MONSANTO

WHAT IS TRIAZINE TOLERANT ROUNDUP READY® CANOLA?

Triazine Tolerant Roundup Ready canola is a new herbicide tolerant canola system which combines triazine tolerance and Roundup Ready technology. Monsanto has worked in conjunction with Seed Companies to combine these two herbicide tolerances through hybrid breeding techniques.

This combination of herbicide tolerant traits provides greater weed control later into the crop's growing season, through excellent broad spectrum weed control of Roundup Ready Herbicide with PLANTSHIELD® by Monsanto and the long residual control of the triazines.

Triazine Tolerance

The first herbicide tolerant canola cultivars to be developed and registered in Canada were triazine tolerant. These were developed through conventional breeding with a weedy relative.

Triazine tolerant bird's rape *(Brassica rapa)* plants were discovered in two corn fields near Quebec in the mid-1970s (Maltais and Bouchard, 1978) and provided the source for all triazine-tolerant oilseed rape cultivars developed in Canada and elsewhere. The first commercial triazine tolerant canola varieties became available in Australia in 1993.

Triazine tolerant canola is now widely grown across Australia and provides high levels of control of key brassica weed species, such as Wild Radish. This system also provides control of key grass species such as annual ryegrass, thereby taking pressure off herbicide resistance development in these grass species.

The site of action of triazine herbicides is in the chloroplasts where they inhibit photosynthesis, eventually causing plant death.

Triazine herbicides block electron transport in photosystem II by irreversibly binding to protein D1 of photosystem II, thereby blocking plastoquinone QB from its binding site on protein D1 (Fuerst and Norman, 1991).

The tolerance to triazine herbicides is due to an alteration of the binding site on the D1 protein. A mutation occurring on the *psbA* gene results in the substitution of a serine amino acid by a glycine amino acid at amino acid position 264 on the D1 protein. This single amino acid substitution reduces the binding of triazines to the D1 protein by 100–1000 times. The *psbA* gene mutation also results in impaired electron transport in photosystem II, accounting for some, but not all, of the seed yield reduction seen in triazine tolerant canola.

Roundup Ready CANOLA

Roundup Ready PLANTSHIELD

RT TRIAZINE HYBRIDS ROUNDUP READY

PACIFIC SEEDS

BAYER

Roundup Ready technology

Glyphosate is an inhibitor of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), a well-known enzyme of the shikimate pathway for aromatic amino acid biosynthesis present in plants, fungi and bacteria. Plants, including weeds, exposed to glyphosate are unable to produce aromatic amino acids and hence die.

Roundup® (glyphosate) herbicides provide excellent knockdown control of a wide range of grass and broadleaf species. Roundup herbicides are post-emergent and have no residual soil activity.

To produce Roundup Ready canola, two genes were introduced into the canola genome:

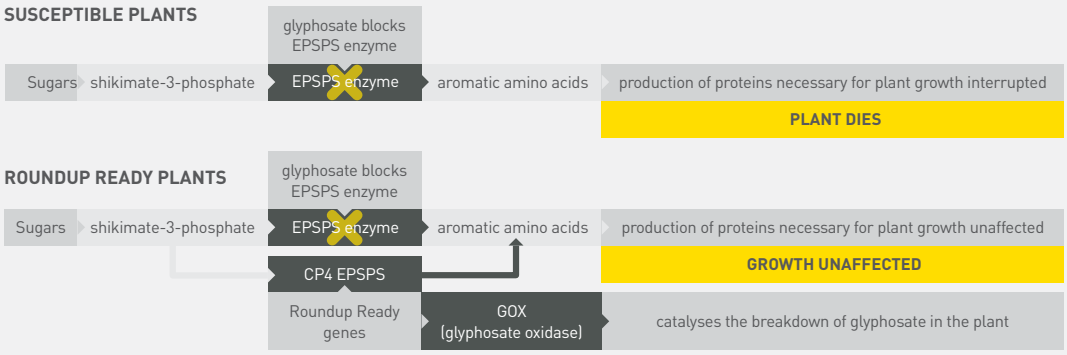
- The *cp4 epsps* gene, derived from the common soil bacterium Agrobacterium strain cp4, which encodes for the production of the CP4 EPSPS enzyme.
- The *gox* gene from Ochrobactrum anthropi strain LBAA, which encodes for the production of the enzyme glyphosate oxidase (GOX).

Both gene products are expressed within in the plant and together are responsible for tolerance to glyphosate (refer to below diagram). Because cp4 EPSPS has a naturally high tolerance to inhibition by glyphosate, Roundup Ready canola plants continue to produce aromatic amino acids even after treatment with glyphosate. In addition, the GOX protein catalyses the breakdown of glyphosate into glyoxylic acid and aminomethylphosphonic acid (AMPA).

The action of cp4-EPSPS in allowing Roundup Ready canola to tolerate applications of Roundup Ready Herbicide with PLANTSHIELD by Monsanto, whilst susceptible plants cannot produce essential amino acids and, therefore, senesce.

The disarmed Agrobacterium tumefaciens plant transformation delivery system was used to produce Roundup Ready canola line GT73 (White, 1989; Howard et al., 1990). This system is well documented to transfer and stably integrate T-DNA into a plant nuclear genome (White, 1989; Howard *et al.*, 1990).

Only the DNA required for glyphosate tolerance was transferred and inserted at a single locus in the canola genome. A single chromosomal copy of the DNA has been stably inherited across multiple generations of Roundup Ready canola plants. Moreover, the consistent commercial performance of Roundup Ready canola further supports the stability of the inserted DNA and functioning of the cp4 EPSPS and GOX proteins.



The action of CP4-EPSPS in allowing Roundup Ready canola to tolerate applications of Roundup Ready Herbicide with PLANTSHIELD by Monsanto, whilst susceptible plants cannot produce essential amino acids and, therefore, senesce.

Fuerst, E. P. and M. A. Norman (1991). Interactions of herbicides with photosynthetic electron transport. Weed Sci 39, pp. 458–464.
Howard EA, Citovsky V, Zambryski PC (1990) The T-complex of Agrobacterium tumefaciens. UCLA Symp Mol Cell Biol 129: 1–11.
Maltais B, Bouchard CJ (1978) Une moutarde des oiseaux (B. rapa L.) resistante a l'atrazine. Phytoprotection 59, pp. 117–119.
White, F. F. (1989) Vectors for Gene Transfer in Higher Plants. In: Plant Biotechnology. S. Kung and C.J. Arntzen, editors. Butterworths, Boston. pp. 3–34.

For further information visit www.roundupreadycanola.com.au, www.pacificseeds.com.au/products/canola, bayergoldenage.com.au/canola or contact your Roundup Ready canola Technology Service Provider (TSP).

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