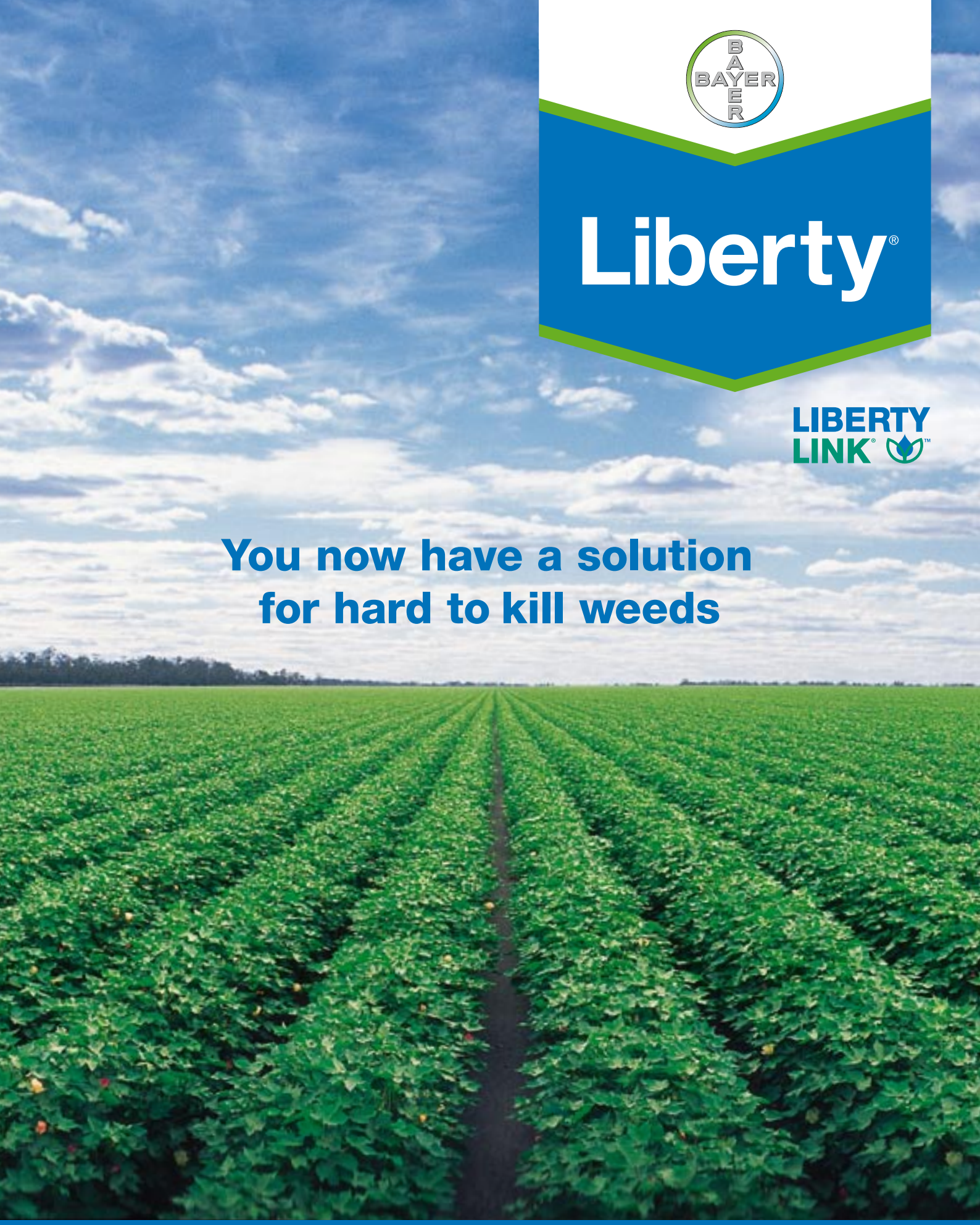


Liberty®

LIBERTY LINK®™

You now have a solution for hard to kill weeds

Liberty 200 Herbicide Technical Guide

Bayer CropScience

Introduction

Liberty Link® Cotton is the first genetically modified crop developed and sold by Bayer CropScience in Australia. Liberty Link Cotton has been developed to be tolerant to Liberty® 200 Herbicide.

Liberty 200 Herbicide contains the active ingredient glufosinate-ammonium, a member of the glycine group of herbicides, Group N, and offers a new and exciting option for weed management in cotton.

Liberty 200 Herbicide is a non-volatile herbicide with selective activity against many annual weeds in Liberty Link® cotton varieties.

The key benefits of Liberty 200 Herbicide include:

- Control of hard to kill weeds including volunteer cotton (excluding Liberty Link Cotton), peach vine, sesbania pea and bladder ketmia.
- A novel herbicide group – Group N, providing a new herbicide rotation option.
- A wide application window – up to 70 days prior to harvest.
- An easy to use product which does not require additional wetter.
- An easy to mix product.

