The agronomic benefits of glyphosate in Europe

Review of the benefits of glyphosate per market use

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Contents

1 Summary

Since its discovery in the early 1970's the unique herbicidal active ingredient glyphosate "has become the world's most widely used herbicide because it is efficacious, economical and environmentally benign" (Powles, 2008).

These properties have enabled a plethora of uses which continue to expand to this day providing excellent weed control both in agricultural and non-crop uses to benefit mankind and the environment. The latest advances are in the development of new and improved machines to enable low doses of glyphosate to be applied using shielded applicators to control weeds inter-row in vegetables and other row crops, on pavements and for the selective control of invasive weeds where use of glyphosate can provide very cost effective and safe weed control.

This summary provides an overview of a detailed technical review of at least 16 use areas and the benefits of glyphosate in each compared to alternative practices. In several cases the alternatives are no longer practiced as they are regarded as too injurious or expensive leaving glyphosate as the only viable solution. Glyphosate provides excellent long-term cost-effective weed control with an excellent safety profile to operators, the public and the environment.

The benefits of glyphosate include the following;

a. **Excellent broad-spectrum weed control**: glyphosate moves throughout the plant and controls the growing shoots and roots, thus providing long-term control of a very wide range of species from annual to perennial grasses and broadleaves, invasive species that are spreading in agricultural, non-crop, amenity and industrial land uses, aquatic uses as well as weeds resistant to selective products in arable crops.

b. **Cost effective weed control**: one application can control perennial weeds for many years and application of glyphosate can be made in low water volumes meaning fewer fills and very efficient spraying operation compared with expensive mechanical techniques that require a large amount of manpower, machines and transport. For this reason glyphosate is the chosen solution for many weed control purposes.

c. **Improved establishment of crops plants, shrubs and trees**: Weed competition can mean at best slow/ suppressed growth, at worst death, of planted crops/ shrubs/ trees. Application of glyphosate to fully control existing weed/ plant cover gives a clean start, optimising establishment and growth of any newly sown/ planted crop/ tree.

d. **Increase yield and quality**: control of weeds removes competition with planted crops for water, light and nutrients and can increase yield by 30-60% with removal of dense perennial weeds, 10% with lower populations and 3-7% with just the ripening of green crops and annual weeds reducing grain losses at harvest. By facilitating earlier harvest grain/ seed quality is maintained compared to later harvesting and seed contains less other material requiring less cleaning and growers can get a better price.

e. **Increased harvesting efficiency and lower fuel use**: studies have shown that crops treated with glyphosate 7-10 days before harvest are more uniform and drier at harvest, so there is less material to be harvested reducing the load on the combine harvester, reducing fuel use by 25% in wheat and 35% in oilseed rape and increasing the speed of harvest, so harvest can be completed earlier.

f. **Reduced soil erosion**: Many traditional practices for weed control rely on repeated cultivation passes to try to control weeds. These cultivations left soil loose and bare so rainfall washed soil away. Use of glyphosate for weed control combined with reduction in cultivation and inclusion of cover crops dramatically reduces soil erosion in olives, vines and even arable crops. This integrated technique is called Conservation agriculture.

g. **Increased flexibility**: The ability to control weeds with glyphosate provides greater flexibility in cropping (ability to sow winter crops). Harvest management allows an earlier harvest which means autumn cultivations and planting can start earlier in better conditions meaning better crop establishment and higher potential for the next crop. Non-residual so growers can sow or plant after spraying. Specialised applicators mean glyphosate can be used selectively to control weeds between crop rows or stand above the crop or grass sward or between desirable plants.

h. **Preserve soil moisture**: water is a precious finite resource in many countries. Control of weed cover preserves soil moisture for current or subsequent cropping. In irrigated crops this is particularly important and can also facilitate more precise irrigation around trees in orchards.

i. **Adoption of conservation agriculture**: Traditional cultivation relied on mouldboard plough or repeated cultivations with discs or tines to control weeds and break up the soil to make a seedbed. Integration of glyphosate for weed control means growers can reduce the depth and intensity of cultivation improving soil structure, crop establishment, crop yields and even benefitting the environment with increased invertebrates and birds, reduced soil erosion, higher CO_2 sequestration.

j. **Minimise use of selective and/ residual herbicides**: Prophylactic use of pre-emergent residual herbicides in the control of annual weeds in both arable and orchards lead to the development of widespread weed resistance. Glyphosate use can control these weeds, and used as part of an integrated solutions minimises the risk of further resistance development, whilst reducing reliance on residual herbicides. Use of glyphosate to control weeds encouraged to germinate pre-plant reduces the weed pressure on subsequent selective herbicides and improves overall weed control.

k. **Increased wildlife and biodiversity**: Use of glyphosate instead of mechanical weed control techniques on non-cropped/ amenity land preserves wildlife like small mammals and birds. UK studies have shown such benefit that authorities want farmers to put aside 5% non-cropped land for the environment. Adoption of Conservation agriculture encourages earthworms and other invertebrates as well as birds. Judicious use of glyphosate to control excessive plant growth and invasive weeds on or around waterways and lakes encourages wildfowl and much other wildlife. Use of glyphosate tolerant crops allows later control of weeds providing early food sources for many invertebrates and birds and thus increased animal numbers.

l. **Highly safe to operators, public and environment**: glyphosate is only active in plants, acting by blocking the production of aromatic amino acids, a process that does not occur in animals. Modern glyphosate formulations contain adjuvants chosen for safety as well as performance reducing human or environmental impact and enabling use of lower use rates.

m. **Resistance management tool**: Overreliance on selective pre- and post-emergence herbicides for the control of annual grass and broadleaf weeds has lead to the development of herbicide resistant weeds. The use of glyphosate as part of a resistance management programme to control weeds encouraged to germinate pre-plant can reduce the pressure on in-crop herbicides and can even allow the use of lower rates as weed populations decline.

n. **Reduced pest and disease incidence**: Controlling crop volunteers and weeds between crops removes the host for many diseases and pests ('breaks the green bridge') so reducing disease and pest levels in the next crop. Weeds maintain moisture around crop plants so encourage diseases, control of weeds in olive orchards and vineyards reduces disease levels.

Reference;

Powles S B, 2008. Evolved glyphosate-resistant weeds around the world: lessons to be learnt. Pest Manag Sci 64:360–365

2 Introduction

Since its first introduction as Roundup® in 1974, glyphosate has been marketed in several formulations in a wide number of countries around the world and is the world's most widely used herbicidal active ingredient in both agricultural and non-agricultural situations. Glyphosate (N-phosphonomethyl-glycine) is a non-selective, foliar acting, translocated herbicide. It is absorbed by green leaves and stems and transported within the plant to the growing points in shoots and roots. There, glyphosate blocks the activity of the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). Inhibition of this enzyme prevents the plant from synthesizing the aromatic amino acids essential for protein synthesis and leads to plant death by starvation. After application, glyphosate is tightly adsorbed in the soil and is poorly taken up through plant roots. Therefore, it has no herbicidal action through the soil and there is no long-term exposure of plants to herbicidal activity.

Glyphosate is a highly effective active ingredient controlling a wide range of plants, and many different uses have been developed, to manage unwanted vegetation either overall or by selective application to protect desirable vegetation. These uses include;

Vegetation control on land in agricultural production;
- pre-plant, post-plant pre-emergence, pre-harvest, non-cropped land and grassland
- orchards and vines as well as selective uses in many crops
- introduction of Roundup Ready crops would allow the selective application of glyphosate in crop and thus provide alternatives to the existing selective weed control methods

For vegetation control on non agricultural land;
- around structures on farms, amenity and industrial areas and on railways
- aquatic and forestry uses
- invasive and noxious weed control

In the marketed herbicidal products, glyphosate as an active is formulated as a salt to allow solubility, and in mixture with surfactants that contribute to the uptake and translocation of the active in the plant. Some mixtures with other actives are also available. The formulation has an effect on the characteristics of the product and influences hazard rating, use rate, uptake, translocation, performance, degradation and run-off. Individual glyphosate formulations may be targeted locally at specific areas of use; however, this document provides an overview of the recommended uses of glyphosate in both agricultural and non-agricultural areas and mostly just refers to glyphosate mentioning a specific product only where important.

The predominance of development data, reports and research papers available come from northern Europe, in particular the UK, as that is where most research has been done on the primary uses (post-harvest, pre-harvest, harvest management, grassland and non-crop). Extra country specific information has been added to these where relevant and available, together with detail for uses in orchards and vines where the primary countries of use are Spain, France and Italy, and sunflowers/ grain maize in central and eastern Europe where research was done. Considerable data come from the experience acquired with Roundup Biactive, a lead Monsanto commercial brand across Europe especially in the 90's, still marketed in the UK and some other countries. Roundup Biactive was the first of the new generation glyphosate formulations sold for improved performance with improved operator and environmental safety.

Approved uses vary by country. Where an example use is given the country will be referenced, but the reader should not infer this use is approved in all countries or crops and should check local status.

Each section is written as a standalone item to ease reading, so there is some overlap between sections. An introduction to the use, problems observed, needs, alternative practices, fit for glyphosate, benefits of using glyphosate and references are provided for each use section.

Standards;
- Weed names; English common name plus (Latin name) for the first mention per section
- Costs or values are given in £ Sterling and (Euro equivalent) at an exchange rate of €1.4 to £1.
- Glyphosate dose rates are expressed in kg ae (acid equivalent) per hectare.

3 Post-harvest use for perennial weed control pre-plant

Primary benefits

- Broad-spectrum long-term control of perennial weeds provides a clean start for the next crop
- Yield benefit in following crops

Introduction / situation

Perennial weeds including grasses like Common couch (Elytrigia *repens)*, Johnson grass *(Sorghum halepense),* Onion couch (*Arrhenatherum elatius* spp. *bulbosum*), Bent grasses (*Agrostis* spp.), Yorkshire fog (*Holcus lanatus*) and broad-leaved species including docks (*Rumex* spp.), thistles (*Cirsium* spp.), Common dandelion (*Taraxacum officinale*), sow thistles (*Sonchus* spp.) as well as volunteer potatoes (*Solanum tuberosum)* and tough weeds like Field bindweed (*Convolvulus arvensis*), Coltsfoot (*Tussilago farfara*), Mugwort (*Artemisia vulgaris*), Common horsetail (*Equisetum arvense*) and Rosebay willow herb (*Chamaenerion angustifolium*) can infest crops. Populations can increase rapidly on lighter land in particular with conservation tillage, but also with plough tillage, where repeated cultivations cut/ drag perennating organs across fields. In Western Europe perennial weeds are relatively under control, but in the Eastern Europe perennial weeds are still common and a significant drain on yield.

Before the advent of glyphosate in 1974, dense infestations of perennial weeds, in particular Common couch, were a huge drag on agricultural production and the only control was for rhizomes to be raked up and burnt (Smith, 2008).

Common couch can impede crop establishment, compete with the growing crop, and at high populations reduce cereal yield by 30-60%, volunteer potatoes can reduce sugar beet yield by 30% (O'Keeffe, 1980 & 1981a).

Problems:

Perennial weeds can grow rapidly and compete with crops reducing yield. At crop establishment dense Common couch populations compete strongly with the newly establishing crop for nutrients and space. In summer perennial species have a large mass of lush green foliage, have grown to maturity above crop height and can smother crops causing severe lodging with increased difficultly and cost of harvesting.

With increased winter cropping across northern Europe over the period 1980-present day there is more pressure on farmers to establish crops in good time, particularly if ploughing. A recent survey in the UK showed 96% of growers thought it was slightly/ significantly more challenging to achieve weed control in autumn stubble. They quoted uncertain weather, a large area of winter crops and desire to plant early as the main difficulties (Monsanto, 2008). Control of perennial weeds removes the need to cultivate for weed control easing crop establishment.

Needs:

To control perennial weeds in autumn stubble prior to planting the next crop.

Alternative practices:

Spray glyphosate pre-harvest of combinable crops.

Previously a range of treatments were used to provide a level of control; ploughing, raking out Common couch rhizomes and burning them, paraquat and glufosinate, but none of these provided long-term control of perennial weeds.

Hormone herbicides in cereals and sulfonylurea use in cereals and some other crops are useful against docks and thistles, and some graminicides like fluazifop-p-butyl and propaquizafop are useful in suppressing Common couch and other perennial grasses in broad-leaved crops like oilseed rape and sugar beet, but give little long-term control.

Fit for glyphosate:

- Stubble use of glyphosate started in 1974 and revolutionised perennial weed control

- Stand alone treatment or as part of a spray programme with another treatment pre-harvest on weeds like Onion couch and volunteer potatoes and tough weeds
- Non-residual and bound by mineral soils so not available for root uptake
- No delay to planting beyond 5 -7 day cultivation interval to allow translocation

Benefits of using glyphosate:

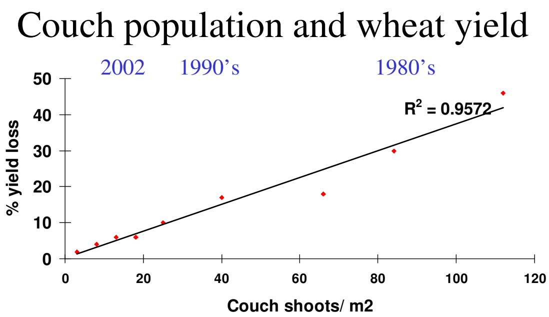
Average 90+ % control of a range of perennial grass and broadleaved weed species

Weed species	*% control*		*Years Monsanto trials*
	1.08kg ae/ ha	*1.44kg ae/ ha*	
Common couch	*95*		*1993/4*
Docks	*81*	*90*	*1992-4*
Thistles	*95*	*97*	*1993/4*
Field bindweed		*90-100*	*Ranyan and Peeper (1980)*
Volunteer potatoes		*80-100*	*O'Keeffe and Makepeace (1985)*

Increased yield of following crops through control of Common couch pre-harvest;

With dense weeds 30-60% increases in yield have been observed in cereals following pre-harvest treatment in the previous cereal (O'Keeffe, 1980 & 1981).

However, yield response depends on weed population, illustrated on Common couch here, particularly important now with lower populations after 34 years of glyphosate use.



