.

**Information sheets available on the SRA website**

- Aphids
- Froghoppers
- Planthoppers

**Publications available on the SRA website**

*Pests of Australian Sugarcane Field Guide*

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**Weevils**

- Weevil damage is rare and of minor importance.
- Control of the weeds that weevils eat will reduce insect numbers in cane.

**Wart-eye**

- Use good quality planting material to offset any shoot failure due to wart-eye.
- Some varieties are damaged more than others.
- Chemical control is not effective.

**Information sheets available on the SRA website**

- Butt weevil
- Stenocorynus weevil
- Whitefringed weevil

**Above:** Whitefringed weevil.

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**Sugarcane planthopper**

*Above: Planthopper.*

**Froghopper**

*Above: Froghopper.*

**Wart-eye**

*Above: Wart-eye.*
**Sugarcane mealybug**

- Control is generally not required as natural enemies exercise effective control.
- Tighter-trashing varieties are more prone to attack.

**Linear bug**

- Control is generally not required as natural enemies exercise effective control.
- Rarely present in grass-free fields.

**Sugarcane scale**

- Use scale-free planting material to reduce the chance of spread to a clean field.
- Avoid having stand-over cane.

**Wallabies**

- There are limited methods of control:
  - Electric fences: Six- and seven-wire vertical electric fences are effective against wallabies. Positioning of the bottom earth wire close to the ground is essential to prevent animals crawling under the fence. The top two wires are electrified (live) to prevent shorting if they are twisted together.
  - Shooting: Of limited effect and a Damage Mitigation Permit from the Queensland Government is required. Contact productivity services groups for more advice.

**Foxes**

- Control is not required as damage is generally minor.

**Striped possum**

- No control is required other than removing overhanging branches.
- The animal is a protected species.

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**Information sheets available on the SRA website**

- Linear bug
- Mealybug
- Scale insect

**Publications available on the SRA website**

- *Pests of Australian Sugarcane Field Guide*
Birds

- Specific control is generally not required, and control of the birds is difficult.
- Gas scare guns can be used to frighten the birds, but the effect is generally temporary.
- Where the problem is of concern, contact productivity services groups for advice. Growers can apply to the Queensland Government for a Damage Mitigation Permit to manage wildlife co-existence.

Understanding the science

Integrated pest management

- Integrated pest management, or IPM, combines a range of suitable pest control methods in as compatible a manner as possible to maintain pest populations below levels to limit economic damage.
- Emphasis is placed on the best way to combine the methods to achieve cost-effective, but long-term, control with a minimum of harmful side effects.
- The IPM concept is a significant change from the notion of pest eradication that predominantly uses pesticides.
- IPM in the Australian sugarcane industry has three main thrusts:
  1. The most efficient use of present control methods, especially of registered pesticides.
  2. The use of benign substitutes for chemical pesticides, such as attractant traps, and biological control agents.
  3. The redesign of farming systems to reduce their attractiveness to pests and to ensure that pest levels remain below those likely to cause economic damage.
- IPM depends on a good understanding of the pests, their life cycles and their ecology.

Important components and principles of IPM

Use of chemicals (pesticides)

- There is no limitless pool of pesticides available to the sugar industry. Those we have must be used efficiently and effectively.
- There is no point in using a pesticide if the economic benefit of controlling the pest is less than the cost of the product plus application costs. Monitoring of pests and their damage is important in determining economic injury levels.
- The long cropping cycle of sugarcane presents special problems. For example, soil pests will always be difficult to control with insecticides. For this reason, other types of controls must be used in conjunction with pesticides.
- Correct placement of the pesticide is vital to achieving good results. For example, the active ingredient imidacloprid, for canegrub control, degrades rapidly in sunlight. This means the insecticide must be positioned deep enough in the soil to prevent phyto-degradation. Placement in relation to grub activity and roots is also important to optimise uptake by the canegrub.
Above: Liquid insecticide applicator combined with fertiliser applicator.

**Biological controls**

- This refers to the use of predators, parasites or diseases to reduce pest numbers.
- Its main advantage is its safety – low toxicity to humans and low hazard to non-target species. However, it can also be very economical if the biological agent is established and self-perpetuating.
- While much of the focus on biological control is on overseas introductions of parasites or predators, most of the pests of Australian sugarcane are native species, so conservation of native natural enemies is often overlooked. These can be easily disrupted by the inappropriate use of broad-spectrum pesticides and excessive tillage.

Above: Canegrub affected by Metarhizium fungus.

**Cultural controls**

- Cultural control aims to manipulate the environment to make it less favourable for the pest. It requires a thorough knowledge of the life history and habits of the pest, particularly when in its life cycle it is most vulnerable.
- Cultural controls are often cheap to employ but require forward planning to be implemented successfully.
- A good example is plough out of infested crops. Insects such as canegrubs, soldier flies and ground pearls are often in higher numbers in older ratoons. A plough out will prevent their numbers increasing even further, and kill a proportion of the pests present. It also allows the opportunity for even greater impact on pest numbers through the use of a fallow break or non-host rotation crop.
- Another example is the mowing of headlands and control of grass weeds in the crop to reduce the availability of grass seeds – an essential protein source for the breeding of rats.

Above: Minimum tillage practices such as zonal cultivation encourages natural soil borne pathogens like *Metarhizium* and *Adelina*.

**Quarantine**

- Quarantine restrictions on the movement of cane between the canegrowing regions are sometimes useful in minimising the spread and impact of pests.
Importance and occurrence

- With 20 different species, canegrubs have the highest potential of all sugarcane pests to cause economic loss.

Major canegrubs

- Greyback canegrub (*Dermolepida albohirtum*) is the most serious of the canegrubs and the most serious pest in the major productions areas from Central Queensland to the northern districts.

- French’s canegrub (*Lepidiota frenchi*) occurs in most areas south to Bundaberg. It is more prevalent from Mackay north, but is a relatively minor species at Bundaberg. A closely related species, Negatoria canegrub (*Lepidiota negatoria*), occurs from Proserpine south to Beenleigh. It is less common at Mackay than French’s canegrub, is the major species of the two at Bundaberg, and is the only one of the two at Maryborough and further south.

- Childers canegrub (*Antitrogus parvulus*) occurs chiefly around Childers, but also at Woongarra, Bingera and Gin Gin in the Bundaberg area. Larvae are found predominantly in red volcanic clays or clay loams.

- Consobrina canegrub (*Lepidiota consobrina*) occurs from Mossman to Babinda. Most infestations occur in dark-coloured sandy loam soils.

- Southern 1-year canegrub (*Antitrogus consanguineous*) occurs in the Bundaberg and Maryborough areas in sandy alluvial or yellow podsol soils, especially wallum country.

- Rhopaea canegrub (*Rhopaea magnicornis*) occurs at Rocky Point and Nambour in Queensland and in northern NSW, especially in the Tweed Valley. They prefer loam to clay-loam soils, especially those with high organic matter. It is a major pest species in the NSW area.

- Nambour canegrub (*Antitrogus rugulosus*) occurs at Didillibah and Bli Bli in the Nambour district, at Rocky Point, and in northern NSW, usually in sandy soils. It is a major pest species in the Nambour to Rocky Point areas.

- Bundaberg canegrub (*Lepidiota crinita*) is a major pest species in the Bundaberg–Isis area and usually occurs in forest loams, light clay-loams and some sandy soils.

Above: Adult beetle of Bundaberg canegrub (left) and Childers canegrub (right).

Above: Adult beetle of greyback canegrub.

Above: Greyback canegrub larva.

Minor canegrubs

- Planiceps canegrub (*Antitrogus planiceps*) occurs in the Harwood and Broadwater districts of NSW. They have been found in loams, silty loams, sandy loams and silty clay loams.

- Noxia canegrub (*Lepidiota noxia*) occurs north of the Burnett River in the Bundaberg area in red and brown forest loams, and scrub soils at Gooburrum, Sharon, Bingera and Yandaran, and in coarse alluvial soils at Waterloo. They also occur at Ninenbah and Pialba at Hervey Bay, and at Yandina and west of Caloundra in the Nambour area.

- Picticollis canegrub (*Lepidiota picticollis*) occurs in the Bundaberg area at Yandaran, Elliott Heads and Kolan, and in the Isis area at Logging Creek and Goodwood. They always occur in very sandy beach or forest soils.

- Squamulata canegrub (*Lepidiota squamulata*) is found from Herbert to the Isis regions and only in sandy soils.

- Grata canegrub (*Lepidiota grata*) occurs from the Mossman to Isis regions and is most damaging in the Herbert region. They occur mostly in light sandy soils but can also be found in loamy silts and granitic loams. Grubs are often found in hot, dry soil under conditions that are not tolerated by other species.
• **Rothe's canegrub** (*Lepidiota rothei*) occurs in forest country throughout northern Queensland and the Northern Territory. It rarely damages cane but grubs are very common in weedy fields and when grassy fallow fields are ploughed for planting.

• **Caudata canegrub** (*Lepidiota caudata*) occurs in north Queensland from Tully to Mossman and the Atherton Tablelands. Infestations occur in both alluvial and red volcanic clay-loam soils, primarily near rainforest.

• **Froggatt’s canegrub** (*Lepidiota froggatti*) is confined to far northern Queensland mainly in the Innisfail region, in or near rainforest on red volcanic loams, often in association with Caudata canegrub.

• **Grisea canegrub** (*Lepidiota grisea*) has been recorded at Yule Point near Mossman, and Behana near Gordonvale, but is also suspected of causing damage at Ayr and Ingham. It appears to prefer sandy soils.

• **Sororia canegrub** (*Lepidiota sororia*) occurs at Yule Point and Port Douglas near Mossman, and at Coolbie, Yuruga, Bambaroo and Braemeadows in the Herbert Valley. Larvae inhabit soils with relatively shallow subsoil, often almost waterlogged during the wet season.

• **Plectris canegrub** (*Plectris aliena*) is found in NSW in sandy soils. It is the only introduced species of canegrub.

**Pest and damage**

• Grubs feed on cane roots and stalks. Damage is characterised by loss of root mass leading to yellowing of cane leaves, poor growth and in severe cases, stool tipping and the death of the stool. Harvesting and milling problems result from extensive stool tipping. Damage causes a reduction in yield, CCS and ultimately a shorter cropping cycle.

• Canegrubs such as Greyback, Consobrina, Southern 1-year, Rhopaea and Nambour cause what is known as 1-year type damage from February to July.

• Canegrubs such as French’s, Negatoria, Childers, Consobrina and Bundaberg cause what is known as 2-year type damage in spring or early summer. They cause more severe damage to young ratoons.