The active ingredient of Liberty, glufosinate-ammonium, is a substance with a natural origin. First isolated from cultures of the soil bacteria *Streptomyces viridochromogenes*, the amino acid phosphinothricin (glufosinate) was found to have herbicidal activity. Synthetically produced as the ammonium salt, glufosinate-ammonium, in the form of Liberty herbicide, is now available to cotton growers in Australia.

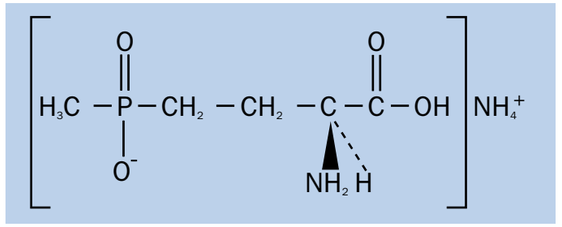
Active ingredient

Common name: glufosinate-ammonium

Chemical name (IUPAC):

Ammonium DL-homoalanin-4-yl (Methyl) phosphinate

Structural formula:



Empirical formula: $C_5 H_{15} N_2 O_4 P$

Chemical Group: Glycine

Mode of Action: Group N Herbicide

Product formulation

Liberty 200 Herbicide contains 200 g/L glufosinate-ammonium as a soluble concentrate (i.e the active ingredient is dissolved in water). The formulation also contains 30% surfactant.

Physical properties

Appearance: Blue liquid

Density: 1.11 g/cm^3 (20°C)

Odour: Weakly pungent

Flammability: Non-flammable

Corrosiveness: Non-corrosive to glass, stainless steel and high-density polyethylene containers, but unsuitable for steel and aluminium. The spray mixture (in water) is not corrosive to galvanised steel, copper and polyethylene spray equipment.

Miscibility: The formulation is miscible with water.

Stability: In unopened original containers at temperatures of 25 +/– 5°C, the product remains stable for at least two years.

Poison classification: Schedule 5

Dangerous Goods Classification: Not classified as dangerous goods.

Toxicological properties of formulated product

Acute oral LD_{50}: Rat (m) 2170 mg/kg Rat (f) 1910 mg/kg

Acute dermal LD_{50}: Rat (m) 1400 mg/kg Rat (f) 1380 mg/kg

Skin irritation: Slightly irritating

Eye irritation: Moderately irritating

Effects on flora and fauna

Aquatic organisms:

Liberty 200 Herbicide exhibits only slight toxicity to a range of aquatic organisms.

Fish-LC_{50} (96 hours) Rainbow Trout: 34 mg/L

Daphnia-EC_{50} (48 hours) *Daphnia magna*: 27 mg/L

Algae-EC_{50} (72 hours) *Desmodesmus subspicatus*: 36 mg/L

Soil micro-organisms:

Studies indicate that at label rates, glufosinate-ammonium and its key metabolites have negligible impact on soil microflora responsible for both nitrogen and carbon turnover.

Bees: Practically non-toxic to bees.

Earthworms: Practically non-toxic to earthworms.

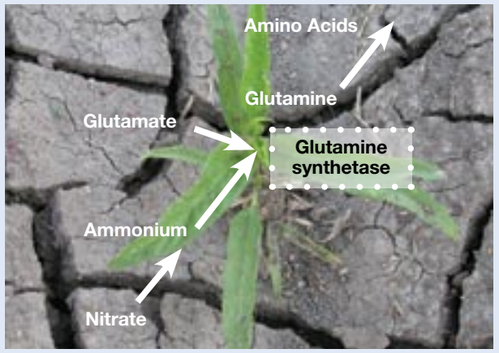
Birds: The acute oral LD_{50} of >2000 mg/kg for quail indicates that Liberty 200 Herbicide represents no significant risk to birds.

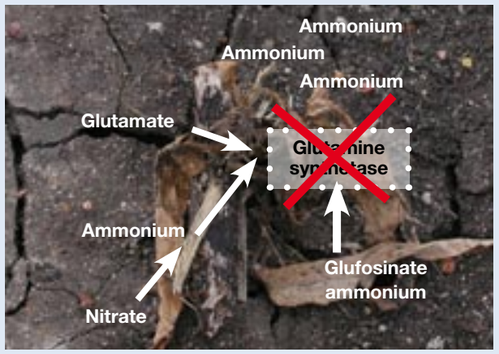
Biological Properties

Mode of action

Biochemical action

The unique mode of action of Liberty herbicide is of great benefit to Australian cotton growers. During the normal processes of plant metabolism, nitrate (NO_3^-) is absorbed by the plant and broken down to ammonium (NH_4^+). Normally it combines with glutamate within cells to form glutamine. Glutamine goes on to feature in a number of other important reactions, some of which lead to processes which are vital for photosynthesis.





The initial ammonium plus glutamate combination is made possible by the presence of an enzyme, glutamine synthetase. Liberty disrupts the action of glutamine synthetase, thereby preventing this reaction. As a result:

a) levels of ammonium build up in plant cells;

b) production of glutamine is slowed, disrupting the subsequent reactions and quickly leading to a breakdown of photosynthesis.