Data from Monsanto trials

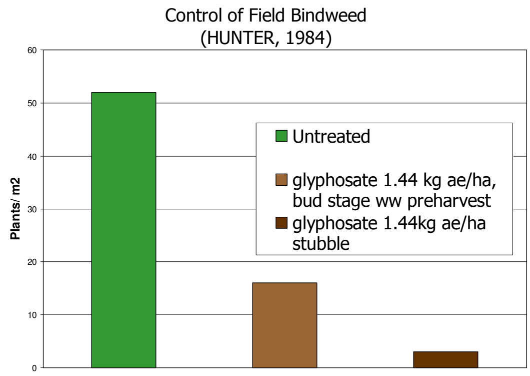
Yield increase from control of perennial broad-leaved weeds

Studies show significant increase in yield from 90-100% control of Field Bindweed by glyphosate (Ranyan and Peeper, 1980; Swan, 1982).

Better weed control than pre-harvest

Glyphosate sprayed in autumn stubbles 4-6 weeks after harvest, but before autumn frosts, can control early maturing species that cannot be controlled pre-harvest, like Onion couch and Bent grasses in winter wheat, or Common couch on light sandy land that has died early in dry years.

Glyphosate in autumn stubble achieved higher control of Field Bindweed than achieved pre-harvest (Hunter, 1984). Further work showed a rate of 1.8kg ae/ ha gave 95% control one year after treatment (Monsanto trials, 2004). Trials on thistles showed complete control 1 YAT from 1.08kg ae/ ha.



Non-residual

No delay to planting the next crop.

Preserve soil moisture and nutrient for next crop

By removing competitive perennial weeds before planting following crops can establish free from competition for water and nutrients and later light.

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4 Post-harvest use for annual weed control pre-plant

Primary benefits

- Broad-spectrum pre-plant control of annual weeds provides a clean start for the new crop
- Fewer weeds in crop brings improved selective weed control
- Facilitates adoption of Conservation tillage for economic and environmental benefit

Introduction/ situation:

Stubbles and other bare ground before planting are often smothered in the growth of volunteer crops (cereals/ oilseed rape), annual grasses; Black-grass (*Alopecurus myosuroides*), Wild oats (*Avena* species), Brome grasses (*Bromus* spp.) and Rye grasses (*Lolium* spp.) and annual broadleaved weeds that if left get transplanted to compete with the newly established crop and make selective weed control very difficult.

These annual weeds and many others infest much of the major European arable combinable crops; 57 m ha of cereals, 6.5 m ha of oilseed rape and 1.82 m ha legumes grown in the EU-27 (Eurostat, 2008), notably in NW Europe.

Germination of many annual weeds is stimulated by cultivation as evidenced by the flush seen on drilling the crop; however certain weeds have different germination characteristics depending on the dormancy of their seeds. Sterile brome (*Bromus sterilis*), Wild oats (*Avena fatua and Avena ludoviciana*), Italian rye-grass (*Lolium multiflorum*) and cereal volunteers mostly germinate straight away given sufficient moisture. However, left on the surface Sterile brome can go into light induced dormancy whilst Rye brome (*Bromus secalinus*), Soft and Meadow brome (*Bromus mollis* and *Bromus commutatus*) seeds which are green and unripe at harvest need a period of after-ripening on the soil surface for 30 days before they will germinate. This effect is more pronounced and widespread in cool moist summers when most grass seeds will be unripe. Contrast hot dry summers when annual grass seeds will germinate immediately if sufficient moisture is present. Thus the prevailing climatic conditions and weed biology need to be understood when considering annual weed control in autumn stubbles.

With the increased winter cropping of cereals and oilseed rape in a tight rotation over the period 1980-present day, often using conservation tillage, there is even more risk of annual grass weeds populations increasing. Traditional mouldboard ploughing was relied on for weed control through burial, though incomplete and costly.

New EU regulatory restrictions mean fewer herbicides are available to control annual grass weeds, so there is a greater need to control weeds before planting. For example, approvals for trifluralin and isoproturon were revoked in cereals in the UK and across much of Europe, although isoproturon is still approved in Germany; with the move away from propyzamide in oilseed rape and growing of greater cereal and oilseed areas there is greater pressure on selective post-emergence herbicides.

Problems:

Crop volunteers can smother a new crop wrecking establishment or can make harvest difficult and reduce harvested grain quality by admixture of wheat in barley, barley in wheat, oats in barley etc.

Annual grasses present a major modern challenge to combinable crops as populations increase after periods of poor weather with the associated poor in-crop control. Increased areas of cereals and oilseed rape up to 2009 with the recent decline in set-aside from circa 10% in 2006 to 0%, as well as land coming out of dairy farming have put more pressure on weed control programmes. Greater adoption of conservation tillage to cut costs and enable even larger areas to be farmed means good annual grass weed control is essential. Get it wrong and weed populations will explode.

With modern high yielding varieties farmers want the best from their crops, so high levels of weed control are essential. Highly efficacious selective post-emergence herbicides are available and are often relied on so it is not surprising that herbicide resistance has developed in grasses like Black-grass and Rye-grass, even within 1-2 years of the launch of new products. Target site and enhanced metabolism resistant grass weeds have been confirmed on well over 2000 farms across 31 counties of England, Wales and Scotland. Eighty separate cases of resistance to Atlantis (iodosulfuron + mesosulfuron) have been observed in the UK across 19 counties within 2 years of launch (Monsanto, 2007). When herbicide resistance is prevalent many strategies need revising and new tools utilised.

Some of the worst annual grasses like Black-grass are most prevalent on the heavy soils that grow good wheat crops. On heavy soils it is challenging to get a good seedbed for pre-emergence products to work well so there is greater reliance on selective post-emergence products and the risk of resistance development is higher all of which makes control more difficult.

Good inversion ploughing of annual weeds or volunteers can reduce populations by burial, but larger plants get transplanted to infest the next crop. Surface cultivators (discs/ tines) can reduce populations on dry soils but mostly transplant weeds on moist soils, particularly with larger weeds. A major restriction on the adoption of conservation tillage systems was weed control. Regular deep cultivating, just for weed control, damages soil structure, is expensive and releases carbon dioxide to the atmosphere as soil carbon is oxidized. Ploughing releases five times more carbon dioxide to the atmosphere than conservation tillage (Reicoski, 1997). Ploughed soils are also more prone to run-off, erosion & leaching.

Needs:

Control annual weeds and crop volunteers before planting after ploughing or conservation tillage. Manage the build-up of herbicide resistance. Reduce production costs and minimise soil damage.

Alternative practices:

The mouldboard plough is the most commonly used alternative to spraying weeds as certain growers (typically smaller, mixed, family farms) perceive free weed control from traditional ploughing.

Other herbicides widely used included paraquat, paraquat/ diquat mixes and glufosinate. Although these can give good control of annual broadleaved weeds their performance on volunteer cereals and annual grasses is much more variable, particularly when those grasses are at the spike stage or are tillering. The choice of alternative herbicides is now greatly reduced since the revocation of approval for paraquat in the EU and glufosinate approvals will not be renewed as they expire.

Fit for glyphosate:

- Stubble use of glyphosate started in 1974
- Broad-spectrum activity on annual grass and broadleaved weeds
- Complete weed control including roots
- Non-residual
- Stubbles pre-cultivation and/ or stale seedbeds pre-drilling
- Start of annual weed control programme

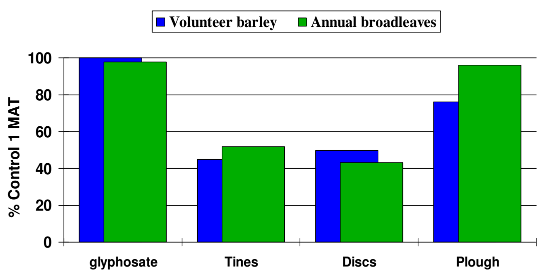
Benefits of using glyphosate:

Complete control of weeds, with no regrowth

Glyphosate at rates of 0.36-0.54kg ae/ ha provides at least 90% control of a wide range of annual grass and broad-leaved weed species in stubbles/ pre-plant even with cultivation just 6 hours after treatment. This ensures a weed free start for the next crop.

Cultivation alone particularly on moist soil risks transplantation and only partial weed control.

glyphosate kills weeds...
cultivation transplants them...

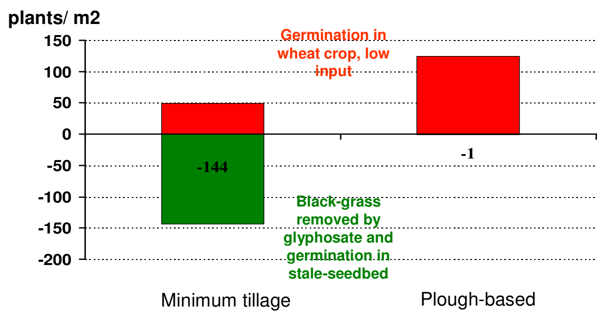


Monsanto trials

Effective stale seedbeds provide a clean start

A natural germination of weeds can be obtained by shallow cultivations to create a consolidated stale seedbed ahead of drilling. Spraying of glyphosate to control weeds encouraged to germinate in a stale seedbed before drilling reduces the subsequent weed population in crop (Stride and Wright, 1997). Repeated stale-seedbeds encourage more germination before drilling thus improving weed control (Townsend, 2004).

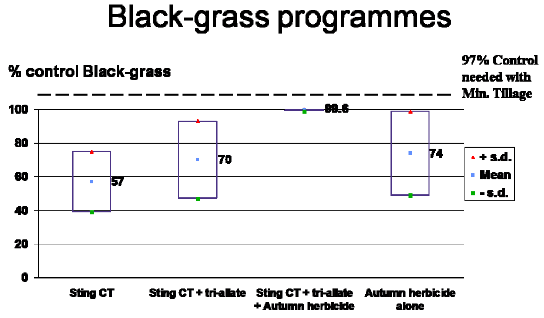
Impact of using stale seedbeds on black-grass germination in crop



Stride and Wright (1997). Mean of 6 trials, 1996/7, Untreated = 213 plants/m2

Controlling annual grasses early minimises the allelopathic effects seen when larger grass weeds exude auxins which limit further weed germination (Townsend, 2007). The benefit of stale seedbeds was recognised in farm trials at CWS Stoughton (Leake, 1996) and IACR LIFE project research (Jordan & Donaldson, 1996).

Improved weed control in programmes
Early stale seedbeds can remove around 57% of the weed population that would germinate in crop thus reducing the pressure on in-crop herbicides and increasing the overall level of control and reliability (Stride and Wright, 1997; Overthrow, 2001). This is particularly important with Black-grass, Brome and Rye grasses where in-crop control is increasingly difficult, particularly with high populations. It is increasingly useful in crops such as potatoes and vegetables where there are fewer selective herbicides available.



Stride and Wright (1997). 4 trials 1992-95, untreated = mean 150 heads/m2

Reduced herbicide usage in crop
Use of good stale seedbeds, combined with good crop rotation to maximise the time opportunity for germination outside the crop, has been shown to reduce the numbers of annual grass and broadleaved weeds in crop. Reductions in herbicide usage were possible over a 7 year period in the LIFE project with no loss in weed control (Jordan and Donaldson, 1996; Hutcheon et al, 1998).

No need for cultivation after treatment
Treated weeds will not re-grow so there is no need to cultivate to bury them. Treated small it is possible to drill straight into treated ground, although with larger weeds there is benefit in waiting for weeds to collapse before drilling – although, so long as drilling is not impeded, this is not necessary.

Facilitates the adoption of conservation tillage
Through improved control of grass weeds growers, using glyphosate treated stale seedbeds, can more easily adopt conservation tillage techniques with considerable further benefits;
– economic benefits include cost saving, time and fuel saving as shown below
– environmental benefits include improved soil structure, less leaching and run-off, less soil erosion, carbon sequestration with incorporation of crop residues, 5 times less C02 released due to less cultivation, increased invertebrates (36% more earthworms) and more seed eating birds (SMI, 2004).

Cultivation type	Costs (£/ ha) [€/ ha]	Time (Min./ ha)	Energy Use (KW/ ha)
Plough based	85-120 [120-168]	150-220	213
Conservation tillage	40-70 [56-98]	60-100	137
Average saving	£45 [63]	60 minutes	33L/ ha fuel

(Monsanto, 2002, and Monsanto CT benefits summary slide)

Alternative mode of action
The use of glyphosate in stubbles/ pre-plant provides another mode of action to manage weeds that have developed resistance to certain selective herbicides, so providing a vital tool in the management strategy of those weeds.

No delay to sowing
Glyphosate is non-residual so crops can be drilled immediately, 6-24 hours after spraying.

Breaks green bridge
Through controlling green weeds and crop volunteers before drilling glyphosate can reduce the transfer and impact of aphids carrying viruses like BYDV, foliar fungi and slugs on the next crop.

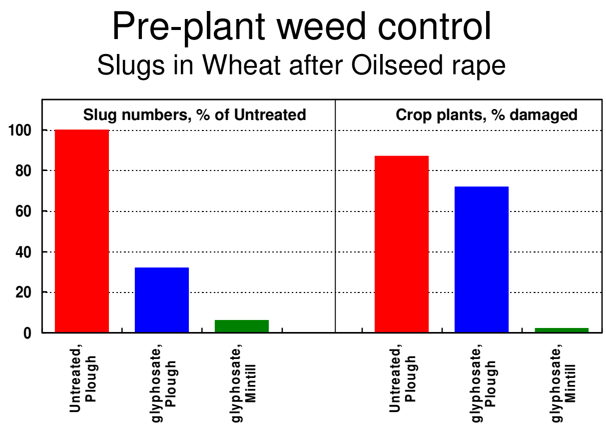
Limited trials by ADAS on behalf of Monsanto showed some reduction in aphid numbers as cereal volunteers died back after spraying with glyphosate.

Removing cereal volunteers early in stubbles with glyphosate can minimise foliar diseases multiplying between crops and windblown spores infecting emerging crops nearby.

Reduced slug numbers and crop damage was observed when volunteer oilseed rape was sprayed with glyphosate before cultivating and drilling wheat, as illustrated. Bigger reductions were seen when spraying and establishing the crop with shallow consolidated minimum/ conservation tillage rather than ploughing.

Farmers note if weed/ volunteer populations are allowed to grow you get desperate slug problems (Farmers Guardian, 2007).