**Important points about biology**

• The larvae of cane beetles, depending on their species, have either a one-year or two-year life cycle.
  > One-year life cycle – Greyback, Consobrina (one-year form), Nambour, Squamulata, Rothe’s, Grisea
  > Two-year life cycle – French’s, Negatoria, Childers, Consobrina (two-year form), Rhopaea, Noxia, Bundaberg, Picticollis, Froggatt’s.
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<tr>
<th>Advice for new growers</th>
<th>Understanding the sugarcane plant</th>
<th>Climate</th>
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<tr>
<td>Drainage</td>
<td>Planting and crop establishment</td>
<td>Variety selection</td>
<td>Nutrition</td>
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<tr>
<td>Pest control</td>
<td>Chemical use and application</td>
<td>Harvesting and transport</td>
<td>Milling issues for the grower</td>
<td></td>
</tr>
</tbody>
</table>

- **Weed control**
Everyday advice and recommendations

Integrated weed management

- Monitor how well your strategy works and record all chemical usage.
- Always follow label instructions to optimise herbicide effectiveness, ensure operator safety and minimise off-site movement.

In selecting herbicides, it is generally recognised that there are six different crop situations where herbicides may be required (see Table 1).

Integrated Weed Management (IWM) involves using a combination of cost-effective management techniques to effectively control weeds in an environmentally responsible manner.

Its basis is set on minimising the potential for weeds to set seed in all crop phases and therefore reducing the weed seed bank. IWM involves a number of key components:

- **Reducing the weed seed bank** is seen as the most cost-effective method in controlling weeds. Understanding the cause of a weed problem is important as this will influence the weed management strategy. For example, by preventing weed seed entering the paddock (by slashing adjacent headlands, spraying along fence lines and around hydrants, pumps, sheds, machinery) the weed pressure in adjacent blocks of cane is greatly reduced.

- **Practising good hygiene procedures.** Practices such as cleaning down machinery including slashers and harvesters will minimise the introduction of weed seed to the farm.

- **Using appropriate cultural practices.** Trash blanketing in ratoons suppresses weeds, especially grasses. A well-managed legume crop during the fallow period will further reduce the grass weed pressure for the following plant cane crop.

- **Applying suitable herbicides** in a program of both pre-emergent residual and post-emergent control. Care must be taken to choose the correct herbicide according to the soil type and weed species and to apply it at the right time and in optimum conditions.

- **Mechanical control.** This involves a range of possible cultivation operations in plant cane and non-trash blanket systems.

Above: A young cane crop showing effective weed management.
<table>
<thead>
<tr>
<th>Situation</th>
<th>Photo</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plant or ratoon cane on bare soil: <strong>Early crop emergence</strong></td>
<td><img src="image1.png" alt="Photo" /></td>
<td>Herbicide absorption into sugarcane at this stage is minimal provided leaves are still unfurled in the spike. This allows for over the top application of some herbicides. This stage of crop growth is known as 'spike' stage.</td>
</tr>
<tr>
<td>2. Plant or ratoon cane on bare soil: <strong>3- to 4-leaf crop stage</strong></td>
<td><img src="image2.png" alt="Photo" /></td>
<td>Grass controls should be applied at spike or during this stage as there are limited options until a directed spray is possible. This is the last opportunity for broadcast paraquat application. Paraquat will need to be mixed with some systemic herbicides to prevent cane leaf uptake.</td>
</tr>
<tr>
<td>3. Plant or ratoon cane on bare soil: <strong>Stooling crop stage</strong></td>
<td><img src="image3.png" alt="Photo" /></td>
<td>Limited grass control options during this stage, due to potential crop damage caused by cane leaf uptake.</td>
</tr>
<tr>
<td>4. Plant or ratoon cane on bare soil: <strong>Established crop</strong></td>
<td><img src="image4.png" alt="Photo" /></td>
<td>Apply residual herbicides using directed spray to provide weed control after crop is out-of-hand. Alternatively apply knockdown herbicides after out-of-hand using high-rise spray equipment and spray shields if required.</td>
</tr>
<tr>
<td>5. Ratoon crop on Green Cane Trash Blanketing (GCTB)</td>
<td><img src="image5.png" alt="Photo" /></td>
<td>Heavy trash layers may reduce herbicide contact with the soil. Rainfall or irrigation following herbicide application may improve herbicide movement to the soil and increase the effectiveness of residual herbicides. Establishing weed-free plant cane may reduce the need for grass control on a trash blanket. However, broadleaf weeds such as vines may become more dominant in trash. Trash delays germination of vines, increasing the risk of summer storms impeding treatment. Trash is very good at suppressing annual grasses.</td>
</tr>
<tr>
<td>6. Fallow stage</td>
<td><img src="image6.png" alt="Photo" /></td>
<td>Plant-back periods for fallow crops vary depending on the herbicide. There is an opportunity to use different herbicides and to use fallow crop competition to reduce weed seed bank.</td>
</tr>
</tbody>
</table>
Outside of these six situations, there will be occasions when specialised control will be required for hard-to-kill vines, problem broadleaf weeds (such as sicklepod and milkweed), problem grasses (such as guinea grass, sorghum, setaria and paspalum) and nutgrass.

Because the weed mix of each farm is unique, and there are many herbicide options available, herbicide recommendations need to be tailored to each situation. For this reason, no ‘blanket’ herbicide recommendations are made here. However, guidelines on selection are in the range of publications available on the SRA website. Specific weed control recommendations for some production regions can also be found on various productivity service group’s websites.

For information on herbicide application, see the Chemical use and application section.

Understanding the science

The impact of weeds on sugarcane

The impact of weeds in sugarcane is greater than in many short-season row crops. This is because the wide inter-row spacing, high temperature, high 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. This is because during the period of 3 to 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. While this period is the most critical, weed control at later stages of the crop is still important for a range of reasons, including competition, harvesting efficiency, reducing weeds in ratoon crops, and reducing harbourage for rats.

Weed life cycles

There are three types of weeds which differ based on their life cycle:

1. **Annual.** Annual weeds live for one season only. Examples are milkweed, red convolvulus, Star of Bethlehem and summer grass.

2. **Biennial.** Biennial weeds live for two seasons and most have a thick storage root (tap root). Some weeds can be either annual or biennial. Sicklepod and blackberry nightshade are examples of weeds that have either an annual or biennial life cycle.
Weeds are either grasses (monocots) or broadleaves (dicots). Seedlings of monocots have only one seed leaf, called a monocotyledon. Seedlings of dicots have two seed leaves, called a dicotyledon.

1. Grasses (monocot)
   - Grasses can be either perennial or annual.
   - Control 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. They can become an uncontrollable problem that may necessitate a premature plough out 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.
   - GCTB suppresses the germination of many grasses and only the stronger, larger-seeded grasses tend to germinate.
   - In the development of new cane land from previous pasture, the perennial pasture grasses can be difficult to control and have a significant impact on the first cycle of cane cropping.

2. Sedges (monocot)
   - Occur mainly in the wetter areas.

3. Perennial. Perennial weeds produce vegetative structures that allow them to survive for more than two years. They produce new independent plants from rhizomes, tubers, bulbs, stolons, creeping roots or seed. Examples are common sensitive weed, pink convolvulus, Johnson grass, Guinea grass and nutgrass.

- However, nutgrass is prevalent in all districts and on all soil types. It is very difficult and expensive to control and is the most prevalent and important weed of sugarcane. GCTB does not suppress nutgrass.

3. Broadleaf weeds (dicot)
   - Generally less of a problem than grasses.
   - Can also be annual or perennial.
   - The younger the weed, the easier it is to control.

4. Vines (dicot)
   - Generally tend to germinate later in the season when the cane is more advanced.
   - Relatively easy to kill but can be difficult to manage as they germinate over a long time. Even under a closed canopy they are difficult to remove in one operation.
   - GCTB tends to delay the germination of vines resulting in germination closer to the wet season. Delayed germination may also result in residual herbicides being less effective as vine germination may occur outside the herbicide's period of activity.
   - Vines are particularly important because if left uncontrolled, they can significantly impair harvesting by:
     > entangling several rows of cane, making it difficult for the harvester to separate the rows
     > damaging the cane crop by the harvester pulling the entangled vines and cane plants out of the ground
     > wrapping around the moving parts of the harvester, possibly requiring manual removal.
   - Vines have become more prolific since the adoption of GCTB.

2. Sedges (monocot)
   - Occur mainly in the wetter areas.

Important tip
The Grains Research and Development Corporation's (GRDC) Weed ID: The Ute Guide is a valuable weed identification tool. It is available in hard copy or as an app.
Methods of weed control

- There are three main methods of weed control:
  1. Mechanical cultivation.
  3. Trash blanketing.

- Herbicides and trash blanketing are now the two most dominant weed control methods in most areas. Cultivation still plays an important role in all non-permanent bed systems as it contributes to weed control while performing other functions.

1. Mechanical cultivation

Plant cane

- Cultivation in plant cane serves several purposes, including:
  > shaping row profiles for irrigation, drainage and harvesting
  > removing surface crust to allow for improved germination of cane
  > applying sub-surface fertiliser products
  > weed control.

- The timing of these cultivations allows for weed control while performing other operations.

- Cultivation has the dual purposes of weed control and gradual filling in of the planting furrow (in non-permanent beds).

- While the cane drill is still open, cut-away equipment is used for weed control and tillage operations. These implements effectively cultivate the shoulders and base of the drill, remove weeds and remove excess soil on top of the planted cane.

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

- A series of cultivations is usually required to provide an acceptable row profile for harvesting. They also provide opportunities for weed control.

Left: Weeds are controlled while cultivating for other purposes, e.g. cut-away.

Ratoon cane

- Little cultivation since the advent of reduced tillage systems in conjunction with burnt cane and GCTB.

2. Application of herbicides

Above: Spraying operation in crop.

- Herbicides are generally divided into two main groups:
  > Selective herbicides – damage or kill only certain plant species. For example, 2,4-D amine will kill broadleaf weeds but will have no effect on grasses. Many herbicides are selective at low rates but are non-selective at high rates.
  > Non-selective herbicides – damage or kill a wide range of weed species. For example, paraquat and glyphosate will kill both broadleaf and grass weeds.