The herbicidal activity of Liberty results from the combined effects of ammonium toxicity, and the inhibition of photosynthesis.

Activity in the plant

Uptake

When Liberty 200 Herbicide is applied to a leaf, it must first penetrate the leaf surface before it can begin to disrupt the plant. Glufosinate-ammonium moves into the leaf through interruptions in the cuticle of the leaf surface.

Studies of uptake in a variety of weed species have found that:

In 4 to 6 hours, between 15 to 50% of applied glufosinate-ammonium had penetrated the leaves; after 24 hours, this had risen to between 20 and 80%.

The speed and extent of uptake depends on many factors, including the weed species, stage of growth, air humidity, air temperature and the rate of chemical applied.

Translocation

After being taken up by the leaves, some glufosinate-ammonium may move in the plant; around the leaf, from leaf to leaf, and to the roots and rhizomes underground. However this movement is very limited (unlike glyphosate, which shows strong movement in the plant), and varies in extent between species. Liberty is best described as having very limited systemic activity.

Studies have shown translocation to the roots ranging from 0.3 to 2.3% of applied glufosinate-ammonium. In a specific study with the perennial weed *Imperata cylindrical* (Blady grass), it was shown that regrowth from rhizomes of plants treated with glufosinate-ammonium was severely inhibited, following translocation of 0.9% of applied glufosinate-ammonium to the roots and rhizomes. From an application and spray coverage point of view, Liberty should be regarded as a contact herbicide. Complete and thorough spray coverage of weeds is therefore necessary for best results.

Symptoms

Plant growth ceases soon after the application of Liberty. Symptoms can often be seen within a day or two of application in warm conditions. There is often an initial general yellowing (particularly for grassweeds) before damaged patches appear, which enlarge as the plant wilts and collapses. Plant death will follow within 1 to 3 weeks.

Under cold conditions, the first obvious symptoms may take more than a week to appear and plant death up to 6 weeks.

The speed of activity of Liberty is mid-range between paraquat-based herbicides (which are faster) and glyphosate herbicides (which are slower).

Behaviour in the Environment

In soil

Breakdown

In the soil, Liberty 200 Herbicide is rapidly broken down by micro-organisms. Field trials confirm a half-life, generally between one and three weeks, for the active ingredient glufosinate-ammonium. This is influenced by soil temperature, moisture and soil type.

Glufosinate-ammonium breaks down to 3-methyl-phosphinico-propionic acid (MPP) and 2-methylphosphinico-acetic acid (MPA).

The breakdown of these metabolites, with mean half-lives of 13 and 8 days respectively, yields carbon dioxide (CO_2) and carbon 'bound' within the structure of soil micro-organisms.

Leaching

Glufosinate-ammonium and its degradation products are loosely adsorbed to soils, with clay content correlated to glufosinate-ammonium adsorption in particular.

The results of field dissipation studies however suggest limited movement of glufosinate-ammonium into the soil profile. This appears to be primarily a result of its rapid degradation by soil micro-organisms and its limited soil adsorption.

In water

Glufosinate-ammonium is extremely stable in sterile water, with a half-life of more than 300 days. In biologically active water it will degrade by microbial action, with a half-life of less than 2 weeks.

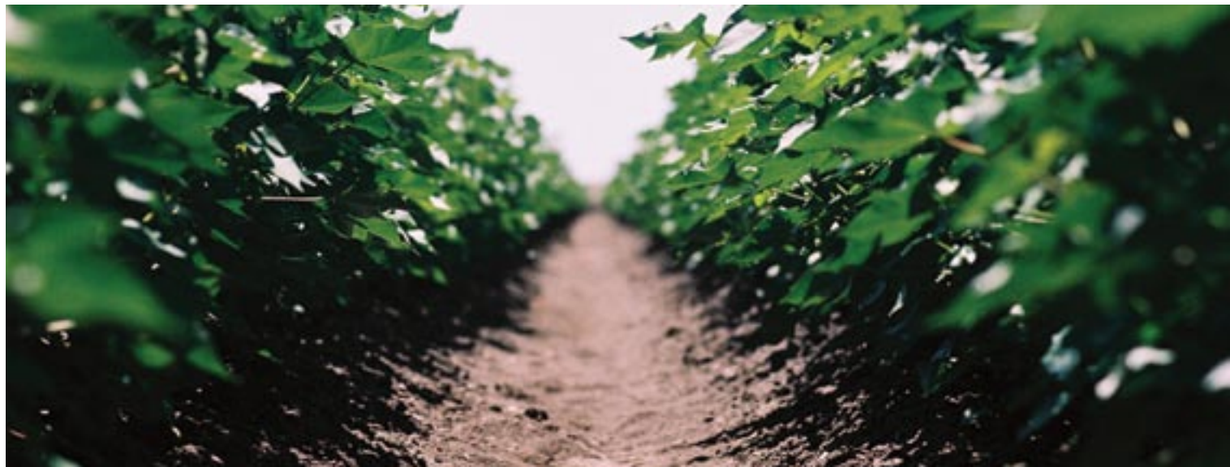
Aspects of water quality which may affect the performance of herbicides are:

pH – the pH of water, within the range 4 to 9, has no influence on the activity of Liberty.