Research at IACR (Glen et al, 2004) showed reduced slug damage when wheat was drilled at 4cm into a good consolidated seedbed. Shallow cultivation soon after harvest was also beneficial in reducing slugs (HGCA, 2005).



Monsanto trial, Scotland – Volunteer oilseed rape +/- sprayed out with glyphosate

Use of glyphosate

Market research by Precision Prospecting found 41% of growers used pre-plant herbicides and 98% of the land treated pre-plant was treated with a glyphosate based herbicide and some 55% of farmers treating pre-plant used stale seedbeds (Monsanto, 2000).

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5 Post-plant pre-emergence

Primary benefits

- Broad-spectrum control of weeds pre-emergence even in slow emerging crops
- Maximises weed control in crop bringing increased yield
- Saves time and money

Introduction/ situation:

When farmers hurry, or when the weather is too windy or wet to allow spraying pre-plant, or after ploughing when many growers do not spray out weeds, there is a considerable risk of annual grass and broadleaf weeds and crop volunteers being transplanted into the new crop.

Cultivations to establish a seedbed and drilling can trigger weed seeds to germinate. The new fine firm seedbed prepared for the crop is ideal for weeds to rapidly colonise and compete hard with the crop.

Many crops, particularly under cool or dry conditions, can take a considerable period of 5 to 21 or more days to emerge, during which time well adapted weeds can germinate in huge numbers from firm fine moist seedbeds of arable and vegetable crops.

Problems:

- Transplanted weeds, already being established and having survived cultivation can quickly grow ahead of the new crop competing for space, light and nutrients
- A spread of weed sizes makes timing post-emergence sprays difficult and larger weeds are less susceptible to post-emergence herbicides so the level of weed control in crop is reduced
- Weeds that germinate after planting can quickly smother a newly emerging crop and be difficult to control post-emergence
- The result is lower yields and higher seed return

Needs:

To control weeds that have been transplanted or grown from seed after planting the crop but before crop emergence.

Alternative practices:

Ideally spray glyphosate pre-plant and aim for rapid crop emergence from a firm moist seedbed followed by applying a selective herbicide programme.

Few non-Monsanto glyphosate products are approved for use post-plant pre-emergence and only two of those that are have label approvals allowing tank-mixing with pre-emergence herbicides.

Paraquat used to be applied post-plant pre-emergence before its approvals were revoked. Diquat is now used but, like paraquat, is not very effective on grasses.

Fit for glyphosate:

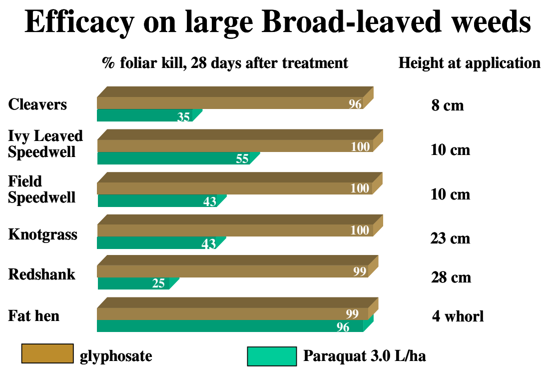
- Broad-spectrum control of annual grass and broadleaf weeds and crop volunteers
- Controls annual weeds of all sizes: spike/ cotyledon to tillering/ large plants
- Translocated so controls weed roots and branched shoots
- Some approved products in the UK; all Monsanto Roundup brands, as well as some competitors, can be applied post-plant pre-emergence of cereals, oilseed rape, mustards, linseed, peas, field beans, Swedes, turnips, onions and leeks and even asparagus
- Monsanto products in the UK also have label support for tank-mixing with a wide range of pre-emergence residual herbicides following physical, dynamic and biological compatibility testing. Roundup Biactive, developed to be tank-mixable, has the following products listed on the UK label;

Afalon, Alpha chlorotoluron 500, Bullet, Butisan S, Centium, Crystal, Goltix WG, Fiesta T, Katamaran, Kerb Flo, Liberator, Magnum, Pyramin DF, Ramrod Flowable, Reflex T, Stomp 400, Takron, Tolugan 700, Venzar Flowable. Remember products differ in their tank-mix compatibility and need checking for physical, dynamic and biological compatibility before use

- Non-residual so no effect on emergence of crop

Benefits of using glyphosate:

Full weed control up to crop emergence
Glyphosate controls weeds of all sizes, grasses and broadleaves, including those missed pre-plant, those partly covered in soil and those emerging in the new seedbed, thus providing a clean start for the new crop. Faster more even crop establishment is often seen due to a lack of weeds and higher retained soil moisture.

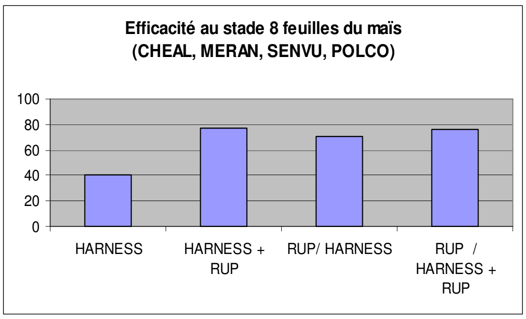


Monsanto trials clearly show the benefit of glyphosate over contact products like paraquat in controlling large annual broad-leaved weeds; Cleavers (*Galium aparine*), Ivy-leaved speedwell (*Veronica hederifolia*), Field speedwell (*Veronica persica*), Knotgrass (*Polygonum aviculare*), Redshank (*Polygonum persicaria*) and Fat hen (*Chenopodium album*).

Optimizes weed control by selective products
Post-plant pre-emergence use of glyphosate provides a second chance to treat challenging weeds like Black-grass in cereals or some difficult broadleaf weeds in maize to further deplete the seed bank. This is particularly useful for winter crops in a dry autumn or a year with higher seed dormancy and thus later germination of annual grass weeds, or for spring crops with slow germination.

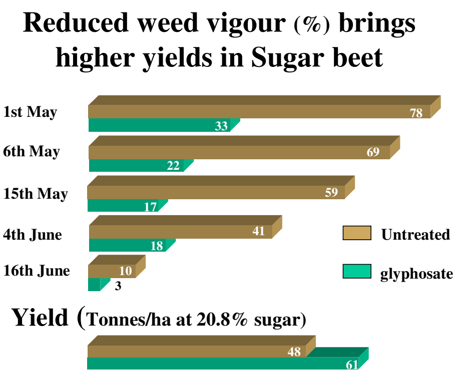
By providing a clean start glyphosate not only reduces weed numbers emerging post-crop emergence, but also ensures a narrow spread of weed sizes making it easier to correctly time post-emergence product application thus optimising weed control (Farmers Weekly, 2007). This can allow the use of lower rates of pre- or post-emergence selective products and an opportunity to reduce costs.

Increased weed spectrum of pre-emergence products
Combination of glyphosate (RUP) and acetochlor (Harness) gave 78% control on a mixed population of Fat hen (*Chenopodium album*, CHEAL), Annual mercury (*Mercurialis annua*, MERAN), Common groundsel (*Senecio vulgaris*, SENVU) and Black bindweed (*Polygnum convolvulus*, POLCO) in French maize trials as depicted (AGPM, 2002), compared to 40% control with acetochlor alone.



Maximises crop yield
Optimum weed control allows crops to establish free of weed competition and maximises yield potential.

This trial with British Sugar on conventional sugar beet clearly shows the reduction in weed vigour achieved by spraying glyphosate early and the subsequent improvement in yield of sugar beet through spraying post-planting but before crop emergence. Yield was increased from 48 to 61t/ ha.



Save time and minimise cost
Better weed control means there is less reliance on inversion tillage to bury weeds so facilitating the adoption of conservation tillage, where appropriate, thus minimizing fuel and labour costs - see previous section 4 (annual weed control pre-plant).

Ability to tank mix means growers can combine two operations in one, post-plant pre-emergence glyphosate plus pre-emergence residual herbicide to save around £10/ ha (approx. €11.4/ ha) and 15 minutes per hectare when sprayed in 200-250L/ ha water volume (Nix, 2009).

Resistance management
Glyphosate is a broad-spectrum herbicide of different mode of action which takes pressure off selective herbicides and reduces risk of the development of weed resistance.

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6 Pre-harvest perennial weed control in arable crops and grassland

Primary benefits

- Broad-spectrum long-term control of perennial weeds to provide a clean start for the next crop
- Improved harvesting efficiency in treated crop
- Facilitates adoption of Conservation tillage for economic and environmental gain
- Yield benefit in next crop

Introduction/ situation:
Perennial weeds including grasses like Common couch *(Elytrigia repens)*, Onion couch (*Arrhenatherum elatius* spp. *bulbosum*), Bent grasses (*Agrostis spp.*), Yorkshire Fog (*Holcus lanatus),* Johnson grass (*Sorghum halepense*), Bermuda grass (Cynodon dactylon) and broad-leaved species including docks (*Rumex* spp.), thistles (*Cirsium* spp.), sow-thistles (*Sonchus* spp.), Water knotweed (Polygonum amphibium), Field bindweed (*Convolvulus arvensis*), Hedge bindweed (*Calystegia sepium*), together with Common reed (*Phragmites australis*) as well as volunteer potatoes can infest crops and grassland. Populations can increase rapidly on lighter land in particular with conservation tillage, but also with plough tillage where repeated cultivations cut/ drag perennating organs across fields. Before the advent of glyphosate in 1974, dense infestations of perennial weeds were a huge drag on agricultural production and the only control was for Common couch rhizomes to be raked up and burnt (Smith, 2008). Common couch can reduce cereal yield by 30-60% (O'Keeffe, 1980 & 1981), Common reed by about 20% (Czepó, 2005). Volunteer potatoes can reduce sugar beet yield by 30%. Weeds like docks, thistles and rough grasses including Common couch infest grassland and reduce productivity. Common reed is a significant weed in low lying heavier soils in central Europe. It is considered a dangerous weed in Hungary where it infests 170-180, 000 ha of arable land (Czepó, 1999). The introduction of the use of glyphosate in stubbles in 1974 made a huge difference, but the autumn timing was restrictive after later crops and if bad weather set in autumn crop establishment was poor, or impossible, forcing growers into growing less productive and less profitable spring crops.

Problems:
Perennial weeds can grow rapidly and compete with crops. At harvest time perennial species have a large mass of lush green foliage, have grown to full maturity above crop height and can smother crops causing difficultly at harvest and increased costs.

Performance of the combine harvester is impaired both by the moist material but particularly the increased volume of material other than grain (MOG) which reduces forward speed, reduces threshing efficiency, increasing fuel consumption, increases separation losses and means otherwise dry grain will have higher harvested moisture content due to condensation transfer from green wet vegetation.

Weeds reduce the productivity and palatability of grass swards, necessitating expensive reseeding. If reseeding was to be done after cutting silage/ hay there was a risk of a poor reseed or a loss of feeding time while reseeding and waiting for the new sward to establish.

Needs:
To control and dry out perennial weeds prior to harvest and reduce moisture content and material other than grain going through the combine harvester thus improving harvest, and to increase yield of following crops.

Alternative practices:
Slow harvesting, accepting increased losses and increased grain drying and cleaning costs were all farmers could do before glyphosate pre-harvest was approved. Spray glyphosate in stubbles. Application of fluazifop-p-butyl or propaquizafop for selective control of perennial grasses in approved broadleaf crops provides short-term control in that crop but does not control perennial broadleaved species and is not only more expensive, but requires follow-up with glyphosate in the next crop.

Fit for glyphosate:

- pre-harvest use of glyphosate started in 1980 and revolutionised perennial weed control
- at harvest perennial weeds are at maturity and flowering presenting an excellent target for control
- best opportunity to control perennial weeds
- green perennial weeds obvious in brown crop prior to harvest enabling cheaper spot treatment
- at maturity perennial plants move sugars down to their perennating organs (roots, rhizomes, stolons and bulbils) for storage, glyphosate is moved with sugars in the phloem of plants
- desiccation of green weed material
- in summer better drier calmer weather eases herbicide application

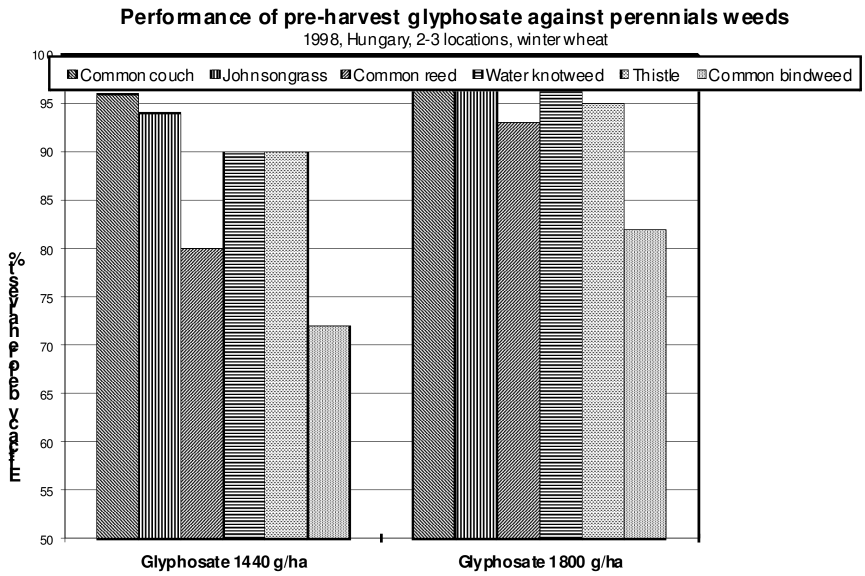
Benefits of using glyphosate:

"The pre-harvest application of glyphosate for the control of perennial weeds has brought tremendous benefits to the UK farmer. When compared to post-harvest application, it generally increases the control of perennial weeds and, in addition, its time of application does not result in a delay in cultivation after harvest. Indeed, it can be argued that the pre-harvest application has resulted in an overall reduction in glyphosate usage for perennial weed control." and "…pre-harvest application for perennial weed control, has resulted in the potential to reduce significantly the energy involved in crop production and has improved soil management and flexibility in cropping" (HGCA, 2007).