- 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. They move little inside the plant. They normally act rapidly inside the plant and are used mainly 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 is essential. Contact herbicides can be either selective or non-selective at normal application rates. Many become non-selective at high application rates. There are very few contact herbicides used in sugarcane; the main one being the active ingredient paraquat.
  > Translocated or systemic herbicides – applied to the foliage and stems of weeds. They then move throughout the plant. They usually act slower and have a wider range of effects on the weed than contact herbicides. Because translocated herbicides move through the plant, coverage is not as critical as for contact herbicides. They are more effective for controlling perennial weeds. However, favourable environmental conditions following application are more critical because they act slower. Translocated herbicides may be selective (e.g. 2,4-D amine) or non-selective (e.g. glyphosate).
> **Residual herbicides** – 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 herbicides. Residuals act in the top 50 to 80 mm of soil. They must generally be fixed at the correct soil depth by irrigation or by mechanical incorporation. Excessive rainfall or irrigation after application may wash these chemicals into the root zone of the cane where they may cause serious damage. Alternatively, the chemical may be washed away to nearby areas and damage other plants. 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. The effectiveness of a residual herbicide relies on its ability to persist in the soil until soil conditions promote germination of weeds. This depends on soil type, soil pH, rainfall, temperature, sunlight, organic matter, and the presence of herbicide-aggressive microorganisms.

- Herbicides are also grouped by the means they use to target the biochemistry of weeds (mode of action). Similar modes of actions are catalogued into the same ‘Group’.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mode of action</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Inhibits lipid synthesis</td>
<td>Verdict®, Fusilade®</td>
</tr>
<tr>
<td>B</td>
<td>Inhibits the enzyme ALS</td>
<td>Flame®, Spinnaker®, Sempra®</td>
</tr>
<tr>
<td>C</td>
<td>Inhibits photosynthesis at photosystem II ALS</td>
<td>Atrax®, Diurex®, Barrage Mentor</td>
</tr>
<tr>
<td>D</td>
<td>Inhibits tubulin formation</td>
<td>Stomp® Extra</td>
</tr>
<tr>
<td>G</td>
<td>Inhibits protox</td>
<td>Blazer®, Valor®</td>
</tr>
<tr>
<td>H</td>
<td>Inhibits 4-HPPD</td>
<td>Balance®</td>
</tr>
<tr>
<td>I</td>
<td>Disrupts plant cell growth</td>
<td>Starane™ Advanced, Agritone™ 750, Amicide® 625</td>
</tr>
<tr>
<td>J</td>
<td>Inhibits lipid synthesis (but not ACC-ase as does Group A)</td>
<td>Dalapon 740 SP</td>
</tr>
<tr>
<td>K</td>
<td>Multiple sites of action</td>
<td>Dual Gold®</td>
</tr>
<tr>
<td>L</td>
<td>Inhibits photosynthesis at photosystem I</td>
<td>Gramoxone®</td>
</tr>
<tr>
<td>M</td>
<td>Inhibits EPSP synthase</td>
<td>Roundup®</td>
</tr>
<tr>
<td>R</td>
<td>Inhibits DHP synthase</td>
<td>Rattler®, Asulox®</td>
</tr>
<tr>
<td>Z</td>
<td>Unknown, probably multiple</td>
<td>Daconate®</td>
</tr>
</tbody>
</table>

• Herbicide use presents a number of challenges:
  > minimising impact on the environment off-farm
  > safe use on the farm – people using herbicides need to be properly trained and to follow correct safety procedures
  > using weed control strategies to reduce the likelihood of herbicide resistance developing.

3. **Trash blanketing**

- GCTB is normally used in conjunction with reduced or zero tillage in ratoons.
- With less soil disturbance, fewer new weed seeds are brought to the surface ready to germinate.
- GCTB leaves a thick layer of cane trash on the cane stubble, which stops most annual weeds from germinating and growing through the trash blanket.
- There are some more vigorous weeds that can penetrate the trash layer – vines, nutgrass, couch grass and guinea grass. Germination of vines may be delayed under trash and this may reduce the ability to control them if germination coincides with the onset of the wet season. Generally there is a strong reliance on herbicides to control these weeds.

### Factors affecting herbicide performance

1. **Humidity and temperature**

- Humid conditions greatly improve the leaf absorption of most herbicides. This is because 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.
- Temperature increases volatilisation or evaporation of herbicides. For example, the triazine herbicides such as atrazine and ametryn are prone to volatilisation at high soil temperatures.
Delta (Δ) T is a measurement that describes the difference between the wet and dry bulb temperature measured in degrees Centigrade. Many hand-held wind meters also measure Δ T. Generally, spraying should only be carried out between Δ T readings of between 3°C and 8°C. Δ Ts below 3°C increase the likelihood of small droplets surviving and moving off-target, while Δ T readings above 8°C reduce droplet survival and hence reduce the amount of herbicide hitting the target.

2. Rainfall and dew

- 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 re-dissolve herbicides that have dried on the leaf, thus assisting uptake. Usually, however, rain washes off the herbicide. The length of the ‘rain fast’ period varies – paraquat is rain fast in minutes; 2,4-D in 4 hours; and glyphosate in 20 minutes to 6 hours, depending on formulation.

3. Plant age and growth rate

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

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

4. Soil effects

- Soil-applied herbicides, such as trifluralin, which have very low solubility must be incorporated or receive rainfall to be well distributed. For effective mechanical incorporation, soil should be in reasonable tilth and not cloddy.

- Soluble products, such as atrazine, move with the soil water which means they can be lost through run-off or leaching through the soil profile.

- Soil ‘splash’ from travelling irrigators can move herbicide-treated soil and leave areas with insufficient herbicide. Similarly furrow irrigation can cause movement of treated soil. When applying pre-emergent herbicides to plant cane, drills should be wide enough to prevent untreated soil falling back to the bottom of the drill.

- Soil adsorption (bonding of herbicide onto the soil particles) increases with increasing levels of organic matter, clay content and cation exchange capacity. Poor results may occur where cane tops have been raked and burnt or where mill mud/ash mixtures have been applied.

- Soil degradation of herbicides by soil organisms, primarily fungi and bacteria, occurs fastest in warm, moist, well-aerated soils. Soil pH is important in this degradation.

5. Sunlight

- Photodecomposition of herbicides by sunlight is important in tropical and subtropical areas which receive more UV light than temperate areas.

- Mentor® WG (metribuzin) is not UV stable and therefore needs to be incorporated to prevent photodecomposition. Other products such as Balance® (isoxaflutole) and Flame® (imazapic) are UV stable and can remain on the soil surface until activated by rain or irrigation.

6. Variety

- Some varieties are more tolerant of herbicides. Phytotoxicity of herbicides in sugarcane usually appears as chlorosis of leaves and stunting of shoot growth.

7. Correct use

- Herbicides need to be:
  > applied at the correct rate
  > properly mixed, particularly important for wettable powders used with good quality water that is not hard or dirty
  > applied in conjunction with a wetting agent where directed – this is important with post-emergent herbicides to maximise leaf contact
  > applied in compatible mixtures
  > mixed according to a particular order (see Table 2).

### Table 2

<table>
<thead>
<tr>
<th>Order</th>
<th>Chemical type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60–80 percent water volume</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Wetter conditioners/ Acidifiers</td>
<td>Liase, LI-700*</td>
</tr>
<tr>
<td>3</td>
<td>Wettable/ Dispersible powders</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dry Flowable/ Water-dispersible granules</td>
<td>Barrage</td>
</tr>
<tr>
<td>5</td>
<td>Flowables/ Suspension Concentrate</td>
<td>Diuron, Atrazine (liquids)</td>
</tr>
<tr>
<td>6</td>
<td>Adjuvants (when using Emulsifiable Concentrates (ECs) – apart from water conditioners or acidifiers added at stage 2)</td>
<td>Activator®, Chemwet 1000</td>
</tr>
<tr>
<td>7</td>
<td>Emulsifiable Concentrates</td>
<td>Fusilade Forte®</td>
</tr>
<tr>
<td>8</td>
<td>Soluble Liquids</td>
<td>Agritone® 750, Amicide®, Glyphosate</td>
</tr>
<tr>
<td>9</td>
<td>Adjuvants (when not using ECs)</td>
<td>LI 700®, Chemwet 1000, Oils (e.g. Bonza®)</td>
</tr>
</tbody>
</table>
Note: Adjuvants to be added at stage 6 if using ECs. If no ECs are used, mix the adjuvant at stage 9. Oils must be added last in all mixtures.

- The plant must be sufficiently covered – nozzle selection and adjustment are important. Boom sprays should be set up with tapered fan nozzles set at the correct height above the target to avoid ‘striping’ effects. Banded sprays should be set up with even fan nozzles set at the correct height above the target to ensure optimum coverage of the band.

8. Dust

- Herbicide effect is reduced if plants are covered in dust.

Herbicide resistance

Understanding resistance

- Resistance of weeds to herbicides is rapidly becoming a major issue. Potentially, it can cause costly chemical application failures, limit the types of herbicides available for a particular weed control, and require other control measures that result in reduced production, such as long fallowing and crop rotation.

- Resistance develops through two mechanisms:

  1. When a small number of plants, in a weed population naturally resistant to a particular herbicide, survive and increase through repeated doses of that herbicide, or herbicides with the same mode of action. Eventually, the herbicide-resistant weeds increase to make up the bulk of the population and the herbicide becomes ineffective.

  2. When a mutation occurs in the weed, with the new genetic individual being naturally resistant to the herbicide. As the weed sets seed and increases, the herbicide will no longer effectively control it. The more specific the mode of action of a herbicide, 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 that weed.

- The rate at which resistance develops 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 (Cyperus rotundus), 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 cortorta), barley grass (Hordeum leorinum), climbing buckwheat (Fagopyrum esculentum) and summer grass (Digitaria ciliaris).

Preventing resistance

- The most effective way of preventing resistance is to use a range of chemical and non-chemical weed control measures.

- Rotating the use of herbicides from different groups (see Table 3) and tank mixing herbicides with different modes of action will limit resistance development.

- Non-chemical control measures include cultivation and trash blanketing.

- A fallow can also be used to break the weed cycle and to reduce weed seed numbers.

Table 3

<table>
<thead>
<tr>
<th>Common sugarcane herbicides and their activity group with resistance risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High risk</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Medium risk</strong></td>
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</table>

Minimising environmental impacts from herbicides

- Herbicides may move to non-target areas through run-off, leaching, spray drift, attached to eroded sediments, or from chemical spills. The risk is highest with very soluble herbicides that can leach through the soil into the groundwater, and with herbicides that have broader environmental impacts – for example, seagrass is highly sensitive to diuron, even at low concentrations.
Key management practices include:

1. **Minimise herbicide run-off.** It is vital to ensure that herbicides are applied at a time when they are not subject to run-off from irrigation or heavy rainfall. Generally, residual herbicides require a minimum of two days without rainfall or irrigation after application to bind to the soil particles. Knockdown herbicides should not be applied when rain is imminent. Products of major concern are atrazine, ametryn, hexazinone and diuron (all Group C or PSII herbicides). These products and others are being detected in waterways and in the Great Barrier Reef Lagoon (GBR). Use of equipment such as Irvin Legs and high-clearance tractors increases the flexibility of application timing.