Hardness – water that contains a high concentration of metal ions such as calcium, magnesium, iron or aluminium is known as hard water (hard water will not easily produce a lather with soap). Very hard water can reduce the performance of Liberty, however it appears that this is not as critical a concern as with glyphosate. There is some evidence that high levels of iron may be the most disruptive to Liberty. Water of 200 ppm hardness has been shown to have no impact on Liberty performance, and in fact to have a positive effect by reducing foaming of the spray mixture, which is occasionally reported to be a problem.

Clay particles – many herbicides are strongly attracted to clay particles and organic matter in dirty water, and can be bound to these particles, rendering them inactive. Glufosinate-ammonium is only 'loosely' adsorbed to clay particles and organic matter, and water cleanliness is not as critical as with glyphosate and paraquat-based herbicides. However, clean water should always be the preferred option.

It appears water quality has little effect on the efficacy of Liberty, certainly when compared with glyphosate or paraquat. If the spray solution is used within a few hours of preparation, there should not be a problem with water quality, unless water is extremely hard or dirty. In clean, high-quality water (e.g. rainwater), Liberty is very stable and could be expected to remain suitable for application for at least 24 hours after preparation of the mixture.



Proposed Directions for Use

Restraints

DO NOT apply to cotton varieties other than Liberty Link Cotton varieties.

DO NOT apply by aircraft.

DO NOT apply by mister.

DO NOT apply when rain is expected within 6 hours or irrigate until at least 6 hours after application.

DO NOT apply onto weeds when dew, fog or mist is present.

DO NOT apply to weeds under stress, for example due to very dry, very wet, frosty or nutrient deficient conditions or as a result of windblast, insect damage, disease or a previous herbicide treatment.

CROP	WEED	WEED STAGE	RATE	CRITICAL COMMENTS
Liberty Link Cotton	**Control of:** Annual polymeria Bellvine Bladder ketmia Caltrop Dwarf amaranth Field bindweed (European bindweed) Paddy melon Peach vine Red pigweed Rhyncho (Rhyncosia) Sesbania pea Sowthistle (Milk thistle) Volunteer cotton (other than Liberty Link Cotton) Yellow vine **Suppression of:** Chinese lantern (Wild gooseberry) Noogoora burr complex	2-6 leaf	3.75 L/ ha in a minimum of 100 L water	Apply to actively growing weeds. Good coverage is essential. Refer to **Climatic Conditions** section of the label. Do not apply more than 3 applications per season. Liberty 200 Herbicide may cause minor and transient spotting on leaves which are directly contacted by spray applications. This has not been shown to have any impact on crop growth and development.

Window of application

The window of application for spraying Liberty to Liberty Link cotton varieties is up to 10 weeks or 70 days prior to picking.

Climatic conditions

Best results are achieved when Liberty is applied under warm humid conditions (e.g. temperatures below 33°C with a relative humidity above 50%). Under any other conditions efficacy and speed of action of Liberty may be reduced.

Resistant Weeds Warning – GROUP N Herbicide

Liberty 200 Herbicide is a member of the glycine group of herbicides.

Liberty is an inhibitor of glutamine synthetase. For weed resistance management Liberty is a Group N herbicide. Some naturally occurring weed biotypes resistant to Liberty and other Group N herbicides may exist through normal genetic variability in any weed population. The resistant individuals can eventually dominate the weed population if these herbicides are used repeatedly. These resistant weeds will not be controlled by Liberty or other Group N herbicides.

Since occurrence of resistant weeds is difficult to detect prior to use, Bayer CropScience Pty Ltd accepts no liability for any losses that may result from the failure of Liberty to control resistant weeds.

Do not rely exclusively on Liberty for weed control. To minimise the risk of weeds developing resistance to Liberty use in conjunction with herbicides from alternative mode of action groups and/or non-chemical weed control measures such as chipping and inter-row cultivation.

General Instructions

Liberty 200 Herbicide is absorbed by plant foliage and green stems. It is inactive in soil and does not provide residual weed control. Liberty is not greatly translocated as an active herbicide throughout the plant, and therefore will only kill that part of a green plant that is contacted by spray. Best results are achieved when applications are made under good growing conditions to young, actively growing weeds. Liberty will have an effect on weeds that are larger than the recommended leaf stage, but speed of activity and control may be reduced. Application to weeds under stress should be avoided. Visible symptoms of control appear in 3 to 7 days, but complete desiccation may take 20 to 30 days under cool conditions.

Application equipment

Liberty 200 Herbicide can only be applied through a ground boom sprayer.