Excellent broad-spectrum weed control;

Glyphosate provides at least 90% control 1 YAT (year after treatment) of a wide range of perennial weeds including Common couch at rates of 0.72 to 1.44kg ae/ ha depending on population, other perennial grasses (including Bent grasses, Yorkshire Fog and Onion couch) and perennial dicots (including docks, thistles, sow-thistles and even Field bindweed) and volunteer potatoes (that are more difficult post-harvest due to frosts) at 1.44 kg ae/ ha (Grossbard and Atkinson, 1985; Monsanto trials 1980-2002).

Broad spectrum activity was observed against 6 different perennial weeds in Hungary (Czepó, 1999).



Weed desiccation means lower harvested moisture content and easier combining.

Control early maturing perennial grass weeds;

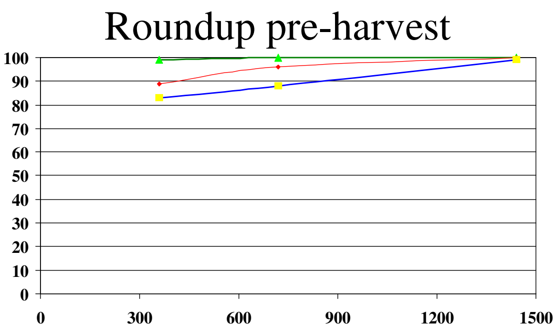
Pre-harvest use of glyphosate in early crops like winter barley or oilseed rape means you can even control Onion couch, Bent grasses and Common couch on light sandy drought prone soils which would not be susceptible in winter wheat due to early senescence.

Increased levels and reliability of weed control at lower rates in combinable crops;

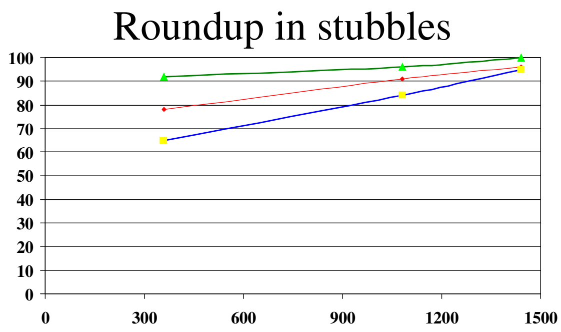
Weed target	Dose (kg ae/ ha)	Pre-harvest range of % control 1YAT	Stubble range of % control 1YAT
Common couch	0.72	98 – 99	32 - 95
Common couch	1.44	98 – 99	92 - 98

3 trials, 1979 (O'Keeffe *et al*, 1981)

Trials illustrated in the two charts below, clearly shows a smaller range from minimum (blue line) to maximum (green line) of results and higher average (red line) level of control 1year after treatment (YAT) of Common couch grass from applications made pre-harvest;

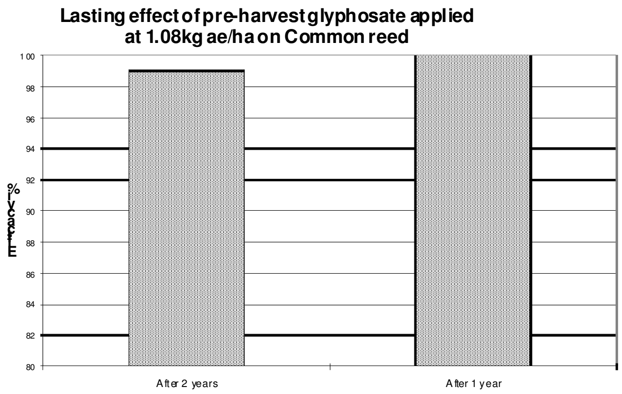


5 Monsanto Couch trials 1980, 1 YAT



4 Monsanto Couch trials 1984, 1 YAT

Long-term control of Common reed
Glyphosate provides excellent long-term control of weeds like Common reed which are otherwise difficult to control and have a large green mass at harvest (Czepó, 2001). The following figures are from a trial with glyphosate on Common reed in 2000 at Tiszalok, Hungary.



Picture: Left – 2 years after treatment; middle – untreated; right – 1 year after treatment

Improved control of weeds in grassland
Three trials with application of glyphosate at 1.8 kg
ae/ ha clearly showed the improvement in weed control from spraying pre-harvest as opposed to post-harvest of grass, notably on improved control of perennial broadleaved species.

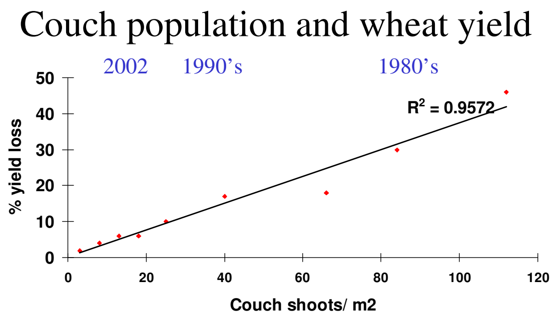
Timing of treatment	% control grasses	% control perennial broadleaves
Post-harvest spring	75	79
Pre-harvest: June-September	89	92
Post-harvest 3-6 weeks after cutting	87	66

Stride, Edwards and Seddon (1985)

Increased yield of following crops through control of Common couch pre-harvest;

With dense weeds 30-60% increases in yield have been observed in cereals following pre-harvest treatment in the previous cereal (O'Keeffe, 1980 & 1981a).

However, yield response depends on weed population, illustrated on Common couch here, particularly important now as populations are lower due to 34 years of glyphosate use.



Data from Monsanto trials

Reduction in glyphosate usage for perennial weed control in cereals;
Higher performance and reliability means some label rates are lower pre-harvest than in stubble making savings available to growers on light Common couch populations and perennial broadleaved weeds.

UK Roundup Biactive label (2007)	Pre-harvest label rate (L/ ha)	Post-harvest label rate (L/ ha)
Light Common couch up to 25 shoots/ m2	2	3
Moderate Common couch up to 75 shoots/ m2	3	3
Heavy Common couch >75shoots/ m2	4	4
Perennial broadleaved weeds	4	4-5

Improved harvesting efficiency (as summarised under harvest management);
Illustrative data summarised here from four Common couch infested trials (HGCA, 2007)

- throughput of material other than grain reduced 17%: means faster combining, better threshing and less wear and tear
- grain separation losses reduced by 1.6% of yield: 4.8% higher harvested yield, fewer volunteers
- grain moisture 1% lower: reduced drying saves £1.5-2/ t (approx. €2.1-2.8/ t), lower risk of moulds and mycotoxins
- lower energy requirement: less fuel needed for harvesting and drying or cleaning
- lower labour input for harvesting: time freed for autumn cultivations
- drier straw can be baled more easily and more quickly clearing ground for autumn cultivation
- harvest quality maintained under poor conditions: Hagberg, hectolitre weight, oil content, lower admixture of seed
- significant cost saving: less grain dying, less cleaning, less fuel, less labour

No/ less delay in stubble cultivation and drilling of the next crop;
As perennial weed control is completed before harvest there is no need to wait 4-6 weeks before cultivating. Treated crops produce drier straw which can be baled more quickly. So pre-harvest treatment maximises the time for seedbed preparation and drilling and reduces the need for cultivation so growers can utilise best conditions for crop establishment.

Improved annual weed control in autumn;
Pre-harvest control of perennial grasses means there is no need to wait for regrowth of perennial weeds in the stubble so attention can be focussed on the establishment of a good stale-seedbed to encourage germination and control by glyphosate of annual grasses like Black-grass (*Alopecurus myosuroides*), Brome grasses (*Bromus* spp.) and Rye-grasses (*Lolium* spp.) before establishment to optimise weed control and minimise the development of resistance to selective herbicides.

Lower costs for cultivation for the next crop;
With no need to wait a month for perennial weed regrowth and then 5 days after spraying, stubbles can be cultivated immediately after harvest, often using conservation tillage techniques;

Cultivation type	Costs (£/ ha) [€/ ha]	Time (Min./ ha)	Energy Use (KW/ ha)
Plough based	85-120 [120-168]	150-220	213
Conservation tillage	40-70 [56-98]	60-100	137
Average saving	£45 [63]	60 minutes	33L/ ha fuel

(Monsanto, 2002, and CT benefits summary slide)

Improved soil management;
Increased use of conservation tillage techniques as well as cultivation under drier conditions means soils are maintained in better condition and even improve over time resulting in better drainage, cultivation and cropping.

Cropping flexibility;
Increased growth of winter cereals, winter oilseed rape, other winter crops and sequential winter crops was enabled by control of Common couch pre-harvest that previously had to be sprayed in stubbles often leading to delays and drilling of spring crops.

Use of glyphosate

According to the Pesticide Usage Survey Group at CSL glyphosate was used on 253kha out of the 1.98m ha of UK wheat in 2004 (HGCA, 2007), some 13% of the wheat area pre-harvest. However, according to the National Harvest Management Practice Survey glyphosate was used by some 94% of UK growers on at least 40% of cereal and 80% of oilseed crops for weed control or harvest management in 2006 and 2007 (Monsanto, 2008).

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7 Harvest management/ crop desiccation in combinable crops

Primary benefits

- Green material in crop is desiccated so crop is evenly ripened allowing an earlier harvest
- Improved combine harvester efficiency saves fuel, labour and time whilst maximising yield
- Crop quality maximised (dryer, cleaner, maintains quality characteristics) for best price

Introduction/ situation:

In summer, depending on weather, farmers are keen to harvest their crops under the best conditions, to achieve the maximum yield and best quality they can with lowest costs to maximise their return on investment over the previous 6-12 months. Whilst in hot dry weather crops ripen naturally, such weather is not a reliable feature of northern European agriculture and with global warming intense depressions can dump a huge amount of rain driven by strong winds that can damage crops and delay harvest.

Harvest management and desiccation treatments are used increasingly in uneven crops to achieve an earlier more reliable harvest despite the weather by evening up the ripening or advancing the ripening process. In fact HGCA (2009) estimate glyphosate is used on 78% of UK oilseed rape as a harvest aid. The technique is useful in the major European arable combinable crops; 57 m ha of cereals, 6.5 m ha of oilseed rape and 1.82 m ha legumes grown in the EU-27 (Eurostat, 2008) as well as some minor crops like linseed, lupins, flax and linola.

Maize and sunflower are summarised separately in section 8 below.

Problems:

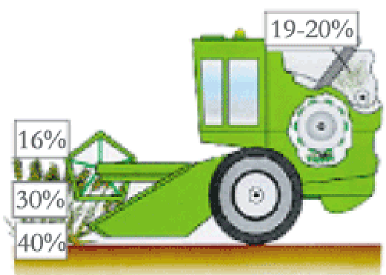
Uneven crop establishment, wet summers, or years with poor annual weed control can mean crops ripen unevenly and contain considerable green seeds, stems, secondary tillers/ late plants and weeds at harvest. In oilseed rape when seed and pods are ripe it is often stems that delay combining and thus ripe seed can be lost thus reducing yield and increasing volunteer populations in the next crop.

In extreme cases uneven/ unripe/ weedy/ lodged crops mean a much delayed harvest with consequent quality loss, or worse total crop loss. The delay can mean later establishment of the subsequent winter crop, often in poorer conditions, and risk a poor following crop too.

Adoption of strobilurin fungicides at higher rates in cereal crops has also been shown to increase the amount of green crop tissue left at harvest with consequent increase in harvested grain and straw moisture contents (Wacker, 2000; Jorgensen & Olesen, 2002). Lower rates of strobilurin in mixture with triazole fungicides had less influence however, but more green material is left at harvest (Claas, 2006).

Such green material can make harvest more difficult putting extra strain on combine harvesters, slowing progress and increasing machinery, fuel and labour costs. Green crops reduce threshing efficiency of the combine resulting in higher seed losses over the back and increased volunteer problems in the next crop as well as increased cleaning of harvested grain due to higher seed admixture. Green wheat grains, high in alpha amylase, can reduce Hagberg falling number in bread making wheat, reducing quality and risking loss of valuable sale premium.

Field tested moisture content of grain maybe 15-16%, ready for harvesting, yet harvested seed moisture content can be increased (as illustrated) to 19-20% as moisture transfers from the greener stems at 30-40% moisture and green grains. This results in storage problems like mould growth, hotspots, and condensation unless wet seed is artificially dried incurring higher costs.



Fusarium ear blight *(Fusarium culmorum & F.graminearum*), produces two of the most prevalent mycotoxins – nivalenol and deoxynivalenol (DON) and also HT-2, T-2 and zearalenone on cereal crops left in field. *Penicillium* spp. grow rapidly on cereal grain above 17% moisture during storage producing ochratoxin A (Food Standards Agency, 2007). 'The presence of mycotoxins in cereals reduces the quality of grain, is likely to be a risk to human and animal health and causes economic loss through their effect on livestock production' (HGCA, 2002). If a new EU limit of 1.250 ppm DON in unprocessed wheat grain and 0.75 ppm in grain and flour products, or proposed 0.005ppm ochratoxin A are exceeded the crop is unsalable.

'It is important that preparations are made for harvest to ensure delays are minimised. Grain should be harvested as soon as possible once ripe. The concentration of Fusarium mycotoxins can increase if harvest is delayed due to wet weather' (FSA, 2007a). 'Harvest capacity should match the acreage to be harvested' and 'grain should be rapidly dried to below 18% moisture content to minimise the risk of ochratoxin A occurrence in storage' (FSA, 2007b).

Needs:

To desiccate annual weeds and green crop tissue in unevenly ripening crops as a harvest management treatment to minimise the problems outlined above.

Alternative practices:

Swathing can be used in crops like oilseed rape to cut and lay the crop in rows allowing wind drying prior to combine harvesting. However, timing is difficult; too early and oil content is reduced (HGCA, 2006), the lying crop is prone to the rain and birds feeding and later harvesting can mean considerable seed loss from overripe seed pods.

The only other approved desiccant for combinable crops is diquat, but this is only approved for laid cereals crops and those for animal feed/ industrial use. In oilseed rape the rapid desiccation afforded by diquat leaves crops exposed to huge losses from pod shatter if harvest is delayed by bad weather much beyond the optimal 5-6 days. Glufosinate used to be used but is now restricted to potato haulm desiccation.