2. **The 20-day period** after herbicide application is critical in how much residual herbicide is lost in run-off. Run-off during this time may account for up to 92 percent of total herbicide losses for the whole season. Overhead irrigation or light rain during the first 20 days after application also significantly reduces the risk of herbicide loss in run-off after that time period.

3. **Retain trash on ratoons.** Recent trials have shown trash blankets in ratoons can reduce the run-off loss of PSII herbicide products by 43 percent on average and by 24 percent on average for knockdown herbicide products. Trash also reduced run-off of non-PSII residual herbicides by an average of 74 percent.

4. **Band spraying versus broadacre application.** Consider applying residual products as a band on the row. This substantially reduces the amount of applied herbicide and also the input costs.

5. **Residual versus post-emergent.** With GCTB systems, often the trash layer, if heavy, will suppress germination of grass and broadleaf weeds until canopy closure; with the exception of specific weeds like vines, nutgrass and couch. This provides an opportunity to limit herbicides to knock-downs applied late for vine control.

6. **Shielded/hooded spraying.** Shields and hoods can be used to minimise drift and apply a band of herbicide inter-row. This allows the use of a broader range of knockdown herbicides. The QDAF dual sprayer is a non-shield design for a two circuit sprayer, allowing for separate row and inter-row spray mixes.

7. **Label instructions.** Ensure that all herbicides are applied in accordance with the label.

8. **Awareness of legislation.** Be aware that all marine plants are protected under legislation. Control of weed growth in tidal drains should be carried out in accordance with the guidelines in the *SmartCane Riparian and Wetlands Area practice booklet* or with an individual permit. All other watercourses in Queensland are protected under the *Water Resources Act 1989*. In Queensland, farmers should contact authorities to determine whether a permit is required before any herbicide application in watercourse areas.

9. Growers should also be aware of the current *Reef Protection legislation*. 

Above: High-clearance tractor.

Above: Shielded spraying.

Above: Non-shielded dual herbicide sprayer.
### Chemical use and application

- **Advice for new growers**
  - Understanding the sugarcane plant
  - Climate
  - Soil health
  - Irrigation

- **Drainage**
  - Planting and crop establishment
  - Variety selection
  - Nutrition
  - Diseases and disease control

- **Pest control**
  - Weed control
  - Harvesting and transport
  - Milling issues for the grower
Chemical use and application

Everyday advice and recommendations

Herbicide application

- Boom sprays operated under hydraulic pressure are the most common form of application equipment.

- To minimise herbicide contact with the cane crop and direct herbicide sprays more effectively to the weeds or soil surface, modern boom sprays are often modified to include droppers, adjustable nozzles, Irvin legs, Costanzo legs and spraying shields.

- Aerial spraying is commonly used for 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 enable spot application of herbicides such as glyphosate onto the leaves of weeds such as guinea grass and phragmites.

Spray calibration

Step 1: Pre-spray checklist

- Check spray equipment well in advance of any spraying operation. Examine the following items for damage or wear:

  > Tank: check for cracks in tank and hoses.
  > Pump: check if shaft rotates freely by hand. Is there free play in the shaft? Is there oil in the pump? If using a diaphragm pump, ensure correct air pressure in the air chamber above the diaphragm. To do this, pressurise the air chamber, then bleed air from the chamber while the pump is operating until the spray fans stop pulsating.
Filters: check the filters – tank screen, suction line filter, pressure line and nozzle filters – are all clean and fitted in the correct place.

Pressure regulator and control valves: check if the regulator is easily adjusted and that the control valves operate freely.

Pressure gauge: check it is on zero. If not, replace the gauge. If the gauge is a high-pressure type, replace it with either a low pressure or dual state gauge.

Boom: check for damage and that it can be adjusted in height to suit the spraying task at hand.

Step 2: Check equipment operation

• Fill the tank with water, start the pump and check the spraying unit for leaks. Repair leaks where necessary.

• Agitation: Make sure the recirculating/agitation system operates effectively. Check there are no bubbles coming back into the tank from the bypass line. With a diaphragm pump this could indicate a damaged diaphragm.

• Spray pattern: Examine the spray pattern for each nozzle against a dark background. Clean and/or replace any nozzles that show streaks or signs of blockage. Note that even new nozzles can be faulty. Clean nozzles with a nylon toothbrush. DO NOT USE A WIRE BRUSH.

• Nozzle output: Collect the output of each nozzle for one minute. Replace any nozzles that vary by more than 10 percent from the average.

• Nozzle adjustment: Make sure fan nozzles are offset 10 degrees to the spray boom. With flood jet nozzles, adjust the angle to ensure spray covers the required area.

• Boom height: Adjust the boom height above the target to that recommended for the nozzles being used. To determine the correct boom height, spray over a clean, dry concrete or dirt surface and watch the sprayed area dry out. If stripes appear, the boom is set too low. A stripe associated with one nozzle indicates a faulty nozzle that needs replacing. Once an even drying pattern is established, the boom height should be measured and used to set the boom height above the spray target in the field.

Step 3: Calibrate sprayer (band spraying)

Band spraying calibration example (see page 126 for work sheet)

• It is necessary to band spray a block of recently harvested cane with Bobcat combi as a pre-emergent spray.

• The sprayer available has a 600 L tank and a 5-row boom, with a single nozzle spraying a 0.6 m band over each of the 5 rows. Row spacing is 1.8 m.

• Using the calibration method described, the following information was obtained:
  Time to travel 100 m = 50 s
  Output from one nozzle for 50 seconds in litres: 1.92 L
  Water rate (L/ha) = 1.92 (L) x 100 ÷ 0.6 (m) = 320 (L/ha)
  Area sprayed per tank = 600 (L) ÷ 320 (L/ha) = 1.9 'sprayed' ha
  Amount of chemical required per tank = 1.9 (ha) x 3 (kg/ha) = 5.7 kg
  Area driven (ha) = 1.9 (ha) x 1.8 (m) ÷ 0.6 (m) = 5.7 ha

Step 3: Calibrate sprayer (directed spraying)

Directed spraying calibration example (see page 127 for work sheet)

• It is necessary to spray a block of established plant cane with Bobcat combi as a pre-emergent spray, using a directed spray at 3 kg/ha.

• The sprayer available has a 600 L tank and has four octopus spray bars (four row). Each spray head sprays a swath of 1.6 m.

• Using the calibration method described, the following information was obtained:
  Time to travel 100 m = 50 s
  Output from ALL nozzles on one spray head = 5.2 (L)
  Water rate (L/ha) = 5.2 (L) x 100 ÷ 1.6 (m) = 325 (L/ha)
  Area sprayed per tank = 600 (L) ÷ 325 (L/ha) = 1.85 ha
  Amount of chemical required per tank = 3 (kg/ha) x 1.85 (ha) = 5.5 kg
Cleaning and storing spraying equipment

• Chemical residues can block nozzles and filters, affecting flow rates and the amount of chemical applied. This reduces efficiency.

• Clean the spray unit each day after use, as well as thoroughly cleaning the unit before it is stored at the end of the season.

• The steps to follow are:
  > Dispose of any chemicals left in the tank (refer to the Chemical Safety section). Do not leave liquids in the tank overnight.
  > Partly fill the tank with clean water. Scrub the inside of tank, tank filler and lid.
  > Flush out through the drain plug.
  > Remove, clean and refit the suction line filter and pressure line filter.
  > Remove and wash nozzles and nozzle filters.
  > Fill the tank with clean water and pump through the spray lines.
  > Replace nozzles.
  > Hose down the tank, frame and boom to remove dirt and chemical residues.
  > If spray equipment used for applying herbicides is to be used to apply fungicides or insecticides, it is essential that all traces of herbicides be removed. Follow the same procedure.

• After cleaning, hose down the unit as follows:
  > Fill the tank with clean water, add 200 g of washing soda to 100 L of water or purchase a special tank cleaner from a pesticide retailer.
  > Agitate and spray out.
  > Repeat the washing soda treatment and leave overnight before draining.
  > Fill the tank with clean water, agitate and spray out.

End-of-season storage

• Follow the above cleaning procedure.

• Remove nozzle tips and store in a sealable container.

• Store the tank and boom under cover. Cover openings in tank and spray lines to control build-up of dust and prevent hornets building nests.

• Check the oil level in the pump. If the level is low, fill the pump with a recommended oil to the required level.

• Lubricate moving parts of the spray rig.

• Protect parts that are subject to rust with oil or proprietary rust inhibitors.

Calibration of granule and liquid cane grub insecticide applicators

• Information sheets which detail calibration processes are available on the SRA website. Follow the instructions provided.

Information sheets available on the SRA website

Calibration of ground-driven granular insecticide applicators for canegrub management

Calibration of liquid insecticide applicators for canegrub management
Understanding the science

Chemical safety

Pesticide toxicity

- Pesticide toxicity is ranked on the basis of how much of the material is required to kill half a group of test animals (usually rats) when fed to them in their diet. This is termed the oral (LD50) and is given in units of milligrams per kilogram of body weight.

Highly toxic materials have LD50s less than 50 mg/kg and are rated on the poison schedules as S7 (Dangerous Poison); examples are zinc phosphide (Ratoff®) and fenamiphos (Nemacur®) with LD50s of less than 20 mg/kg.

Materials such as chlorpyrifos with LD50 values of 50 to 500 mg/kg are moderately toxic and are rated as S6 (Poison). Those with values of 500 to 5000 mg/kg are slightly toxic and are rated as S5 (Caution) on the poison schedule.

Labels and Safety Data Sheets (SDS)

- Always read the label as it contains essential information on the safe use and storage of chemicals.

- SDS are available at the point of sale of pesticides. They contain more-detailed information about the hazards associated with particular products than the label.

Importantly, SDS provide a 24-hour contact telephone number in case of an emergency. All users of pesticides should keep a log of all current SDS in an easily accessible format for use in emergencies.

Cleaning up a pesticide spill

Disposal of unused pesticide and empty pesticide containers

Safe storage of pesticides

Mixing and the storage of chemicals

Follow these precautions:

Storage

- Chemicals should be stored in a structure that:
  > can contain any spills that might occur, for example – impervious floor, dwarf walls and doorsills and a disposal pit
  > is built of fire-resistant materials
  > is isolated from other buildings
  > is sited away from water leaks, hose spray and drainage courses
  > is well ventilated and lockable
  > is identified by signs
  > has easily accessible fire control equipment (hoses, extinguishers).