Ground boom sprayers only

Aim to apply a thorough and even coverage of spray to the target weed. Dense stands of weeds should be thoroughly wetted with spray. Incomplete coverage may result in poor control. Equipment set-up should be such that adequate coverage, penetration and volume of spray liquid can be achieved while the potential for off-target movement is minimised, by consideration of factors including nozzle type and size, spray pressure, temperature, relative humidity, wind speed and direction.

Liberty should be applied at the recommended rate in sufficient water to give thorough coverage of weeds. Application volumes of at least 100 L water/ha through flat fan nozzles with a droplet size of 200 to 300 microns are recommended for most situations.

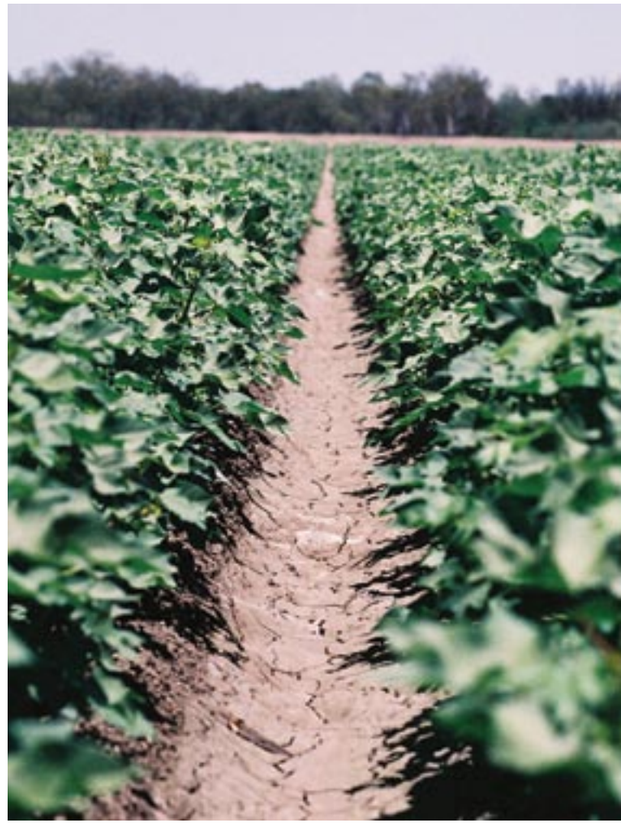
Sprayer cleanup

Clean all equipment after use by thoroughly flushing with water.

Mixing instructions

Liberty 200 Herbicide mixes easily with water. Clean water should always be used for mixing with Liberty.

Ensure that the spray tank is free of any residues of previous spray materials. Two-thirds fill the spray tank with clean water, and with the agitator operating add the required amount of Liberty. Add other relevant compatible products. Top the tank up to the required volume with clean water with agitator running.



Factors Affecting Performance

Application

Liberty 200 Herbicide is primarily a contact herbicide with very little systemic activity on target weeds. Coverage of the target weed is important with all herbicide applications. However coverage is extremely critical to the effectiveness of a contact herbicide.

Good coverage is reliant on many factors such as the total water volume applied, droplet size or spectrum achieved and the number of droplets achieved in a given area. Some of the key variables on a spray rig that can affect good coverage are the size and type of the nozzle and liquid pressure achieved at the nozzle.

For Liberty 200 Herbicide it is recommended that a minimum of 100 litres of total volume is applied per hectare. The experience with Liberty suggests that higher application volumes may achieve improved product performance under less than ideal conditions.

Environmental factors such as high temperature, low humidity and stressed weeds due to lack of moisture also affect the performance of Liberty. Application of Liberty under such conditions (i.e. less than ideal conditions) may compromise herbicide performance. Compensating for one or more of these factors by increasing total water volume applied may improve Liberty performance.

Physical factors also need to be considered in the set up of spray rigs for any application. An example is the pressure drop over long booms with small diameter spray lines. The smaller the spray line the faster the pressure will drop and the less volume able to be physically pumped to the end nozzles.

Pressure measured at the pump is not necessarily the pressure at the nozzles. It is the pressure at the nozzles that creates the droplet spectrum required for the coverage intended. It is therefore important to ensure that if a high volume application rate with a fine to medium droplet spectrum is required that the spray lines and application equipment is built to handle this situation.

An increase in total application volume alone is not a solution to increasing coverage or getting better coverage. Increasing total application volume by increasing nozzle size by one or two levels may reduce coverage by producing fewer droplets of a much larger droplet size.

Application volumes of at least 100 L water/ha through flat fan nozzles with a droplet size of 200 to 300 microns (fine to medium size droplets) are recommended for most situations.

The example below demonstrates the differences between changing nozzles and pressure and how it can affect droplet size.

Using the same pressure with different nozzles

XR TeeJet	XR 110-02 @ 1.5 bar = Fine droplet
	XR 110-06 @ 1.5 bar = Coarse droplet

Note that changing nozzles while maintaining the same pressure will cause a difference in droplet spectrum.