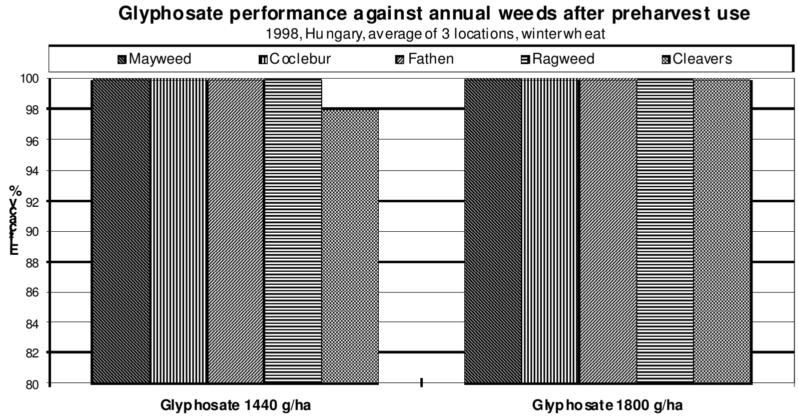
Fit for glyphosate:

- to control and dry out annual weeds prior to harvest
- to ripen uneven non-seed crops of winter and spring cereals, oilseed rape, legumes, linseed, cotton (and minor crops in UK rye, triticale, lupins, flax, linola) to facilitate an earlier more efficient harvest
- excellent safety profile of Roundup Biactive, accepted even by UK brewing (British Beer and Pub Association and Brewing Research International, Technical Circular 405) and Scotch Whisky Association and United Distillers for pre-harvest use although growers must check the conditions of their contract. NOTE: not for use in seed crops as germination of less ripe grain/ seed will be reduced. Offers no advantages in evenly ripening crops in normal sunny summers
- when the bulk seed/ grain moisture content is below 30% moisture then residue levels are minimal. At this moisture level there is no longer translocation into the seed/ grain. Green tissue and green grains are controlled and shrivel following treatment and are screened out by the combine/ cleaner
- at 30% moisture or less glyphosate has no negative effect on grain/ seed yield, thousand grain weight, crude protein or oil content, Hagberg, energy potential or tetrazolium test data

Benefits of using glyphosate:

Note: Benefits from the pre-harvest use of glyphosate for harvest management are only seen in unevenly ripening or weedy non-seed crops, there is no effect in evenly ripening crops.

- Dry out green material (secondary tillers, green grains, green stems, green annual weeds);
  - *Green grain moisture reduced 27%:* 63% unt. to 36% treated (3 Monsanto trials)
  - *Straw moisture reduced 13%*: 44% untreated to 31% treated (6 Monsanto trials)
  - *83% stem desiccation 14 DAT in oilseed rape* means ripe seed can be harvested at the optimum time at lower moisture content compared to 39% untreated stem desiccation (Monsanto trials). Intensity of green oilseed rape stems reduced from 3.5 (moderate) to 1.5 (low) some 14 days after treatment in German trials (Feiffer & Hesse 2007)
  - 50% fewer green oilseed rape pods in German trials (Feiffer & Hesse 2007)
  - *80-100% desiccation of annual weeds in 14-17 DAT (Monsanto trials 1982-92)*
  - *98-100% desiccation* of many annual weeds in Hungarian wheat (Czepó, 1999). Annual weeds can be a problem especially under dry conditions when cereal crops tiller less and crops are less competitive. Green weeds can hinder harvest.



- Lower harvested grain/ seed moisture content in uneven crops/ wetter years;
  - *1.5% lower wheat grain moisture*: 23% unt. to 21.5% treated (11 Monsanto trials)
  - *2.2%* lower wheat grain moisture: 17.4% unt. to 15.2% treated (1 trial, HGCA, 2007)
  - *1.8%* lower wheat grain moisture (2 Monsanto trials with SAC, 2007)
  - *1.4%* lower barley grain moisture: 20.3% untreated to 18.9% treated (7 weed free trials 1980/1 – HGCA, 2007)
  - *2% lower oilseed rape seed moisture* than direct cut (3 Monsanto trials, 1991-2)
  - *4.6% lower average and extreme of 8% lower oilseed rape seed moisture* with glyphosate than in direct cut untreated (Monsanto, 2001)
  - *Lower drying costs:* save £3-4/ t (approx. €4.2-5.6/ t) if grain at 2% lower moisture (Monsanto, 2008b)
  - *Less risk of mould and mycotoxin development* in store thus maintaining quality and allowing long-term storage as required

- Increased combine harvester efficiency;
  - *Material other than grain throughput increased* by 20% in wheat (7 non-weed trials by SAC 1980/1 - HGCA, 2007) and 15% in oilseed rape (Feiffer & Hesse 2007)
  - *Separation losses in wheat reduced* from 2.9% to 1.9% of yield thus retaining 3% of yield (11 Monsanto trials) ensuring lower admixture in harvested grain, or allowing 20% higher throughput while maintaining same grain loss
  - *Separation losses in barley reduced* from 2.6% to 1.5% of yield, resulting in a 0.3t/ ha, 7% higher retained yield, in 7 non-weed trials by SAC 1980-1 (HGCA, 2007)
  - *Combining speed can be increased up to 44%* from 4.5 to 6.5kph (Claas, 2006) and growers in The Best of British Oilseeds survey reported 41% of treated crops were harvested at more than 4kph compared to 32% of untreated oilseed crops (Farmers Guardian, 2008)
  - *Less wear and tear on* straw chopper blades - set costs up to £450 (approx. €630) (Claas, 2006)
  - *Free up labour for cultivations*; over 300ha, increased harvest speed with harvest management could free up 7 extended working days for cultivations (Claas, 2006)
  - *Efficient harvesting* is particularly important on large farms with fewer men and fewer larger machines and there is less capacity for risk (Farmers Guardian, 2008)
  - *Lower harvesting costs*:
    - 26% less fuel and 31% less time required per hectare wheat (Claas, 2006)
    - up to 28% overall cost saving is thus possible in wheat
    - save 3.5L diesel & 0.25hours/ ha harvesting oilseed rape (Monsanto, 2008b)
    - fuel consumption/ t reduced 34% harvesting oilseed rape (Feiffer & Hesse 2007)
    - 13+% cost saving over swathing oilseed rape (Monsanto, 2008b)

- Maintain grain/ seed quality;
  - *Minimise risk of Fusarium growth and production of mycotoxins* through an earlier harvest *and* by reducing the time taken to dry grain below 17% moisture, reducing the risk of hot spots building infection in store. Maximise chances of a saleable crop.
  - *Hectolitre weight maintained in high fungicide regimes* (Monsanto trials)

- *Hagberg falling number (HFN) maintained in wheat*; through reduction in green grains with use of pre-harvest glyphosate (Carswell, 2003) and across a range of fungicide regimes (Monsanto trials at HAAC,1997), HFN in treated 413 versus untreated 348 (HGCA, 1998), providing growers of quality group 1 and 2 wheat crops some quality insurance allowing them to maximise quality premiums (Carswell, 2003) of £45/ t (approx. €63/ t) in milling wheat (UK 2008)
    - *Oil content maintained in oilseed rape* 0.5-1% higher than if swathed. Buyer premium of 1.5% for every 1% increment above 40% oil content (HGCA, 2006)
    - *Lower seed admixture*: means lower cleaning costs and better premium

- Reduced grain/ seed losses;
    - *Less oilseed rape pod shatter means 30-60% less seed loss* at harvest than with diquat (3 Monsanto trials 1983, 2000) as slower action means pods stay rubbery. German trials showed 40% fewer open pods, equating to 1.5% lower yield loss (Feiffer & Hesse 2007)
    - *Harvested yield* increased;
        - Wheat yield 3% higher through 32% reduction in losses (Monsanto trials)
        - Barley yield 7% higher through 42% reduction in losses across 7 non-weed trials by SAC 1980-1 (HGCA, 2007)
        - Oilseed rape yield 7-10% higher in normal sites, 32-53% higher on windy sites compared to diquat, notably with late harvesting in UK (Bowerman, 1986), 3% increase in yield in German work 14 days after treatment (Feiffer & Hesse 2007)
    - *Fewer volunteers* in next crop, lower admixture so higher premium potential

- Maximise harvesting opportunities in changeable weather for an earlier more timely harvest;
    - *Maintain grain/ seed quality* to get highest quality premium with buyers
    - *Earlier entry to following crop* means a greater chance of establishing the best crop

- *Overall ratio of benefit: cost*: of 9:1 in feed wheat and 20:1 in milling wheat (Monsanto UK data)

Use of glyphosate:
85% of UK cereal growers and 93% of UK oilseed rape growers surveyed considered harvest management glyphosate very or fairly valuable over the period 2006-2007 to ensure the most efficient, rapid and reliable harvest, and 40% would use it in most combinable crops (Monsanto 2008a, Farmers Guardian, 2008).

Glyphosate is used on 78% of oilseed rape in UK, mostly as a harvest aid (HGCA, 2009)

Percentage of growers identifying particular harvest management benefits;

Benefit	**% of growers**	
Faster less troublesome combining	91	
Less drying need and cost	80	
More reliable harvest timing	76	
Less risk from poor weather	51	
Better grain quality	51	
Lower losses	50	
Better workload planning	48	(Monsanto, 2008a)

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8 Crop desiccation in grain maize and sunflower

Primary benefits

- Desiccation of green material in crop allows more reliable harvesting of evenly ripe crop
- Reduced losses and drying costs
- Higher price for earlier quality harvest with greater chance of a good harvest

Introduction/ situation:
Across the EU-27 in 2007 there are 8.8 m ha of grain maize producing 47mt grain and 3.9 m ha of sunflowers producing 4.7mt seed (Eurostat, 2008). The major countries growing maize are France, Germany, Italy, Romania and Hungary. The major sunflower growing nations are Romania, Spain, Bulgaria, France, Turkey and Hungary. Hungary which grows 0.9 m ha of grain maize and 0.55 m ha of sunflower is where most of the research quoted below has been done. Hungarian fields can be 100ha; a challenge to crop management, in particular to crop spraying that is only made worse in wet years with insufficient high clearance tractor sprayers for the crop area that needs treatment. Sunflowers are a major source of vegetable oil for cooking, industrial and animal feed uses in Europe (Eppo, 2000).

Modern hybrid maize varieties are more vigorous and often later maturing. Sunflowers are very slow to ripen, particularly the 'stay green' hybrid varieties. Whilst summers can be dry, autumns are more changeable and when wet weather closes in autumn harvest is delayed impacting profitability.

Farmers are keen to harvest their crops under the best conditions, to achieve the maximum yield and best quality they can, with lowest costs, to maximise their return on investment over the previous 6-12 months. Whilst in hot dry weather crops ripen naturally, such weather is not a reliable feature of northern European agriculture and global warming is only adding to the uncertainty.

Crop desiccation treatments are used increasingly, with 50-60% of European sunflowers treated to achieve an earlier more reliable harvest, important in wetter years, where an earlier harvest can achieve the best seed price. This is also true of maize.

A separate summary is given in section 7 of arable combinable crop harvesting including the 57 m ha of cereals, 6.5 m ha of oilseed rape and 1.82 m ha legumes grown in the EU-27 in 2007 (Eurostat, 2008).

Problems:
Uneven crop establishment, wet summers, or fields with poor perennial weed control can mean crops ripen unevenly and contain green foliage, stems, late plants and weeds at harvest. In sunflower when seeds and seed heads are ripe it is often the green foliage, notably on new hybrid 'stay green' varieties, that delay harvest. Ripe seed can be lost on the ground or to birds and diseases like Grey mould *(Botrytis cinerea)* and Sclerotinia head rot *(Sclerotinia sclerotionum)* which infect the seed head.

In extreme cases uneven/ unripe/ weedy crops mean a much delayed harvest with consequent quality loss, or worse total crop loss. The delay can mean later establishment of the subsequent winter wheat crop and risk a poor following crop and yield losses of around 30% (Petróczi and Gyuris, 2003).

Although better than not-spraying, spraying with high ground clearance sprayers flattened 3 rows of sunflowers for each tractor pass, as shown in this picture to the right. There is no such damage with aerial application (approved in Hungary).

Needs:

- desiccate green crop tissue and perennial weeds to minimise crop losses and facilitate an earlier harvest
- sow winter wheat at optimum time to maximise yield and as a break to maize thus managing Western corn root worm

Alternative practices:
The other desiccants of sunflower are diquat and glufosinate but they only desiccate the top of the crop leaving plenty of green foliage and stem to delay harvest. Maize desiccation with diquat delays kernel drying and harvest so is not practical. Neither desiccant provided perennial weed control.

In a hot dry year the sun desiccates crops well, but in Northern and Eastern Europe this is less easy to rely on as the weather becomes more unpredictable and stormy during summer/ autumn.

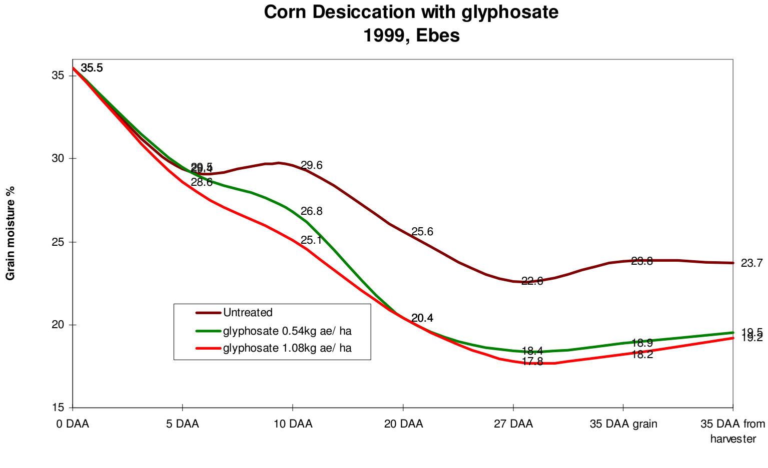
Fit for glyphosate:

- translocated herbicide moves throughout the whole plant providing full desiccation
- ripens uneven non-seed crops of grain maize and sunflower to facilitate an earlier harvest
- to control and dry out annual and perennial weeds prior to harvest
- when the bulk seed/ grain moisture content is below 30% then residue levels are minimal as at this moisture level there is no longer translocation into the seed/ grain
- application when sunflower bracts are turning brown on the margin of the shoulder coincided with physiological maturity and 30-35% moisture content (Howatt, 2007) and had no negative effect on grain/ seed yield, oil content. Earlier application would not only be against label recommendations but cut sunflower yield by 23% and reduced oil content (Holthusen et al, 2005)
- suits lower water volumes and precise targeted aerial application
- glyphosate is safe for humans, birds and the environment so long as it is applied carefully

Benefits of using glyphosate: (Czepó, 2004; Hámos, 2005; Wortmann-Alt, 2005)

Uniform maturity
Uneven maturity and green tissue delays harvest. Spraying glyphosate desiccates green foliage & stems. The photograph (below left) shows the uniform dessication of sunflower by the use of glyphosate (Roundup Bioaktiv) applied by helicopter in Hungary (Czepó, 2009a). The photograph (below right) shows complete foliar desiccation of grain maize on the right side 14 days after application of glyphosate (Roundup Bioaktiv) at 0.54kg ae/ ha in 70L/ ha applied by helicopter using Reglojet nozzles and including Bandrift Plus at 0.1 % at 34% grain moisture in Hungary, with the untreated visible on the left-hand side.