- Do not purchase more chemicals than can be used within a reasonable period of time.

- Always store chemicals in the original labelled container.

- Organise pesticides so that oldest stock can be used first and regularly inspected for leaky or deteriorating containers.

Information available on www.health.gov.au
Above: A dedicated chemical storage facility.

Mixing

- Organise an appropriate mixing area which has good lighting, adequate ventilation, good water supply, ready availability of safety equipment, and is sited away from drainage systems.
- Always read the label and note dangerous properties and precautions.
- If antidotes are mentioned, have them readily available.
- Never eat, drink or smoke when handling pesticides.
- Wear correct protective clothing. The minimum recommended protective clothing is overalls buttoned at the wrist and neck, impervious gloves and footwear, and a washable hat. Do not wear ‘street’ clothing under protective clothing.
- Remove contaminated clothing immediately after use and wash separately in warm, soapy water.
- Ensure that goggles/face shields, aprons, respirators and other safety devices are used as recommended on the label. These devices must conform to the relevant Australian standards.
- If the skin, eyes or mouth are contaminated, wash the affected area immediately with clean water.
- Avoid manual lifting of pesticides above waist height and/or climbing on the spray tank during mixing.
- Clean up spills or dilute them with soil, sand or other absorbent materials to avoid contact hazard.
- Be aware of the typical signs and symptoms of pesticide poisoning:
  - Fever, intense thirst, rapid breathing, nausea, diarrhoea, stomach cramps, blurred vision, lack of coordination, trembling, and excessive perspiration

Disposal of unwanted pesticides and containers

- Offer any unused pesticides in original, well-labelled containers to other farmers who can use them. The supplier may accept unopened containers.
- Always dispose of pesticides and containers at approved or licensed sites if these are available. If they are not available, dilute the chemical to spray strength and dispose of it in a properly built farm disposal pit.
- The drumMUSTER Program is designed to reuse or recycle plastic drums used in the application of farm chemicals. Before consignment to the program always triple rinse the containers.

Precautions during chemical application

- Stand upwind of opening, pouring, mixing and spraying operations.
- Begin spraying downwind and move upwind while spraying.
- Do not contaminate beehives, fish ponds, lakes, streams or canals.
- Keep out of the treated area for several hours after spraying.
- Avoid spray drift, especially onto neighbouring susceptible crops, wild plants, young trees and gardens.

Important tip

Chemicals may be incompatible when mixed. As a result, they may not work effectively, and in some cases, may damage crops. Unless combinations of chemicals are endorsed on the label, do not mix them – apply each chemical separately.

Keep accurate records of chemical purchases, uses and disposal.
• When spraying, wear appropriate protective clothing, a respirator, boots and a washable hat. Soak washable protective clothing in bleach and wash separately each day before reusing. Carefully maintain cartridges in respirators and destroy old cartridges to prevent accidental reuse. A range of compressed-air face shields is readily available from commercial suppliers. These give full-face protection and are comfortable in hot, humid conditions.

**Chemical accreditation and first aid**

• All farmers and users of pesticides should attend a chemical accreditation course. In Queensland, it is mandatory to hold the following competencies if using products containing diuron, hexazinone, ametryn, or atrazine:

  > Prepare and apply chemicals (AHCCCHM303A or RTC3704A)
  > Control weeds (AHCPMG301A or RTC3410A)
  > Transport, handling and store chemicals (AHCCCHM304A or RTC3705A).

These competencies are included in chemical training programs such as ChemCert™ and SafeChem.

• Do a first aid course and have a first-aid kit available in a handy and protective place. The kit should include antidotes, a towel, clean clothing, an approved resuscitation mask for expired air resuscitation, disposable eye wash bottle and solution, soap, nailbrush, and instructions on how to use this equipment.

• Keep the contact details of the **Poisons Information Centre – 131126** – handy, so that emergency information and treatment about particular chemicals can be readily obtained.

**Record keeping**

• Keep an accurate record of each and every application of farm chemicals.

• A good record-keeping tool is CANEGROWERS Queensland’s Crop Care **Farm Chemicals Record Book**.

• Accurate records provide growers with insurance that reasonable precautions were taken at the time of any application. Without written records, growers may be more vulnerable to litigation.

### Chemical application equipment

#### Hydraulic pressure

• **Function**: liquid is forced through an orifice (nozzle) forming a sheet of liquid, which becomes unstable and disintegrates into small droplets. The spectrum of droplet sizes produced depends on the operating pressure and the type of nozzle used (hollow cones, flat fans, even sprays, and flood or anvil nozzles).

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy to use</td>
<td>Gives a wide droplet spectrum resulting in wastage of chemical associated with droplets of non-optimum size being lost to non-target areas or giving poor target coverage</td>
</tr>
<tr>
<td>Can be used for fungicides, insecticides and herbicides</td>
<td>Rapid and variable wear of components can cause wide variation in coverage, requiring constant calibration</td>
</tr>
<tr>
<td>Components are interchangeable</td>
<td>Has to be operated at the right pressure and distance from the target</td>
</tr>
<tr>
<td>Made up of a few simple parts</td>
<td></td>
</tr>
<tr>
<td>Some tolerance of operator error because of the spectrum of droplets produced</td>
<td></td>
</tr>
</tbody>
</table>

• **Equipment types**: hand-operated hydraulic sprayers (knapsack sprayers) – both piston pump types and diaphragm pump types; tractor-mounted boom sprays.

### Controlled droplet application

• **Function**: the spray liquid is fed into the centre of a rotating disc or cage with the droplets being formed at the periphery due to centrifugal force.
Air shear

**Function:** the liquid containing the pesticide is impacted with air or another fluid resulting in the disintegration of the pesticide mixture into droplets. The droplet sizes produced depend on the air velocity at the nozzle and the flow rate of the liquid, with larger droplets produced with increasing flow rates and decreasing air velocities.

**Equipment types:** hand-operated CDA sprayer such as the Micron Herbi and Ulva (spinning discs) and the Micronair AU series (spinning cage).

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>narrow droplet spectrum (optimum droplet size), which maximises target contact and minimises wastage of chemical</td>
<td>no room for error</td>
</tr>
<tr>
<td>lower volume of carrier can be used</td>
<td>requires constant, careful maintenance</td>
</tr>
<tr>
<td>reduced off-target loss by production of droplets with low drift potential</td>
<td>must be understood to be used properly</td>
</tr>
<tr>
<td>requires air assist to move droplets in the canopy if using small droplets for fungicides and insecticides</td>
<td>flow rate, rotation speed and liquid viscosity must be very precise to achieve desired narrow droplet spectrum</td>
</tr>
<tr>
<td>off-target movement of droplets can be a problem if equipment is incorrectly adjusted</td>
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</tr>
</tbody>
</table>

**Herbicide spray drift**

- Spray drift or vapour drift is a potential major problem for the cane industry, given that cane is often grown close to herbicide-susceptible fruit, vegetable and flower crops as well as urban housing areas.
- The biggest risk applies to the phenoxy-type herbicides such as 2,4-D and dicamba. Ester formulations of herbicides are the most vaporous, and amine salts the least. Ester formulations are no longer used in sugarcane.
- A number of factors contribute to spray drift:
  > droplet size – very small spray droplets are lighter, fall slower and drift further than big droplets.
  > pressure – high pressure increases the proportion of small droplets, which can drift further.
  > spray nozzle height – the higher the spray nozzles are positioned above the target weeds, the more likely spray droplets will drift away from the target.
  > spraying speed – high speeds create turbulence that can swirl the small droplets away from the target.
  > wind speed – stronger winds increase spray drift.
  > air temperature and humidity – high temperatures at low humidity cause droplets to evaporate quickly. This reduces the size of bigger droplets and makes them more prone to drift.
- Procedures for minimising spray drift include:
  > use amine or less volatile formulations when applying phenoxy-type herbicides, such as 2,4-D and dicamba, near sensitive crops.
  > use the lowest pressure possible – for example, in sensitive areas this may mean the use of floodjet, low-drift, low-pressure nozzles, which operate at pressures less than 100 kPa.
  > set the height of nozzles as far below the cane canopy as possible with the use of droppers or skids.
  > avoid spraying in very still or very windy conditions. A light breeze blowing away from susceptible plants is ideal.
  > spray when relative humidity is high – normally early morning or late afternoon.
  > technically, controlled droplet application (CDA) spraying equipment produces uniform-sized droplets, which when set up and used correctly, provides little or no chance for drift. However, this type of equipment is more expensive and requires more maintenance.
Broadcast spraying worksheet

<table>
<thead>
<tr>
<th>Step</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Drive tractor in field conditions for 100 metres</td>
</tr>
<tr>
<td>2.</td>
<td>Measure time (seconds)</td>
</tr>
<tr>
<td>3.</td>
<td>Collect output (L) for same time from one nozzle</td>
</tr>
<tr>
<td>4.</td>
<td>Test all nozzles on boom to ensure output is similar. Replace nozzles if variation is greater than 10 percent.</td>
</tr>
</tbody>
</table>

### Calculations

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Output (L) x 100 / spacing between 2 nozzles (m) = water rate (L/ha)</td>
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</tr>
<tr>
<td>Tank size (L) / water rate (L/ha) = hectares / tank</td>
<td></td>
</tr>
<tr>
<td>Label rate (kg or L/ha) x hectares / tank = amount to add / tank</td>
<td></td>
</tr>
</tbody>
</table>
Drive tractor in field conditions for 100 metres

Measure time (seconds)

Collect output (L) for same time from one nozzle

Output (L) × 100 / spray width of one band (m) = water rate (L/ha)

Tank size (L) / water rate (L/ha) = sprayed hectares / tank

Label rate (kg or L/ha) × sprayed hectares / tank = amount to add / tank

Sprayed hectares / tank × row spacing (m) / one band spray width (m) = hectares driven

Test all nozzles on boom to ensure output is similar. Replace nozzles if variation is greater than 10 percent.
**Directed spraying worksheet**

Drive tractor in field conditions for 100 metres

Measure time (seconds)

Collect output (L) for same time from all nozzles on one head (for droppers or any other configuration)

<table>
<thead>
<tr>
<th>Total output from all nozzles on one head (L)</th>
<th>( \times ) 100</th>
<th>( \div ) spray width of one head (m)</th>
<th>= water rate (L/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank size (L)</th>
<th>( \div ) water rate (L/ha)</th>
<th>= hectares / tank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Label rate (kg or L/ha)</th>
<th>( \times ) hectares / tank</th>
<th>= amount to add / tank</th>
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</table>
### Harvesting and transport

<table>
<thead>
<tr>
<th>Advice for new growers</th>
<th>Understanding the sugarcane plant</th>
<th>Climate</th>
<th>Soil health</th>
<th>Irrigation</th>
</tr>
</thead>
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Everyday advice and recommendations

Introduction

• Relative to other crops, sugarcane harvesting involves the collection and transport of high tonnages of a relatively low value product, which also has a limited “shelf life”.
• Since mechanical harvesting began, losses are variable and can be excessive.
• The key issue is that incremental losses add up to significant impacts on overall profitability.
• Reduced tonnes of sugar and cane in the delivered product.
• Almost all significant losses are “invisible” and “forever”.
• Important to look at all operations as part of a total sugar production system.