Reference: TeeJet Catalogue 50-M from TeeJet Technologies (A Spraying Systems Company)

Humidity

The speed and total amount of Liberty 200 Herbicide uptake from the leaf surface into the plant greatly depends on the relative humidity of the surrounding air. As humidity increases, more Liberty is taken up by the leaf. It is understood that Liberty moves through the leaf cuticle only in an aqueous (watery) environment. As air humidity increases, the conditions for this access improve.

For best results Liberty 200 Herbicide should be applied when the relative humidity is above 50% and the temperature is below 33˚C.

Temperature

The major impact of temperature on Liberty performance is that the speed of activity increases as temperature increases. In warm conditions, symptoms will be obvious a day or two after application, while under cool conditions it may be more than one week before symptoms are visible. The time until final weed control is achieved is similarly dependent on temperature.

There is evidence that low temperature conditions may lead to a lower level of weed control than warm temperature conditions, at least for some weeds. However, this evidence is not consistent. In practice, Liberty performs well against weeds that are most susceptible, regardless of temperature, provided an adequate rate of Liberty is applied.

Rainfall after spraying

Because Liberty 200 Herbicide is a highly water-soluble herbicide, it is relatively easily washed off the leaf surface by rain. Once it has penetrated the leaf, however, it is protected from rainfall.

The impact of rainfall after spraying will depend largely on the time taken for sufficient Liberty to be taken up by the leaf.

Speed of uptake depends on:

- The type of weed and its growth stage – large differences have been shown between different plant varieties. However these are difficult to predict.
- Humidity – as humidity increases, the rate of uptake will increase.
- Temperature – as temperature increases, the rate of uptake increases, provided humidity is adequate.

However it is not recommended to apply Liberty 200 Herbicide in temperatures over 33°C.

Achieving sufficient uptake of Liberty (into the weed leaf) prior to rainfall is the critical issue, since once this uptake level is reached, rainfall will not affect the level of control.

It is recommended that Liberty should not be applied if rainfall is likely within 6 hours. Other measures to reduce the impact of rainfall on Liberty efficacy include:

- Avoid application if rainfall is imminent, especially:
  - if conditions are poor for uptake, e.g. low humidity.
  - if rainfall is likely to be heavy or prolonged.
- Liberty should not be applied to wet foliage if run-off is likely to occur.

Sunlight

Light has a number of influences on Liberty 200 Herbicide performance:

- Under low light conditions the development of phytotoxic symptoms is slowed, although the final level of weed control is equal to that achieved under normal light conditions.
- Plants which develop (over the long term) under shady conditions can be controlled more easily than weeds which have developed in full sunlight. This is due to a difference in the leaf anatomy of plants grown in the shade, which allows better spray retention via leaf penetration of Liberty.

Additives

The Liberty 200 Herbicide formulation includes 30% wetting agent. The particular wetting agent selected is the one that has been found to give the best results with Liberty. It assists the herbicide to spread across the leaf and aids the penetration of Liberty 200 Herbicide into the leaf.

Other additives

Many different additives have been tested with Liberty 200 Herbicide.

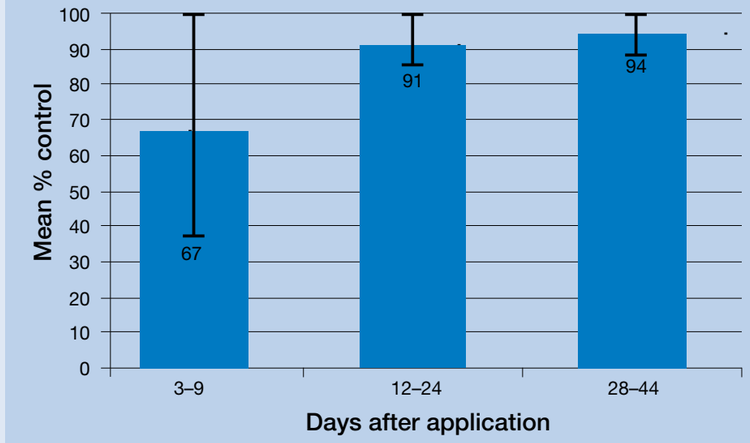
Other additives such as crop oils and a range of wetting agents have not been shown to consistently assist Liberty performance, therefore it is recommended not to add any other additives or adjuvant to Liberty. In some cases, the addition of crop oils or wetting agents may have a negative effect on the efficacy of Liberty.

Summary Results of Weed Activity

The table below demonstrates the efficacy of Liberty 200 Herbicide on various weeds.