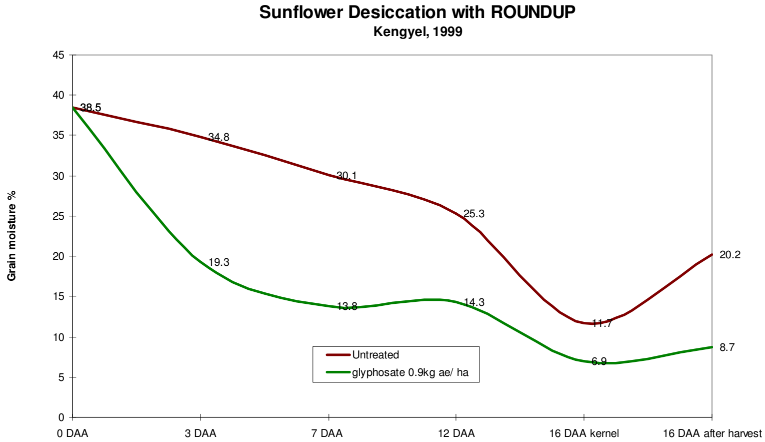
Lower drying costs
Monsanto trials in Hungary on grain maize and sunflower clearly show the effect of the use of glyphosate on % grain moisture as depicted in these two illustrative graphs (Monsanto, 2000).



At harvest glyphosate treated maize had moisture content some 4% lower than untreated maize. Glyphosate treated sunflower seed moisture was 10+% lower than untreated sunflower. Treated grain was at 19 and 7% respectively in these trials.

The requirement to further dry the seed/ grain to 14-16% for stable storage of maize, or 8-10% for sunflower, was thus either reduced or eliminated.

In a further study on 8 grain maize varieties in 1999, glyphosate treatment at 1.08kg ae/ ha reduced average grain moisture by 6% by harvest to 18%, 25 days after treatment, saving 12,000 Ft/ ha net over untreated taking into account drying cost of 320 Ft/ t/% and 5940 Ft/ ha to apply glyphosate by helicopter (Monsanto, 2000).



In 7 commercial maize trials in 1999, application of glyphosate reduced average moisture content from 28% at application to 20% at harvest, some 2.5 weeks after treatment. Four growers commented that glyphosate reduced grain moisture or lowered drying costs (Monsanto, 2000).

Earlier harvest to get higher price

Harvest management is an important management technique enabling earlier harvest, particularly important for the 'stay-green' hybrids. Increased levels of 'stay-green' trait may result in such desiccation practice becoming ever more common in sunflowers (Larson et al, 2008). Some commercial trials on grain maize in Hungary, as above, commented on earlier harvest bringing a higher price. Work on sunflower in by North Dakota State University department of Plant Science show that glyphosate brought harvest earlier by 5-10 days (Howatt, 2007). Sunflower harvest was brought forward 2-3 weeks by glyphosate treatment in Hungary (Monsanto, 2009a).

Reduced losses, maintain yield and quality

North Dakota State University department of Plant Science showed an earlier harvest saved yield from poor weather by reducing seed loss from overripe seed heads as well as reducing bird damage and disease levels that can spoil quality particularly on 'Stay green' varieties of Sunflower that normally get harvested later in poorer weather (Howatt, 2007; Manitoba Agriculture Food and Rural Initiative, 2009).

Establish next winter wheat crop in best conditions to optimise yield

Delayed winter wheat planting can mean poor crop establishment and about 30% yield loss (Petróczi and Gyuris, 2003);

Impact of planting time on yield of 12 winter wheat varieties in Hungary

Variety	Planting time		Difference t/ ha	% yield loss
	17 October	12 November		
GK Öthalom	5.39	3.61	1.78	33
GK Élet	5.86	3.84	2.02	34
GK Garaboly	6.02	4.23	1.79	30
GK Kalász	5.53	3.26	2.27	41
GK Verecke	6.19	4.46	1.73	21
GK Csongrád	5.03	3.37	1.66	33
GK Attila	4.78	3.69	1.09	23
GK Cipó	6.00	4.06	1.94	32
GK Miska	5.82	3.95	1.87	32
GK Petur	5.87	4.51	1.36	23
GK Héja	4.26	3.02	1.24	29
GK Holló	5.28	3.73	1.55	29
Average	5.50	3.81	1.69	31

By bringing harvest date forward 2-3 weeks growers can more often meet the optimum planting date for winter wheat establishment so maximising yield (Czepó, 2009b).

Excellent perennial weed control
Glyphosate provides excellent control of many tough weeds that infest fields in Central and Eastern Europe including Velvetleaf (*Abutilon theophrasti*), Cocklebur (*Xanthium strumarium*), Johnson grass *(Sorghum halepense)* and Common reed (*Phragmites australis*) (Czepó, 2009a).

Improved performance and minimised drift through smart aerial application
Including a polymer, Bandrift Plus, using low drift Reglojet nozzles producing large droplets of 600-800 µm VMD and applying a directed low volume spray only when wind speeds are below 4 m/s in the absence of temperature inversion has meant excellent performance from aerial spraying of glyphosate in Hungary with no complaints since 1997 (Monsanto, 2000; Czepó, 2009a).

Larger droplets reduced drift and research by Monsanto and St Louis University showed larger droplets improved glyphosate absorption into the leaf and improved translocation of glyphosate to root and shoots despite a slight reduction in retention on the leaves of grain maize (Feng C et al, 2003); large droplets gave 49% absorption, medium droplets 35% and fine droplets 30% absorption of glyphosate. This should result in improved reliability of performance whilst minimising spray drift.

This is important as aerial application, approved in Hungary, is often the only way to treat crops in a timely manner on the massive scale required, with fields of 100ha, across 100,000's of hectares of crop requiring treatment in years of poor weather/ uneven ripening, there are simply not enough tractor/ high clearance sprayers.

Differences between high clearance and aerial spraying (Czepó, 2009a);

Comparison	Benefit	Disadvantage
Aerial spraying	Suits large fields/ areas in Hungary No crop damage Fast =60ha/hour (Hajdú et al, 2007) Spray steep slopes/ uneven ground Spray crops on wet soil – no damage Low water volumes Helicopters don't need airstrips	Only treat fields >10ha Needs greater organisation to work Need airstrip for planes Less even spray distribution Higher risk of drift in unfavourable weather
High clearance tractor spraying	More accurate dosage Can be used on small fields	Insufficient sprayers for need Significant crop damage Slow =15ha/hour (Hajdú et al, 2007) Safety issues on steep slopes Compacts wet soil

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9 Grassland management and weed control

Primary benefits

- Excellent safety profile
- Excellent long-term control of weeds and old sward means growers can maximise production
- Cheaper milk/ meat production from improved grass swards rather than bought in concentrates

Introduction/ situation:

Grass swards can become damaged by poaching in wet weather, by Frit fly or leather jacket attack or become infested with lung or intestinal worms. Swards suffer a natural decline in productivity over time, or become infested with annual and perennial weeds if selective herbicides are not applied. As a result swards will need reseeding to boost productivity. Many high-output short-term swards are a 1-2 year part of a rotation with arable crops designed to maximise productivity and economic output so have to be controlled to make way for the next part of the rotation where weed control is even more paramount.

Problems:

- Natural decline in perennial grass content of swards due to other species and low fertility. Surveys by the Institute for grassland and environmental research (IGER) showed the Perennial ryegrass (*Lolium perenne)* content of newly sown swards declined rapidly to 80% after 1 year, 49% after 5 years and just 12% after 20 years (Clements, 1998)
- Gradual infestation of swards by perennial weeds and unproductive and unpalatable grasses
- Palatability is reduced by the presence of coarse grasses and tough perennials
- Decline in feed quality and output as well as ability to hold large stock numbers
- Just ploughing in an old/ new sward can leave big competitive weed problems; Rye-grasses (*Lolium* spp.), perennial grasses, docks and thistles to infest the next crop or sward
- Reseeding is expensive so it is best to only do it right with careful planning and attention to detail

Needs:

When the Perennial ryegrass content of a lowland sward drops below 30% it is time to consider re-seeding (Clements, 1998). However, it is not just a case of getting the seed drill out as this big and expensive decision needs planning and careful practice utilising good weed control to achieve the best outcome.

Alternative practices:

Applying selective herbicides to control perennial broad-leaved weeds is essential in short-term swards, but a waste of time if medium to long-term swards are infested with unproductive weed grasses and have low Perennial ryegrass content. This is because they will no longer be responsive to fertilizer and stocking density will have to be reduced, so it is better to reseed the sward.

Applying glyphosate by a selective weed wiper can control perennial broad-leaved weeds like Thistles (*Cirsium* spp.), docks (*Rumex* spp.) and Common ragwort (*Senecio* jacobaea.), as well as Bracken (*Pteridium aquilinum*) and rushes (*Juncus* spp.) in long-term/ permanent pastures where it is worth keeping the grass sward.

Keeping old swards going ('it's still green', 'reseeding just costs money and makes no difference'), to save cost seems attractive in tough economic times, but a continuing decline in output and achieved stocking density will reduce farm income.

Ploughing in the old sward and planting a cereal or broadleaf crop break prior to reseeding, or plough and reseed. However, this attractive cost saving option often brings poor results due to weed regrowth.

Fit for glyphosate:

- Broad-spectrum control of perennial grass and broad-leaved weeds as well as bracken and rush

- Translocated so controls perennial weed roots
- Glyphosate when formulated adequately provides an efficacious product with an excellent safety profile that suits this safety conscious market associated with milk and meat production (e.g. Roundup Biactive)
- Pre-cut/ pre-harvest as well as post-cut/ stubble application
- The wide spectrum of activity and rapid inactivation by soil makes glyphosate ideal for controlling old grass swards prior to reseeding or sowing other crops (Haggar, 1985).

Benefits of using glyphosate: … Make the most of grass …

Excellent safety
The safety profile of glyphosate and the modern safer adjuvants means livestock growers have excellent weed control with no concerns over safety to animal, milk or milk products – a safe flexible product that can even be used 5 days before cutting or grazing grass, and be cultivated and drilled from 5 days after application. In the UK, Roundup Biactive was tested pre-cut in 180 trials, with 583 feed samples tested and exhaustive feeding studies conducted by respected UK organisations (Stride, Edwards and Seddon, 1985).

Excellent weed control
Glyphosate is translocated to the roots and provides excellent weed control at rates between 1.08kg ae/ ha for of 1-2 year Rye-grass leys; 1.44kg ae/ ha controls Common couch (*Elytrigia repens*), Bent grasses *(Agrostis spp.)* and docks in medium term leys; 1.8kg ae/ ha is needed on tougher species in long-term leys like Field bindweed (*Convolvulus arvensis*), Meadow buttercup (*Ranunculus repens)* and Common bracken; 2.1kg ae/ ha is needed to control rushes, Fescue grasses (*Festuca* spp.) and White clover (*Trifolium repens)* in permanent pastures (Haggar, 1985; Monsanto, 2007).

Good weed control allows improved crop establishment free of weed competition and reduced need for expensive selective herbicides.

Retain more soil moisture
IGER trials showed a 31% increase in soil moisture, because use of glyphosate to control the sward stops evapotranspiration, meaning easier cultivation due to 16% lower soil shear strength and faster more reliable sward establishment with 14% more tillers (Clements, 1998).

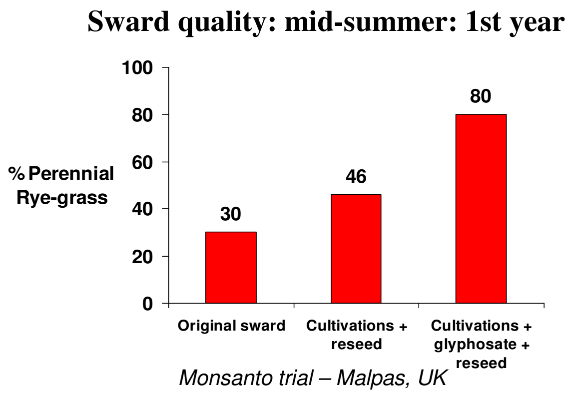
Reseeding benefits

Overall reseeding an old worn out pasture to best practice standards can provide a 7-fold return on investment according to Paul Billings of British Seed Houses (Farmers Weekly, 2008).

Increased perennial ryegrass content
Establishing a new ley through reseeding is the best way to increase rye-grass content.

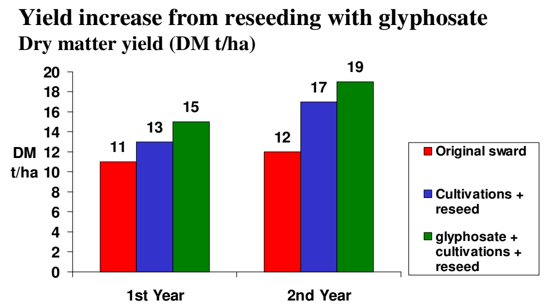
This trial shows that reseeding alone is not enough as the new rye-grass has to compete with weed grasses transplanted by cultivation.

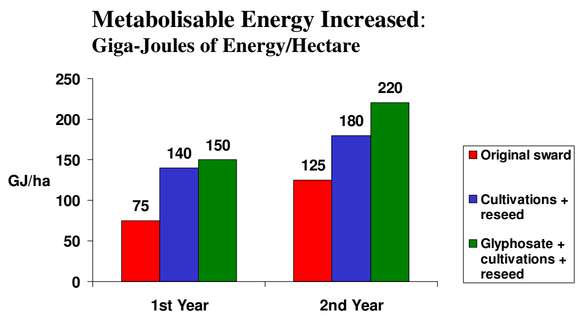
Thorough control of the old sward with glyphosate ensures the best reseed and 80% rye-grass content and subsequent yield increase.