Challenges for harvesting management

• Increase in group sizes due to reducing harvester numbers.
• Increase in machine capacity with corresponding increase in ground speed.
• Diminishing bin weights due to increase pour rate (therefore increase in extraneous matter).
• Trends towards shorter billets to offset decreasing bin weight.

Basic harvester performance principles

• Field conditions have most impact on extraneous matter (EM) and cane loss.

Above: Impact of field conditions on EM levels. (Data is pre anti-vortex and 5 foot extractor data however trend is similar in current models).

• Crop presentation (row profile/width) impacts on stool damage and pickup losses.
• Fan speed determines cane loss levels with limited impact on EM.

Above: John Deere fanspeed versus EM and cane loss.

Publications available on the SRA website

The Harvesting Best Practice Manual for Chopper-Extractor Harvesters

Harvesting Best Practice: the Money Issues

SmartCane Harvesting and Ratoon Management
How growers can improve harvest efficiency – 10 tips

1. **Improve farm layout.** The aim is to increase the proportion of actual cutting time. Pay particular attention to row length and appropriate headland space. Headlands that are wide and smooth increase the efficiency of harvester turning and haul-out.

2. **Ensure row spacing is consistent and rows are parallel by using GPS guidance.** GPS guidance systems can then be used to keep harvesting and haul-out over the cane rows. This contributes to improved ratooning by minimising soil compaction and physical damage to stools.

3. **Ensure row profile is consistent across the farm and matches the harvester.** Poor row profiles increase cane losses at harvest as well as causing stool shattering and splitting that hinders subsequent ratooning. The damage caused also favours the development of fungal rots. Consistent row profiles which match basecutter setup significantly reduce stool damage during harvesting. Remember that damage to hill shape during harvesting cannot be effectively corrected by cultivation in ratoons. Also use ripper tines carefully to avoid having large clods of soil present in the rows.

4. **Select varieties carefully and tailor agronomic practices to the variety.** Highly vigorous and productive varieties grown on good soil may create problems with lodging and stool tipping and may require deeper planting, better hilling up, and reduced nitrogen fertiliser applications. Better still, match vigorous varieties to appropriate soil types. High-yielding erect cane well presented for harvesting significantly increases harvesting efficiency, particularly given the high pour rates of existing harvesters. Also control weeds within the crop to reduce the quantity of potential extraneous matter (EM) in the harvest.

5. **Develop a harvesting plan to maximise cane maturity at harvest.** Plan the order in which blocks will be harvested according to maturity, layout, predicted peak in CCS and seasonal weather conditions.

6. **Pay attention to harvester setup and operation.** Harvester maintenance, particularly the condition of basecutters and chopper blades, has a significant impact on harvester damage and sugar loss. Research has shown that losses can be tripled if blades are not correctly maintained. In the feed-train, optimise feed roller speeds to chopper rotation speeds to reduce juice loss in the billet cutting process. Reduce extractor fan speeds as much as possible to minimise losses through the primary extractor.

7. **Have a wet weather-harvesting plan in place.** Growers should discuss the best harvesting options for wet periods with their harvesting contractor. For example, it may be best to cut plough out blocks in preference to damaging plant, first ratoon and possibly second ratoon crops. Also use trash blanketing and minimum tillage where appropriate as these improve trafficability in wet weather compared to conventional cultivation.
8. **Ensure appropriate harvester hygiene.** To avoid the spread of the serious Ratoon Stunting Disease (RSD), sterilise harvesters between blocks wherever possible. Pay special attention to the crop dividers, basecutters and choppers.

9. **Plan ahead to ensure a sufficient supply of bins.** This minimises the time lost during harvesting operations.

10. **Maintain appropriate records.** Use a logbook for all harvesting operations.

**Important tip**

Modern harvester fronts, commonly available as retrofits, significantly improve gathering and feeding processes by providing a less aggressive separation of tangled crops.

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### Harvesting planting material

- To harvest good quality planting material (billets), harvesters must be specially set up for this purpose.

- It is best to use a modified harvester to cut undamaged billets between 250 and 300 mm long. Regularly take samples of billets and inspect them for split or crushed ends and damaged eyes. Many commercial cane harvesters have variations in feed roller speeds and aggressive ‘teeth’ on rollers. This causes highly variable billet length and damage to eyes, which in turn will reduce germination rates. Modifications such as rubber coating rollers and feed-train optimisation to match all roller tip speeds to chopper tip speed can significantly improve the quality of planting billets.

- Research on billet quality has shown that a modified harvester with rubber rollers and feed-train optimisation produces 70 percent viable billets compared to only 30 percent with a commercial cane harvester.

- Note that cutting lodged cane for planting material significantly reduces the level of viable billets, even with a fully modified harvester.

- It is also important to reduce speed when harvesting for billet planting. This minimises trash levels and avoids overloading the choppers, which can cause billets to become squashed on the ends and split.

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### Understanding the science

#### Key components of chopper harvesters

1. **Toppers – to cut tops and leaves into small pieces**
   - Tops make up a significant proportion of EM standing in the field prior to harvest.
   - Topping removes EM without cane loss.
   - Less EM into choppers will reduce extractor losses by reducing chopper overload.
   - Topping can improve CCS, bin weight, fibre and dollars/Ha.
   - In un-topped cane, modified / high fan speeds gave cane loss up to 25% whilst achieving only moderated EM reduction.
   - Topped cane, lower EM achieved at all fan speeds at lower cane loss.
   - The function of the topper is to cut off the leafy tops and cut or shred into smaller pieces.
   - Consists of either drum choppers with a single set of blades or shredder toppers with multiple banks of blades.
   - Both types of toppers are fitted with a gathering system and reversible throwing mechanism to deliver tops to either side of the harvester away from standing cane.
   - Shredder toppers are generally less effective in gathering tops, but the greater chopping of tops improves ground cover and facilitates subsequent operations such as trash raking and the use of coulters in fertilising, insecticide application, or cultivation.

2. **Gathering system**
   - Cane guided into the front by tapered gathering spirals that rotate inwards.
   - Current machines also have an outer spiral (crop divider) that rotates in reverse to separate lodged cane in adjacent rows.
   - Gathering shoes on the bottom of the spirals follow the ground contour and help gather stalks that have fallen in the interspace between rows.
   - Height of individual gathering spirals controlled either manually from the harvester cabin, or automatically by ground-following wheels to minimise gathering of soil by the shoes in wet conditions.
   - Height control on the crop dividers is important.
   - The tip should typically be operating on the soil surface to ensure proper gathering of the cane stalk.
   - ‘High’ operation of the crop dividers allows lodged cane stalks to then be crushed by the harvester wheels/tracks.

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**Information sheets available on the SRA website**

Billet quality – a key element for planting success
3. Knockdown roller and finned roller

- Cane knocked forward so that it can be fed butt first into the harvester.
- Knockdown angle is typically between 42° and 60° when cane is cut by the basecutter – this can sometimes cause stalk breakage and stool tipping.
- Correct adjustment of the knockdown roller is very important to reduce stool damage, soil in cane and extractor loss from stalk splitting.
- Minimal crop damage should occur when the knockdown roller is correctly positioned.
- When set too low, it will split stalks.
  > Have the knockdown roller up as far as crop conditions allow.
  > Move the knockdown roller up as harvester forward speed increases.
  > Move the knockdown roller up for brittle cane or insect-damaged cane.
  > In erect crops, the knockdown and top roller can be fully up.
  > In lodged or sprawled crops, it may be necessary to move the knockdown roller down to facilitate feeding.

4. Basecutters

- Each basecutter disc has five or six replaceable cutting blades per disc. Blades require regular adjustment and replacement due to wear, and hard-faced blades are used in abrasive conditions to prolong life.
- Basecutters usually have a fixed rotational speed designed to maintain cutting by the blades at the expected average harvester forward speed. Ideally the speed should be adjustable for harvester forward speed to maintain optimal quality of cut.
- Basecutters are tilted forward at an angle to facilitate flow of cane into the feed roller system and minimise dragging of the discs or gearbox on the cut stubble. The angle is variable in the range of 11° to 18° to allow matching of the cutting profile to the hill shape.
- Basecutter height setting is critical in gathering cane and minimising shattering and dirt intake by the harvester. The operator in the cabin sets the height.

5. Feed train (butt-lifter and roller train)

- Cane is guided into the feed train by a butt-lifter mounted behind the basecutter.
- The butt-lifter normally rotates slower than the feed train rollers, improving dirt rejection – typical rotation is 90 to 115 rpm with feed rollers 125 to 200 rpm.
- More even feed, billet length and billet quality is obtained if feed rollers have the same nominal speed and this is matched to the chopper tip speed. Optimum match is roller tip speed of 60 to 70 percent of chopper tip speed. Buttroller tip speed should be 80 – 90% of roller tip speed.

6. Choppers

- Function is to cut the cane into the desired billet length and propel the cane billets and trash into the cleaning system – see the Cleaning system section.
- The chopper system is self-sharpening and has an aggressive self-feeding action.
- Billet length is a compromise between short billets to improve cane packing in transporters and long billets to reduce cane loss in chopping, splitting of billets and the risk of cane deterioration.
- With pressure to achieve high bin weights despite ever-increasing trash levels, billet length has reduced steadily over time. Billet length in commercial operations ranges from 200 mm to 100 mm.
- Billet damage needs to be minimised as mutilated and damaged billets deteriorate much faster in terms of quality than sound billets.
• Reducing billet length is increasingly used as an ‘easy fix’ for load density.

• Shorter billets = Higher load density at low EM only.

• However shorter billet length:
  > Increases juice loss (more cuts per stalk)
  > Juice loss of >10% are supported by data
  > Increases fibre levels (due to juice loss)
  > 1 unit of fibre associated with shorter billet length (due to juice loss)

• Increased cane extractor losses (basic aerodynamics)

• Cleaning efficiency is strongly dependent on the evenness of flow of cane through the harvester.

• The extractors are fitted with shrouds or hoods on the outlets to direct flow of leaf and trash onto the ground beside the harvester.