COMMON NAME	SCIENTIFIC NAME	DAYS AFTER APPLICATION	MEAN CONTROL (%)	CONTROL RANGE (%)
Bladder ketmia	*Hibiscus trionum*	3–9	67	38–100
		12–24	91	85–100
		28–44	94	89–100
Caltrop	*Tribulus terrestris*	4–8	95	95
		12–21	100	100
		26–41	97	91–100
Cotton - conventional	*Gossypium hirsutum*	6–8	77	65–84
		12–19	100	100
		27–42	100	100
Cotton - Roundup Ready	*Gossypium hirsutum (RR)*	4–9	90	71–100
		12–18	100	100
		26–42	100	100
Dwarf amaranth	*Amaranthus macrocarpus*	3–10	88	83–92
		12–21	100	100
		27–43	100	100
European/Field bindweed	*Convolvulus arvensis*	7–8	100	100
		14–16	100	100
		28–43	100	100
Peach vine	*Ipomea lonchophylla*	3–9	87	75–100
		12–23	100	100
		27–43	100	100
Ryhnchosia	*Rhynchosia minima*	3–7	100	100
		12–20	97	93–100
		28–40	96	88–100
Sesbania pea	*Sesbania cannabina*	6	100	100
		12–20	100	100
		40	100	100
Yellow vine	*Tribulus micrococcus*	3–8	–	–
		12–25	100	100
		33–45	100	100

BLADDER KETMIA CONTROL



These results demonstrate the efficacy of Liberty 200 Herbicide applied at 3.75 L/ha.

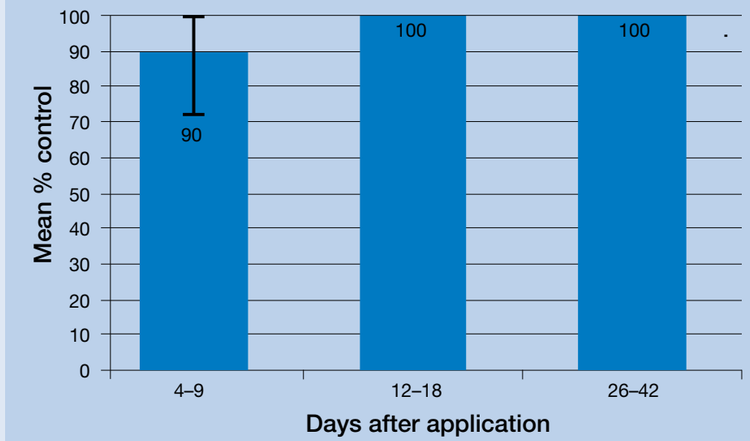
These photos demonstrate the efficacy of Liberty 200 Herbicide on bladder ketmia *(Hibiscus trionum)* at 3.75 L/ha.

0 DAA

3 DAA

20 DAA

NON LIBERTY LINK COTTON



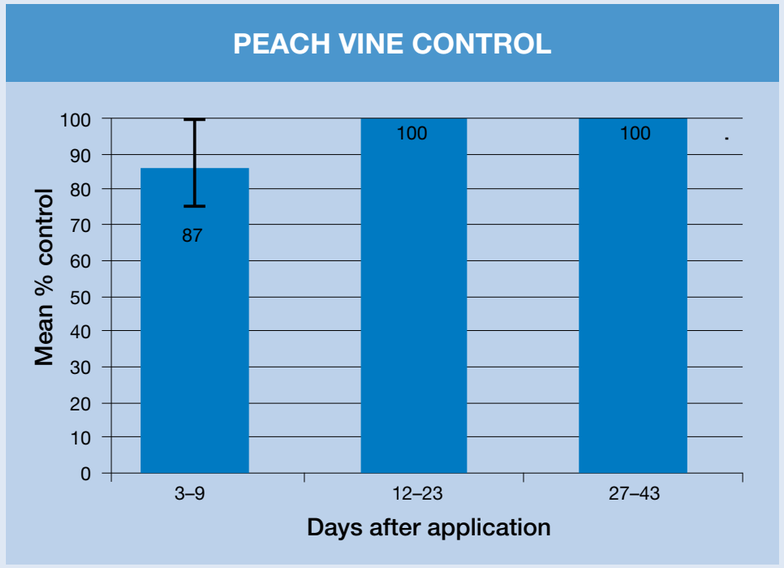
These results demonstrate the efficacy of Liberty 200 Herbicide applied at 3.75 L/ha.

These photos demonstrate the efficacy of Liberty 200 Herbicide on Roundup Ready volunteer cotton *(Gossypium hirsutum)* at 3.75 L/ha.

0 DAA

3 DAA

20 DAA



These results demonstrate the efficacy of Liberty 200 Herbicide applied at 3.75 L/ha.

These photos demonstrate the efficacy of Liberty 200 Herbicide on peach vine *(Ipomea lonchophylla)* at 3.75 L/ha.

0 DAA

3 DAA

20 DAA

Other weeds

Liberty 200 Herbicide has shown activity on a number of other weeds, for which no label claim is made.

These include:

Canadian fleabane
Summer grasses
Common thorn apple
Green amaranth
Anoda weed
Annual ground cherry
Awnless barnyard grass
Bathurst burr
Caustic creeper
Fierce thorn apple
Common vetch

However further investigation is required to show that control is adequate and consistent enough for a label claim to be made.