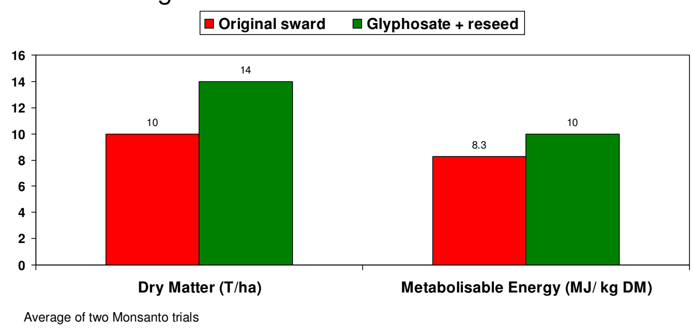
Monsanto trial – Malpas, UK

Increased grass yield
On average 25% increases (Evans, 1998) in dry matter yield are achieved from reseeding and higher quality feed translated as higher metabolisable energy yield. This Monsanto trial in Malpas illustrates the benefits of both reseeding and use of glyphosate for sward destruction in higher dry matter yield and increased metabolisable energy. The benefit seen in year one was even higher in year two;





Reseeding alone provided 41% more dry matter in year 2, but use of glyphosate to destroy the old sward when reseeding produced a further 12% more dry matter and 22% more metabolisable energy over reseeding alone.



Average results for two trials in the first year of production show a 40% increase in dry matter (DM) yield and a 20% increase in metabolisable energy (ME). This can have enormous benefits on the efficiency of meat and milk production.

Cheaper milk or meat production;

- *Increased milk production from higher yields of high quality grass*

Calculation of conservative benefits	Original ley	New ley	Benefit
Annual grass production (kg DM/ ha)	7,620	8,382	10%
Metabolisable energy content (MJ/kg DM)	10.2	11.0	8%
Annual energy output (MJ/ ha)	77,724	92,202	18%
Stocking rate (cows/ ha)	0.8	0.8	
Annual energy for maintenance (MJ/ cow)	25,500	25,500	
Annual energy for maintenance (MJ/ ha)	51,816	51,816	
Annual energy remaining for milk (MJ/ ha)	25,908	40,386	
Annual milk from grass @ 5.2 MJ/litre (litres/ ha)	4,983	7,767	
Annual milk from grass value @ 25 p/litre (£/ ha)	£1,247	£1,946	56%
Extra milk value (£/ ha/ year) or [€/ ha/ year]			£699 [€980]

After British Seed Houses (2008)

- *Saving on concentrates and bought in feed*

According to Helen Mathieu of British Seed Houses reseeding old pastures can offer cost savings on feed of around 12p (17 cents)/ kg DM; grazed grass at 5p (approx. 7 cents) per kg DM was less than a third of the cost of most bought-in concentrate feeds (Farmers Guardian, 2007). Recent costings (Nix, 2009) show extra quality grass silage at £35/ t (approx. €49/ t) could replace concentrates at £200/ t (approx. €280/ t); which equates to 0.49p (approx. 0.68 cents) compared to 1.82p (approx. 2.55 cents)/ MJ ME in dry matter - a 73% saving/ MJ ME.

- *Either, increase stocking levels*

Assuming a 25% increase in grass dry matter production, stocking density could be increased by a similar amount on that area.

- *Or, need less land to keep current stock levels so don't need to rent so much*

With lowland grass rental of £150-200/ ha (Nix, 2009) (approx. €210-280/ ha) savings can be made by reducing land to hold stock.

- *Or, divert other land to other uses like growing an arable crop for a higher gross margin*

Excellent weed control means the new cereal grows free of competition from rye-grass, Common couch and perennial broad-leaved weeds meaning a potential 10-42% increase in wheat yield, 0.8-3.3t/ ha (approx. €1.1-4.6/ ha), over untreated; a potential 10-33% increase in spring barley yield, 0.6-2.0t/ ha (approx. €0.8-2.8/ ha), over untreated. Average gross margin for winter wheat is £602/ ha (approx. €843/ ha) compared to £244/ ha (approx. €342/ ha) for beef sucklers and £279 (approx. €390/ ha) for lambs finished on grass (Nix, 2009).

Pre-cut use of glyphosate saves time, maximises feed and saves cost

Quality of forage maintained over untreated, dry matter increased;

Silage quality assessments	Untreated			Treated		
Days after treatment:	0	3	10	0	3	10
% Dry Matter	22.8	24.8	25.9	22.8	23.4	33.2
% Crude protein	11.0	7.2	8.5	11.0	9.1	8.6
% W.S. carbohydrates	29.9	32.1	27.7	29.9	30.1	29.2
'D' value	71.0	69.0	66.0	71.0	70.0	70.0

(After Stride, Edwards and Seddon, 1985)

NIAB trials suggest every 1 unit increase in D-value (concentration of digestible organic matter in forage dry matter) equates to 1.5% extra dairy milk production or, 5% extra live weight gain for beef, and 10% extra live weight gain for sheep (Turner, 1998). So maintaining D-value 4 units higher than untreated at 10 days could mean 6% extra milk production or 20% higher beef live weight gain.

Water soluble carbohydrates and dry matter increased, silage effluent reduced;

17 silage quality trials; - assessments	Small plot trials		Strip/ user trials	
	Untreated	Treated	Untreated	Treated
% Dry Matter	26.1	40.0	27.4	42.0
% W.S. carbohydrates	2.9	6.7	8.0	10.5

(After Stride, Edwards and Seddon, 1985)

Higher water soluble carbohydrates help ensure good silage fermentation and the making of quality palatable silage. Reduced silage effluent is a real benefit to help reduce the risk of environmental pollution on farm and to avoid potential fines.

Maximise use of season, maximum number of cuts before controlling sward, use treated grass
Use of treated grass maximises utilisation of grass and minimises need to supplement with other feed. Optimum establishment of the next crop by drilling earlier as don't have to wait for 3-6 weeks regrowth before spraying. Also allows earlier grazing of a new ley, even in same season.

Opportunity for reduced tillage as short cut stubble after cutting for silage or hay is ideal for reduced tillage/ direct drilling the next arable / forage crop, or even grass reseed, thus saving around £30-40/ ha (approx. €42-56/ ha), conserving more moisture and avoiding bringing up stones.

Yield maintenance through drilling at optimum timing
Use of glyphosate pre-cut can save 3-6 weeks, through not having to wait for regrowth, thus meaning cereals can be drilled earlier by optimum date. Cereals lose yield potential from later than optimal drilling; winter barley loses 0.1t/ ha per week when drilled after 10-24th September, so pre-cut use of glyphosate could maintain 0.3-0.6t/ ha yield potential; winter wheat loses 0.2t/ ha per week when drilled after 1st-15th October - so pre-cut use of glyphosate could maintain 0.6-1.2t/ ha yield potential.

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10 Orchards and Vines

Primary benefits

- Broad-spectrum weed control with better flexibility, performance and targeted use
- Increase fruit size and quality as well as yield
- Best value for money weed control
- Minimise other risks (soil erosion, frost/ mechanical/ disease / rodent damage of trees)

Introduction/ situation:
This sector includes the various perennial fruit crops that are grown on some 10.5m ha of European farm land; of which olives are the biggest crop covering 4.1m ha, vines cover 3.7m ha, fruits and berries cover 2.4m ha and citrus some 0.52m ha (Eurostat, 2008).

As these crops are grown for many decades on the same plot of land they can easily become infested with weeds, in particular perennial weeds, plus a wide variety of annual weeds. The intensive use of pre-emergence herbicides has encouraged perennial weeds, which are the major weeds of vineyards (Lange et al 1977), as has the introduction of no-till into many orchards/ vineyards (Atkinson, 1985).

Weed control is an essential part of optimum tree and fruit production as growth can be restricted 15-95%. The biggest effect is on fruit size and quality rather than yield; grass weeds around mature apple trees reduced crop weight by 16-35% and reduced economic value by 25-40% respectively (Atkinson and White, 1980). In the first 3-5 years of establishing a new vineyard (Domoto, 2009) or olive orchard (Lanini 2009; TDC 2009) plants/ trees are most susceptible to weed competition, but effects can be longer lasting on shallow soils and in any case will affect harvest and reduce productivity. Common couch can cause crop losses of 25-85% due to intense competition with trees or vines (Huffman, 2005). Water stress can severely damage fruit development (flowering, fruit set, fruit drop, fruit size, yield and internal fruit quality in citrus as 85-90% of the fruit is water (Falivene et al 2006).

Problems perennial weeds include Common couch *(Elytrigia repens)*, Bermuda grass (*Cynodon dactylon*), Johnson grass *(Sorghum halepense)*, Birthwort (*Aristolochia clematis*), Dallis grass (*Paspalum dilatatum*), Mugwort (*Artemisia vulgaris*), Slender St. John's-wort (*Hypericum pulchrum*), Field bindweed (*Convolvulus arvensis*), Hedge bindweed (*Calystegia sepium*), Trumpet vine (*Campsis radicans*), Purple nut-sedge (*Cyperus rotundus*) and Nut grass (*Cyperus esculenta*), thistles (*Cirsium* spp.), docks (*Rumex* spp.) and Bramble (*Rubus* spp.) and a wide range of annual weeds including Barnyard grass (*Echinocloa crus-galli*), Crabgrass (*Digitaria* spp.), Giant foxtail (*Setaria faberi*), Black night-shade (*Solanum nigrum*), Pigweed (*Amaranthus* spp.) and Redshank (*Polygonum* persicaria) which are resistant to many pre-emergent herbicides (Lange et al, 1977).

Problems:

- weed competition for water and nutrients, and in the early 3-5 years after planting for light
- weeds reduce crop yield and impair crop quality
- uneven irrigation pattern meaning some plants get too much water whilst others are deprived
- reduce ground heat radiation increases frost risk in orchards/ vineyards
- harvesting hindered
- weeds around young trees provide cover for rodents that damage the young bark/ stems and such girdling can kill young establishing plants
- costly and difficult to control weeds with manual, mechanical, flame or mulching techniques
- high erosion risk as traditional techniques to keep orchards weed free rely on regular cultivation that damages soil structure and increases soil erosion
- complete weed control leaves soil exposed to risk of soil erosion and is unnecessary
- traditional orchard maintenance with tillage damages tree/ vine roots and reduces yield

Needs:

- to control weeds whilst maintaining ground cover to minimize soil erosion and moisture loss
- to minimize reliance on traditional tillage and pre-emergence soil residuals

- to control a wide variety of perennial and annual weeds that become very well established
- integrated weed control practices to minimize resistance development

Alternative practices:
Traditionally orchards and vineyards used shallow cultivation with disc harrows or tine cultivators to rip up weeds that were left to dry in the sun. This requires regular cultivating, 10 tractor hours/ ha is average in Andalusian olive orchards (Munoz-Cobo, 1990), with associated high fuel and labour cost as weeds continued to germinate through the season with rainfall and risks root damage and soil erosion.

Other alternatives include; flame treatments to burn-off seeds but risks fires and tree scorch, mulches using weed membranes/ black geo-textile or thick layers of organic material to smother weeds or restrict light to foliage, but these need regular maintenance or topping up and are quite expensive (TDC, 2009). Repeated mechanical mowing or grazing with animals has also been used, but water loss from weeds is not prevented and crop damage can occur.

Alternative pre-emergence herbicides used in the past like triazines caused major weed resistance and environmental problems and failed to control perennial weeds. Of the commonly used alternatives; diclobenil was expensive and the approval was withdrawn in the EU in 2008, propyzamide has a narrow optimum use window and 2,4-D is volatile and none of them controlled certain common weeds like Field bindweed, Hedge bindweed or Brambles (Atkinson, 1985).

Fit for glyphosate:
- broad-spectrum long-term control of both perennial/ annual weeds
- control weeds before planting and in tree/ plant rows after planting
- provide chemical mowing of 'middles' at low rates when use approved
- selective treatment either to weed spots or by weed wiper
- low risk to the environment with low leaching potential and broken down without bioaccumulation in mineral soils
- translocated and can be used in low water volumes so controls whole plant including the root
- modern glyphosate products are tank mixable with certain residual herbicides to give long-term control

Benefits of using glyphosate:

Excellent broad-spectrum weed control
Glyphosate controls a wider range of grass and broadleaf weeds in orchards and vines than any other herbicide and offers more flexibility of use (Atkinson, 1985; Hebblethwaite and Schepens, 1985). Glyphosate provides better weed control than cultivation or glufosinate. Weeds controlled from early summer or autumn application include; Common couch*,* Bermuda grass*,* Dallis grass and Johnson grass*,* Mugwort*,* Hedge bindweed*,* Trumpet vine*,* thistles, Slender St. John's-wort*,* Field bindweed*,* Dock spp., Bramble spp. and a wide range of annual weeds (Atkinson, 1985). Glyphosate is the accepted treatment of major perennial weeds Bermuda grass and Field bindweed in European vineyards as it controls the roots (Hebblethwaite and Schepens, 1985). Weed control, mostly down the crop rows, removed weed competition for water, nutrient and light benefiting crop establishment and growth.

Undisturbed perennial weeds like Common couch in vineyards are more difficult to control than in arable crops and rates of glyphosate of 1.7-2.5kg ae/ ha are required (Huffman, 2005). The label rate for control of perennials in French vineyards is 2.88kg ae/ ha (Monsanto, 2008), or 1.8kg ae/ ha in UK orchards (Monsanto, 2007).

With good weed control trees grow more roots in the upper biologically active zone of the soil which is particularly important for productivity on thin soils (Smith, 2009).

Glyphosate can be sprayed only where and when necessary unlike prophylactic residual herbicides.