• The cleaning system is a major source of cane loss – up to 25 percent at excessive fan speeds.

8. Harvester instrumentation

• Instrumentation may include gauges for:
  > Hydraulic pressures in key areas
  > Engine temperatures
  > Oil pressures
  > Basecutter height
  > Feed roller position (for indicating harvester pour rate)
  > Yield monitoring device linked to a GPS (Yield Monitor) for mapping cane yield during harvesting.

• A ground speed indicator is an important instrument in managing and minimising cane loss to allow a set flow rate to be achieved.

Typical performance of harvesters

The overall objective of harvesting is to achieve an output from the harvester with the following characteristics:

1. High-quality billets – of the desired length, with minimal mutilation or damage.
2. Low level of extraneous matter (EM).
3. Little or no soil.

With the high cost of owning and operating a harvesting business, it is difficult to achieve these objectives at the extremely high pour rates/ground speeds needed to maintain viability of the business.
Extraneous matter (EM) levels are driven by harvester pour rate (how fast cane flows through the machine expressed in tonnes of cane/hour) and crop presentation. As harvester pour rates increase, the cleaning system becomes overloaded and is unable to separate trash from cane as effectively as at low pour rates. Increasing extractor speed to improve cleaning has only a small effect on trash removal, but increases cane loss substantially.

There is a strong correlation with the more tonnes of total material extracted out of the cleaning chamber means increase in tonnes of sugar lost per hectare.

Typical cane losses average 5 to 25 percent in green cane and 1.5 to 2 percent in burnt cane except in a poor burn where cane losses are similar to green cane as remaining tops are extracted along with billets. EM levels average 5 to 15 percent in green cane and 3 to 8 percent in burnt cane.

Newer fan designs "pump" more air at lower speeds.

Most data indicates that there has been relatively little gain with respect to the proportion of cane in trash extracted. High trash extraction = high cane loss.

At high pour rates there is a compromise between effective.

1. Crop size

In high-yielding, erect cane, modern harvesters can have instantaneous pour rates in excess of 200 tonnes of cane/hour.

Lodged cane presents particular harvesting problems in feeding tangled material into the harvester. It is often necessary to cut one way to improve feeding and reduce loss of cane on the ground. Throughput is severely reduced in lodged green crops, and cane is burnt in extreme cases to improve feed and reduce the bulk of material processed by the harvester. Amounts of leaf, trash, tops and suckers are generally higher in lodged cane, due to lack of topping and the higher level of suckers. Soil levels also increase, due to partially tipped cane stools being taken into the harvester by the basecutter. Lodged cane that has been flood-affected also contains high levels of silt.

2. Harvesting speed

Levels of trash and dirt in the cane supply are closely dependent on pour rate.

Similarly, damage to cane stubble (stools) by the harvester basecutters increases at high harvester forward speeds, due to cane being sheared by the basecutter discs rather than cut by the blades.

While lower pour rates to minimise EM and reduce stool damage are desirable, the current flat rate per tonne payment system only encourages higher pour rates.
In order to meet grower demands for minimum cost, pour rates have doubled over the past 15 years resulting in higher levels of EM and stool damage.

3. Cane variety

- Cane varieties vary significantly in levels of leaf, trash, tops, stalk diameter and suckers in the field and, therefore, EM levels in the cane supply. Pre-harvest EM levels (excluding suckers) in a range of Australian varieties vary between 16 and 30 percent, with cane supply EM levels of 5 to 15 percent in untopped green cane.
- Erect, free-trashing varieties are the most suitable for green-cane harvesting.
- Suckers have similar aerodynamic properties to cane billets and are not removed by the harvester cleaning system. Immature suckers can have a significant negative impact on CCS levels.
- Some cane varieties are associated with higher soil levels in the cane supply. This is linked with a tendency to lodge and also, in some cases, to stool tip when lodged. In bad cases, roots with attached dirt are tipped from the ground, with both cane and roots being gathered by the harvester. Tall, strong-stalked varieties with a sprawled habit and/or shallow root system appear most susceptible to stool tipping.

4. Weather and crop conditions

- Removal of trash and dirt becomes more difficult and intake of dirt increases in wet conditions. Local policy on harvesting in wet weather determines its impact on cane quality.
- Harvesting at night or early in the morning can reduce cane quality due to the effect of dew on trash and dirt removal.
- Poor weed control in fields increases EM levels and causes wrapping on the gathering spirals and feed rollers.
- Similarly, bad infestations of canegrubs, root diseases or other pests that weaken cane root systems reduce pick-up of cane and increase soil levels in the cane supply.

5. Row spacing

- In narrow row spacings (<1.8 m), cane may need to be cut with the basecutter off centre from the cane row to minimise stalk breakage in the adjacent row of standing cane. This can lead to increased intake of soil, because the basecutter needs to be set deeper to gather all the cane. Alternatively, if the harvester runs on adjacent rows, cane may be broken off and/or the hill pushed out of shape for subsequent harvests.
- Uneven row spacing has a similar effect and may also lead to variable row-profile shape and height where multi-row cultivation equipment is used.

6. Row profile

- The shape of the row profile determines whether cane can be cut at ground level without taking in soil.
- Matching row profile to harvester setup is vital. Discussions between the grower and operator are the best way to achieve the correct profile. In furrow-irrigated fields, hills may need to be higher to prevent overtopping during irrigation, but gradually sloping sides should be retained.
- The most common problem is poor filling in of rows in plant cane leaving a depression in the centre of the row and/or a ridge of soil on either side of the row (‘volcano effect’). This results in either high cutting with damage to stubble and poor gathering of sprawled stalks, or high dirt intake if the basecutter is set below ground to gather all of the cane.
- These problems can be minimised by progressive filling of the planting furrow during cultivation, or the use of well-designed hiller boards to form a low mound. These operations need to be well timed, so that they are completed before the cane stool is well developed and impedes the forming of the hill.

7. Cultivation practices

- Normal tillage operations in ratoons can result in large clods being left in cane rows or tine marks adjacent to the cane row. This may increase soil intake and pick-up loss of cane during harvesting.
- Minimum or zero tillage limits reshaping of row profiles in ratoons and cane often grows from the side of the row in old ratoon crops. This again affects both soil levels and pick-up losses. There is also limited opportunity to remove ruts left after wet-weather harvesting. On the positive side, reduced tillage allows controlled compaction of the interspace and reduces bogging of equipment in wet weather.

Cane transport

1. Field to mill

- Usually a combination of infield transporters delivering to mill bins at local sidings and a dedicated narrow-gauge rail network for delivery of bins to the mill by locomotives.
- In some mills, there is a combined system of mill tramlines and road transport delivering directly to the mill, and several mills have a full road transport system.
2. Infield transport

Roll-on roll-off systems

- Historically, the major infield transport system was a roll-on roll-off system where rail bins are carried into the field on trucks or tractor-drawn trailers. The infield transporters are fitted with drop-down points to allow winching on of empty bins at the rail sidings and drop off of full bins. Modern systems have radio control of winches to speed up loading of empty bins.

- These systems are inexpensive, but poorly suited to wet weather harvesting because relatively small diameter, narrow, high-pressure tyres must be used. Unloading at the mill siding is also relatively slow. However, bin weights are generally higher than in other transport systems because the mill bins are loaded directly beside the harvester.

High-flotation transport systems

- Use of high-flotation tipper and elevator bin systems was brought about by several factors: the need for improved mobility in wet weather; adaptability of self-unloading systems to different bin sizes; faster unloading; and the increased load-carrying capacity of the large tyres that can be fitted to custom-built transporters.

- Typically, high-flotation systems are rubber tyred, but both steel- and rubber-tracked equipment is used in wet districts. The steel-tracked transporters are less mobile and are used in short-haul situations.

- Most high-flotation transporters are drawn by tractors, with articulated and four-wheel-drive tractors being most common. Several self-propelled transporters are also available.

- Tipper transporters are generally matched to mill bin capacity and use fold-out hoppers to minimise cane spillage during tipping. Tippers are a durable, high-flotation option with low maintenance costs and unloading times between 30 seconds and 1 minute.

- Tipper-elevator bins incorporate a dual action with cane being tipped forward onto side- or front-feeding elevators, which load the mill bins. They are more flexible than a standard tipper and can load into a range of mill bin sizes. Unloading times are 2 to 3 minutes and maintenance costs are higher than for tipper bins. There have been problems in maintaining mill bin weights in green cane with tipper-elevator transporters due to the loose packing of billets and problems in obtaining adequate clearance to fill mill bins completely.

Harvest scheduling

- Harvesting is carried out under a grouping system with individual farms within a group rostered for several cuts spread throughout the season.

This helps farmers manage their crop rotation, limits their exposure to adverse harvesting conditions, and helps optimise cane CCS levels. Groups generally include nearby farms within a mill area and may be run by contractors, individual farmers, or as a cooperative between farmers.

- The scheduling of road transport and delivery of mill bins to harvesting groups is a complex operation and sophisticated queuing or scheduling programs are available for optimising the system. Some mills use GPS for tracking locomotives and road transporters to improve flexibility in transport scheduling. Similar GPS systems on harvesters, combined with infield weighing systems, offer potential for further refinement of transport scheduling.

- Delivery and pick up of bins are also designed to minimise cut to crush delays. Typically, there are two deliveries of mill bins each day. Start-up times for harvesters are also offset in some mill areas to provide fresh cane for the early morning changeover of cane supply to the new day’s cutting. Mills employ cane inspectors to help coordinate harvest-related field and mill operations.

- As harvesting group sizes have increased, infield storage capacity has expanded to keep pace and there has been a trend to fewer, larger bin sidings. This trend has to be balanced against the reduction in infield transport efficiency with longer haul distances.

- With road transport, weighing systems are becoming common on infield transporters to maximise legal loads in containers. Concessional arrangements for occasional overloading are also used to improve average loads carried by road transporters.
### Milling issues for the grower

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- **Milling issues for the grower**
Milling issues for the grower

Understanding the science

A brief overview of the farm-to-mill process

• Milling involves the cane being crushed, the juice washed from the cane, and the sucrose being separated from the water, impurities, fibre and dirt.

• The miller’s responsibility for the process begins at the siding or loading pad where the harvested cane is left for collection.

• The cane is transported to the mill by rail or road.

• In the rail system, cane is held either at the mill or at district rail sidings.

• In the road system, storage is usually at field pads with a just-in-time system governing arrival of cane at the mill.

• There are also systems in which road-delivered cane is transferred to rail bins for final transport to the mill.

• The Australian sugar industry tailors its harvesting, delivery and crushing operations to minimise the time between cutting and crushing so that cane deterioration and consequent sugar loss is minimised.