Commonly Asked Questions

Q: Do I need to apply a wetter with Liberty 200 Herbicide?

A: No. Liberty 200 Herbicide contains 30% wetter in the formulation and therefore does not require the addition of a wetter.

Q: What is the rainfastness of Liberty?

A: It is preferable if a minimum of six hours elapses between spraying and rainfall. Rainfall intensity will impact on the degree of rainfastness.

Q: When can the crop be sprayed?

A: Liberty Link Cotton can be sprayed with Liberty over a wide window in the crop's development. Over the top applications can be made until 70 days pre-harvest, which is typically up to approximately 20% flowering.

Q: When do I start to see symptoms of Liberty?

A: Visual symptoms of control appear in 3 to 7 days, but complete desiccation may take 20 to 30 days under cool conditions

Q: What water volume should be used when applying Liberty?

A: An application volume of at least 100 L water/ha is required when applying Liberty.

Q: What size nozzles should be used when applying Liberty?

A: Flat fan nozzles with a droplet size of 200 to 300 microns (fine to medium spray droplet) are recommended for most situations.

To Maximise Coverage and Control Follow the S.T.A.R. Program

The S.T.A.R. program is a simple set of guidelines designed to optimise herbicide results. The basic principles apply to Liberty 200 Herbicide. While it is impossible in any dynamic and changing biological system to guarantee anything, following the S.T.A.R. program can reduce the risk of herbicide failure. The program's aim is to promote understanding and management of the four major factors which influence herbicide effectiveness.

Stress

Weed stress can decrease herbicide effectiveness. Before using chemicals ask:

- Is the soil waterlogged?
- When did it last rain?
- Are there any insect pests?
- What are the temperature and humidity levels?

Timing

Spray at the optimum time. Applying the herbicide on weeds at growth stage 2–6 leaf:

- Minimises weed competition with the crop
- Maximises crop yield

Application

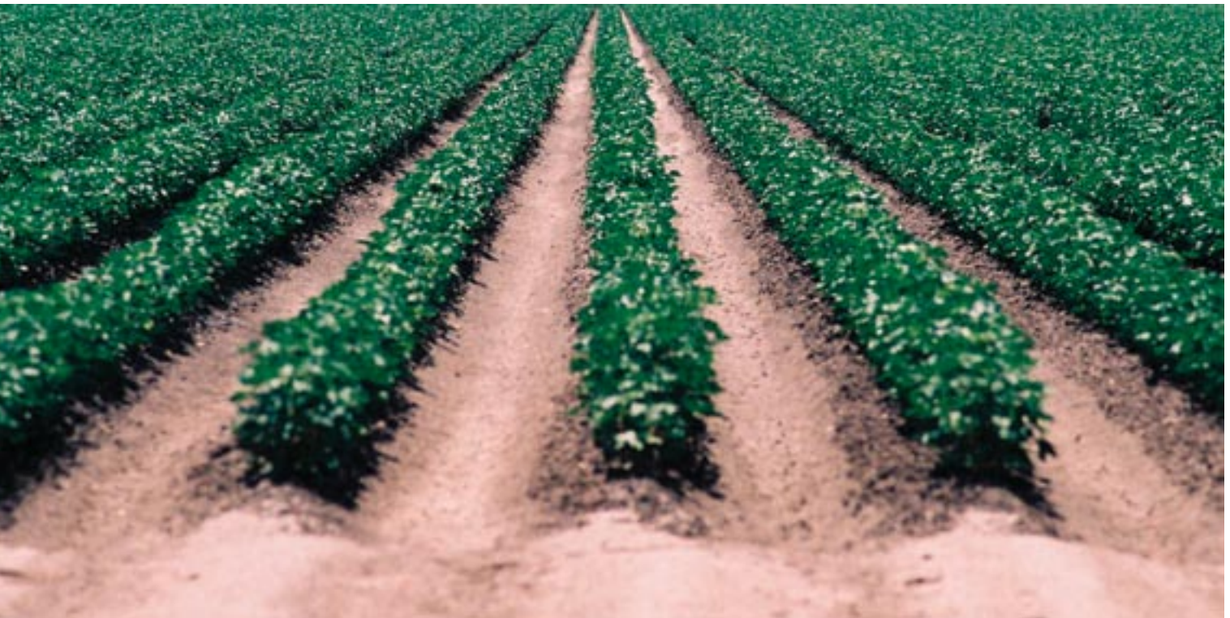
Correct application ensures optimum results.

- Check and clean equipment
- Select a nozzle that will work effectively
- Change nozzles regularly
- Check nozzle pressure
- Follow directions on water volume
- Spray when weeds are 2–6 leaf
- Don't mix products which are not recommended

Rate

Cutting rates does not save money.

- Always use Liberty 200 Herbicide at the recommended rate.
- Gives maximum effectiveness and consistency of control
- Increases the speed of weed control
- Helps overcome possible failures caused by unknown weed stress, timing or application problems



Notes

Liberty®

LIBERTY LINK®

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