• A grower’s consignment of harvested cane is tracked in transit and at the mill before crushing. The juice from that cane is analysed for sugar content and quality in samples that are generally processed in under 20 minutes of crushing time.

• The cane is weighed before crushing. Payment to growers depends on this weight and on quality analyses. These analyses may be either carried out by the mill and audited for the miller and the grower by independent persons called cane auditors, or carried out by independent cane analysts on behalf of the miller and grower.

• The price millers pay growers is based on long-standing cane payment arrangements and the price achieved for the sugar produced by the mill from the cane.
### An outline of the milling process

#### 1. Cane preparation
- Harvested billets are fed into a hammer-mill shredder, which opens about 90 percent of the juice cells in the cane. This improves the efficiency of removal of the sugar from the fibre in subsequent processing.

#### 2. Juice extraction
- The prepared cane is passed through a milling train consisting of three to five sets of crushing or grinding rollers.
- Cane exiting a roller set is called ‘bagasse’. In a typical mill, as it proceeds through the sets of rollers, it is continually doused with juice from another roller set to refill the opened juice cells to help flush out the remaining juice at the next crushing set (a process called maceration). The bagasse entering the final mill is doused with hot water to maximise sugar recovery and the final mill also acts as a dewatering process for final mill bagasse which is used as fuel for the mill boilers.
- A few mills employ diffusers, in which the juice is removed by a counter-current leaching action of water or liquid from a suitable stage in the process. In this situation, the bagasse is ‘dewatered’ by rollers following diffusion to prepare it for use in the mill boilers as fuel.
- Bagasse is used as fuel in the boilers to produce high-pressure steam for driving the turbines for the mills, shredder and power generation. Spent steam from these processes is used for heating and evaporating water in the processing section of the mill.
- The ash from the boilers is high in potassium and at most mills is blended with filter mud (also called filter cake) from a later stage in the process. This is returned to the cane fields as a soil ameliorant and conditioner commonly called mill mud.

#### 3. Clarification
- The juice from the crushing/juice extraction process is screened to remove coarse fibrous matter, then heated and clarified.
4. Evaporation

- The clarified juice (ESJ) from the clarifiers is at 14°Bx (percentage dissolved solids on a weight/weight basis) and is concentrated to 65 to 70°Bx in multiple-effect evaporators (effects). The output is referred to as syrup.

- The evaporators are aligned in sequence. Steam and juice flow together from the first vessel under pressure to the final vessel under the highest vacuum. The vapour from stage one passes off to the calandria (or heating space) in vessel 2 to heat the juice in that vessel which had gravitated in from vessel 1 and so on.

- This is an energy-efficient method of concentration of the juice.

- Cane juice contains substances that rapidly foul the evaporator heating surfaces, necessitating boil-out cleaning with chemicals about every two weeks.

5. Crystallisation

- This involves two stages: a process called ‘pan boiling’ which crystallises the syrup from the evaporators, and high-speed centrifugation (using machines called centrifugals) to separate the crystallised product into raw sugar and the byproduct molasses.

- Australian sugar mills typically use a three-stage pan boiling system, producing A sugar and B sugar which are combined as raw sugar. C sugar is recovered in the lowest purity boiling and is typically used as the starting crystal (or seed) for the A and B sugar boilings. Twice as much A sugar is produced than B sugar.

- The pan boiling operation produces a mixture of sugar crystal and sugar syrup (called molasses). The mixture is termed a massecuite.

- The quality of raw sugar (A or B) is derived by varying the time and speed of rotation of the centrifugals, or the purity (ratio of sucrose to sucrose plus impurities) of the massecuite produced by the pan boiling operation.

- The correct amount of magma or seed crystal is introduced at a known size to reach the desired size crystal at the end of the massecuite stage. C sugar crystals are about 0.3 mm in size and are used as a starting crystal for the production of A and B massecuite where the final crystal size is 0.8 to 1 mm.

- C massecuite is close to 100 percent B molasses. It carries all the impurities in the cane not incorporated into the raw sugar or removed in clarification.

- The presence of fine grain in the raw sugar, caused by spontaneous crystallisation or by poor control of seed crystal addition, interferes with subsequent processing in the refinery. Fine grain above a certain level results in a lower price for the sugar produced. While fine grain is primarily a miller’s problem, the presence of particular impurities in the incoming cane supply, such as dextran, reduces crystal growth and enhances fine grain formation.

- The crystallisation process is managed to produce raw sugar at the quality level desired by the market. The pol of the sugar (similar to sucrose content) is the major index. Australian factories primarily produce Brand JA sugar around 97.8 pol and Brand 1 at around 98.9 pol.
6. Drying

- Drying involves a continuous passage of the sugar through flighted rotating drums with a counter-current flow of air. The flights pick up and drop the sugar as it moves through the drum.

- The air may be heated, or air-conditioned and then heated suitably above dew point, or simply at ambient conditions, depending on conditions and requirements for the dried sugar.

- The moisture content of the raw sugar is most important. If it is too dry, too much dust is produced in subsequent handling, and there is a risk of explosion. If it is too wet, flow characteristics are affected, and conditions could be favourable for bacteria to cause stored sugar to deteriorate.

- The temperature of the raw sugar is also critical, and must be appropriately controlled to avoid development of colour in storage.

7. Shipping

- The raw sugar is transferred to terminals in bulk by road or rail and bulk loaded into ships for dispatch to domestic and international refineries.

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**CCS**

- The sugar that may be produced from a consignment of cane is estimated by CCS (or commercial cane sugar). CCS is a measure of pure sucrose that is obtainable from the cane. It is also referred to as POCs (pure obtainable cane sugar).

- In normal seasons, crop harvest extends from June to December. The level of CCS changes from a low at the beginning of crushing, rising steadily to reach a peak about two-thirds of the way through and then starts to taper off towards the end of the season.

- This pattern may vary with different varieties of cane and is influenced by abnormal conditions such as drought, grub damage, excessive or late applications of nitrogenous fertilisers, or rain during the harvest period. In general, because the peak of CCS is not necessarily in the middle of the season, the CCS curve is not symmetrical.

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**Farm impacts on milling and sugar quality**

**Milling throughput and efficiency**

- The throughput of milling equipment is related to the cane solids that can be processed. An increase in cane-fibre content, particularly because of higher extraneous matter (trash, tops and soil), reduces the crushing rate of the mill and prolongs the crushing season.

- High dirt loading causes severe wear to shredders, rollers, carriers and boiler station equipment, reducing efficiency and increasing maintenance costs.

- Clarification is adversely affected by fine soil particles, and stale and deteriorated juice from delayed or field-damaged cane. It is also overloaded by excessive quantities of dirt in the incoming cane. Poor clarification lowers raw sugar quality and hinders crystal growth rates in the crystallisation process.

**Sugar quality – ash**

- Ash increases the solubility of sucrose in water and as a consequence, reduces the amount of pure sugar that can be produced from cane in a mill or from raw sugar in a refinery. Ash constituents enter the cane from the soil, trash, water or added fertilisers. Ash is high in tops, trash and dirt adhering to cane. For example, cane tops can contain 12 times as much ash as cane stalks on a dry juice basis. High topping can increase ash in juice by 20 percent.

- Ash in the cane supply includes such substances as chlorides, sulfates, phosphates, and silicates of minerals including calcium, potassium, magnesium and aluminium, as well as clay and sand. These originate in the field. The mill process removes phosphates from cane juice into filter mud, but other inorganic salts can continue through processing, largely to molasses and, in much smaller amounts, to raw sugar.
• The presence of elevated levels of salt in soil or irrigation water stimulates uptake of a range of mineral salts by the cane plant in its attempt to maintain a favourable osmotic balance with salts in the root zone. Therefore, ash in juice and sugar increases in response to salts in soil and irrigation water. Salty soils are best avoided for cane production because of effects on yield and ash.

• Potassium salts are major constituents of ash. Sugarcane can acquire excessive potassium from soils of high fertility treated with too much potassium fertiliser, or from soils amended with high rates of ash from sugar mill boilers. Juice ash levels can be increased by 50 percent in cane where excess potassium fertiliser and poor-quality irrigation water have been used. Thus, there is potential for reducing potassium ash constituents in cane by applying only the potash fertiliser required to balance crop requirement against that already obtained from soil and or boiler ash.

Sugar quality – colour

• Cane juice and the resultant sugar contain coloured materials. Reactions between various colour constituents during milling can affect colour quality and overload raw sugar refinery processes.

• Colour is much higher in the tops, trash and suckers than it is in the stalk of the cane. Tops and trash have 7 and 36 times, respectively, as much colour as the cane stalk. Trash not only adds a loading of colour but also increases the loading per unit weight of impurities, which, in practice, increases raw sugar colour.

• The prominent and most damaging colourants of cane or raw sugar are formed by the reaction of amino nitrogen and reducing sugars in the mill or in storage. Sugarcane takes nitrogen from soil as nitrate and ammonium ions and stores nitrogen not needed for immediate growth processes as amino acids, primarily in the stalk. Thus, excessive uptake of nitrogen from highly fertile organic soils, or over application of nitrogen fertiliser, will result in high levels of amino nitrogen in cane. High levels can also result from the use of recommended levels of nitrogen fertiliser in situations where drought has prevented use of plant nitrogen in accumulation of expected stalk yield. Asparagine is the dominant amino acid.

• Soil in cane also increases colour.

• Cane, harvested green, when free of extraneous matter, has a lower colour than the burnt equivalent. This is due to the impact of heat on juice near the epidermis of the stalk.

Sugar quality – dextran

• Dextran is a natural polysaccharide produced by bacteria that infect the sugarcane stalk after damage or cutting. It can also be produced by the same bacteria in the mill and may result from poor mill hygiene.

• Bacterial deterioration and dextran formation is enhanced if the cut-to-crush delay is extended beyond the industry-recommended maximum of 16 hours, by hotter and humid weather, and by shorter billets which increase the cuts per stalk and the number of surfaces through which bacteria can enter the cane.

• Another source of increased bacterial action is damaged, squashed and cut ends providing more access for organisms to the interior of the billet. These often arise from poorly maintained harvesting equipment or the desire to shorten billets.

• Burnt cane deteriorates faster than green cane, and cane subject to an excessively long burning-to-cutting delay deteriorates faster than freshly burnt cane. Stressed or otherwise damaged cane can have elevated dextran levels, as splits, rodent damage and insect entry points allow bacterial access to the interior of the stalk.

Sugar quality – starch

• The leaves and tops contain significantly more starch than the cane stalk – tops, three times as much; and the top of the stalk compared to the base, four times as much. Hence, keeping these to a minimum enhances sugar quality.