High fruit yield and quality
Use of glyphosate for weed control was shown to increase leaf mineral content, fruit weight, number of fruits and yield as well as fruit quality in Washington Navel Oranges (Hafez and El-Metwally, 2007);

Treatment	Fruit weight (g)	# fruits/ tree	Yield (kg/ tree)	Total soluble solids (%)	Ascorbic acid (mg/100ml)
Untreated	191	261	50	13.5	40
Glyphosate	242	310	75	15	48

Reduced disease incidence
Weeds increase humidity and diseases like Olive knot (*Pseudomonas savastanoi*) and Peacock spot (*Cycloconium oleaginum)* in Olives. Frequent cultivation damages Olive roots allowing infection with Crown gall (Agrobacterium tumefaciens) and Olive knot (Lanini, 2009). By safely spraying glyphosate weeds are removed without damaging trees and so air circulation is increased, humidity declines and crop disease incidence is reduced (Domoto, 2002).

Integrated control of soil erosion
Regular cultivation to control weeds creates fragile bare soil, capping, low soil organic matter and poor water infiltration so increasing the risk of soil erosion (Pelegrin et al, 2001). Continued use of the non-tillage bare soil technique was shown to reduce water infiltration on all soils as surface capping built up due to the impact of raindrops and motor traffic (Pastor, 1988).

Sowing an autumn grass/ cereal cover crop between tree rows improves water infiltration and protects soils against erosion in non-tillage orchards like Olives/ vines. Glyphosate is sprayed before the start of weed competition in spring to control the cover and create mulch that further protects the soil against erosion whilst minimising water loss (Pastor et al, 1997; Pelegrin et al, 2001).

Accurate irrigation ensures all trees get the water needed
Use of glyphosate to control weeds above roots prevents weeds interfering with the spray pattern of irrigators and ensures irrigated crops get the water they need (Smith 2009).

Integrated practice for water conservation and to minimise soil erosion and increase yield
Controlling green weed vegetation removes the drain on water resources so conserving moisture in the soil for the vine crop (Domoto, 2002). Early removal of cereal cover crop between vine rows by spraying glyphosate preserves soil moisture for vines, particularly important in drier areas of the Mediterranean or in drought years (Battany, 2007).

Low fertility soils in semi arid areas suit the growing of Olives, but also perennial weeds which can grow vigorously early in the season competing for water. Glyphosate should be used 4-6 weeks before spring growth to minimise moisture competition (TDC, 2009). Use of an autumn sown grass cover crop in Olive groves improved winter water infiltration and reduced soil erosion. Grass cover increased soil moisture above that of tilled soils. The cover was then sprayed out in March to maintain soil moisture for trees and provide a mulch to protect the soil and reduce moisture loss (Castro and Pastor, 1991; Pastor et al, 1997).

Treatment	mm water storage in top 150mm soil in February
Traditional bare / tilled soil	272 - 269
Rye-grass + clover or Oats + Vetch cover crop sprayed out in spring with glyphosate	288 - 294

(After Pelegrin et al 2001)

Olive yield was increased 14% over conventional tillage by using an over-winter cover crop of barley in a non-tillage system, sprayed out in March with low rate glyphosate and rolled (Pastor, 1989).

In citrus it is best to operate an integrated programme of complete weed control with glyphosate in spring to remove competition for water and provide a mulch to protect soil and reduce evaporation loss combined with overnight drip irrigation (Falivene et al, 2006).

In France a natural weed/ cover crop is used in vines to protect the soil between the rows from erosion. This is mown when required and sprayed out prior to harvesting. This improved biological activity of the soil, reduced soil erosion and the risk of residual herbicides getting to watercourses (Monsanto, 2008).

Integrated weed management to minimise costs, root damage, protect soil and retain moisture
Mowed grass between crop rows can be more competitive than un-mowed for both water and nutrients. Chemically mowing grass and broad-leaved weeds with application of glyphosate at 0.115-0.348kg ae/ ha depending on species, taking care not to affect green cover, allowing 45 days before cover is mown to 15-20cm and then retreating with glyphosate 1-2 weeks later retained higher soil moisture, protected the soil from soil erosion and did not damage roots (Tucker et al, 1997; Futch, 2002).

To control current year suckers on fruit trees
Glyphosate can be used to control current year tree suckers without harming the mature tree. Application in July gave good control of Cherry and Plum suckers and excellent control of Apple and Pear suckers (Atkinson et al, 1978). A rate of 1.8kg ae/ ha is approved in UK, sprayed in late spring in apple, pear, cherry, plum and damson orchards.

Tree species	Apple	Pear	Plum	Cherry
% control of first year suckers after 1 year	95	100	82	67

Best value for money and most efficient weed control practice
Rupp and Anderson (1980) showed glyphosate gave the best value as regards tree growth/ unit chemical cost and thus made glyphosate one of only a few herbicides regularly used in fruit orchards.

Non-tillage bare soil techniques using herbicides for weed control were the most efficient in terms of reduced tractor hours, cost and fuel consumption in Andalusian olive orchards (Pastor, 1990);

Soil management method	Tractors use (hours/ ha)	Cost (pesetas/ ha)	Fuel consumption (L/ ha)
Conventional tillage	10.00	20.01K	140
Minimum tillage	6.75	17.07K	102
Non-tillage/ bare soil	1.50	12.54K	45

Use of glyphosate is a cheaper, quicker and more effective way to control weeds than alternatives like tillage, flaming and mulching (Smith, 2009).

Minimise root/ stem damage
The most active root zone of trees is the upper 30-40cm depending on soil type and species (Falivene et al, 2006). Under non-tillage systems olive roots occupy surface soil layers which are richer in nutrients and can access water in low rainfall areas (Pastor, 1990). Careful application of glyphosate with a guarded sprayer removes weeds and leaves the trees/ vines unharmed. Contrast this to traditional tillage methods where root damage is inevitable and even stems/ trunks can be abraded by machines allowing disease ingress (Domoto, 2002). Frequent cultivation damages Olive roots allowing infection with bacterial diseases like Crown gall and Olive knot (Lanini, 2009).

Minimise rodent damage to young trees
Control of weeds around tree stems during establishment with glyphosate removes cover and minimises the risk of girdling of young plants by rodents (Lanini, 2009).

Minimise risk of frost damage in older orchards
Weeds cover the ground and reduce heat radiation from the soil at night increasing the risk of frost damage. Take the weeds away and the risks of frost damage are reduced (Lanini, 2009).

Save fuel and time by tank mixing/ use of low water volume
Modern glyphosate products can be tank mixed with certain approved products to allow control of germinating weeds to provide longer-term control in the growing season and save fuel, time and money.

Application at low water volume through controlled droplet applicators is common in Spain to reduce the amount of water carried, minimise drift and improve performance (Monsanto, 2005).

Devitalisation of vines before replanting
At the end of the useful life of vineyards glyphosate is an excellent tool to destroy the old vines in France. Sprayed just after harvest in October at 2.88kg ae/ ha glyphosate controls the vines and thus controls disease and nematodes that thrive on old vines. By controlling the roots, glyphosate facilitates removal of the old vines that are grubbed out in March/ April before the vineyard is restocked with new vines (Monsanto, 2008).

Integrated practice to minimise weed resistance development
Glyphosate is often regarded as a panacea for weed control, but regular use with no other weed control measure could bring the risk of weed resistance, as with other herbicides so used. It is important therefore to use glyphosate as part of a weed control strategy in these perennial crops and not to rely on it alone (Domoto 2002); Flaming can be used on young weeds and to control seeding, organic mulches can be added once glyphosate has done its job to control weeds the rest of the season, occasional cultivation can be fitted in to control annual weeds. Cover crops like cereal/ grass can also be integrated. It is also important to apply it only as needed, even as a spot treatment and to use full label rates. Integrated weed control practice is best, taking care not to damage young trees (TDC, 2009). Tank-mixing with another herbicide like a pre-emergence residual can also help manage weed resistance as well as prolong weed control.

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11 Selective weed control techniques

Primary benefits

- Broad-spectrum selective control of perennial weeds in standing crops/ plantings
- Improve upland grazing where reseeding is never an option
- Control invasive weeds without destroying underlying flora
- Control weeds in vegetables left with few selective/ residual herbicides

Introduction/ situation:

This section covers specific minor uses of glyphosate using selective weed control techniques (weed wipers, shrouded sprayers and stem injection) where in many cases selective use of glyphosate is the only method of weed control possible or remaining in upland grassland, vegetables/ herb/ soft fruit crops and for the control of invasive weeds amongst desirable plants/ trees.

Upland areas of rough grazing are often infested with rushes (Juncus spp.), Common bracken (*Pteridium aquilinum*), thistles (*Cirsium* spp.) and docks (*Rumex* spp.) and are difficult/ undesirable to reseed due to steep slopes and stones and difficult to cut or spray due to uneven land. Bracken alone infests some 11,000 km2 of the UK and is spreading fast (Monsanto, 2008c).

Invasive weeds require control to minimise their spread. Mechanical control is often too expensive, undesirable or not possible and instead these prolific weeds needs to be controlled selectively to leave underlying/ surrounding vegetation to protect the soil.

Vegetable crop production is growing, but the number of approved herbicides is reducing. Excluding tomatoes as glyphosate is not approved for use near tomatoes or under glass, currently 48.5mt vegetables come from around 1mha of crops across the EU-27 (Eurostat, 2008) with 5.4mt of carrots grown in Poland, UK, France and Italy and 5.3mt of onions grown in Spain, Netherlands, Poland and the UK. Many other vegetables grown in rows like parsnips, leeks, celery, celeriac and legumes and even brassica crops will/ do need new methods of weed control.

The withdrawal of registration and restrictions on certain herbicides listed below, as their registrations come up for renewal, are dramatically reducing the number of available herbicides for weed control in vegetable crops. Prometryn, propachlor and trifluralin, used for annual broad-leaf weed control, and several of the fop and dim herbicides used for annual grass weed control have gone already (EUR-lex, 2008), whilst pendimethalin, metazachlor, ioxynil and linuron used on broad-leaved weeds are under threat (HGCA, 2009). Recent withdrawal of metoxuron means there are even fewer products for use in carrots, leeks, onions and parsnips. Under the Water Framework Directive metazachlor, propyzamide and carbetamide could also be withdrawn which would make annual weed control in oilseed rape difficult (HGCA, 2009), and to this end HGCA are proposing a research project on inter-row use of glyphosate in oilseed rape.

Active ingredient	Main crops registered before active ingredient withdrawn
metoxuron	Carrots, leeks, onions, parsnips
prometryn	Carrots, celery, celeriac, herbs, leeks, onions, peas, potatoes, swedes, turnips
propachlor	Brassicas, leeks, lettuce, onions , swedes, turnips, herbs, strawberries, top fruit
trifluralin	Beans, brassicas, celeriac, celery, lettuce, strawberries
	Main crops still registered but under threat though active ingredient withdrawn
carbetamide	Brassicas, beans, seed crops, turnips
ioxynil	Chives, onions, parsnips, shallots
linuron	Carrots, celeriac, celery, garlic, leeks, parsnips
metazachlor	Brassicas, top fruit
pendimethalin	Brassicas, beans, herbs, onions, peas, potatoes
propyzamide	Lettuce, peas, strawberries, rhubarb, top fruit

UK Pesticide Guide, 2002

Increased requirements for use of safer products, lower amounts of active ingredient and ideally no exposure of vegetable crops to pesticides is putting huge pressure on growers and land owners who still need to control weeds cost effectively.

Specialist equipment to reduce application volume and chemical use by increased precision of application and minimal drift are still being developed and these together with the use of modern wiper technology allow selective application of the non-selective herbicide glyphosate.

Needs:

- Excellent weed control
- Complete safety to surrounding crop/ plants
- Selective weed control on uneven surfaces
- Low volume, cost effective, precision application
- Excellent safety profile

Alternative practices:

- Mechanical weed control by mowing/ cutting weeds
- Tractor hoeing of vegetables
- Hand-weeding of vegetables

All these practices are expensive, labour intensive and have limited benefit.

Fit for glyphosate:

- broad-spectrum long-term control of both perennial/ annual grass and broad-leaved weeds
- selective treatment of problem weeds with weed wipers, shielded sprayers, and injection systems
- inter-row use in row crop vegetables and soft fruit
- low use rate, efficient, precise and rapid treatment
- safe to consumers and environment with low leaching potential, broken down in mineral soils
- translocated so can be used with wiper and low water volume applicators to control the whole plant including roots unlike contact active treatments

Benefits of using glyphosate:

Excellent height selective weed control

Use of equipment to selectively apply glyphosate to taller weed species leaving shorter desirable vegetation unharmed. Weeds must be at least 10cm taller than desired vegetation, and the applicator kept at least 5cm from desired vegetation (Monsanto, 2007). The latest generation of ATV/ tractor mounted weed wipers based on carpet rollers (Carrier Rollmaster or the Rotowiper), rotary brush systems (Logic Contact 2000), hydrostatically fed pads (Micron WeedSwiper) or wool wiping arms (C-Dax eliminator as pictured) have dramatically improved weed control and selectivity over older rope-wick applicators making it possible to treat larger areas even over rough ground with few drips. This has been achieved with reduced chemical use rate through better contact application and flow control with improved differential height selectivity to minimise damage to desired vegetation.

Glyphosate is applied at a dilution of 1:20 to 1:10 depending on the applicator. Weeds controlled include; Broad-leaved dock (*Rumex obtusifolius*), Curled dock (*Rumex crispus*), Creeping thistle (*Cirsium arvense*), Spear thistle (*Cirsium vulgare*), Common bracken, Common nettle (*Urtica dioca*), Japanese knotweed (*Fallopia japonica*), Himalayan balsam (*Impatiens glandulifera*), Rush species (Juncus spp.), Giant hogweed (*Heracleum mantegazzianum*) and Common ragwort (*Senecio jacobaea*). The handheld Microwipe (a rope-wick applicator), using 1:2 dilution of glyphosate, is useful for smaller jobs like spot treatment of weeds around trees and shrubs.

Preserve and improve existing sward, clover or upland grazing
Most selective herbicides in grassland will control a range of broad-leaved weed species of grassland, but also control desirable Clover (*Trifolium* spp.). Selective use of glyphosate controls taller perennial weeds like tussock forming coarse grasses, docks, nettle, thistles, rushes and bracken but leaves desirable species like Clover and palatable grasses untouched allowing full utilisation of treated sward for grazing or making forage. Selective use of glyphosate provides control of bracken and rushes in upland grazing areas, difficult to treat by any other means. If poisonous weeds like Common ragwort, Hemlock (*Conium maculatu*), Water dropwort (*Oenanthe crocata)* and Common bracken are treated, these must be removed or allowed to rot before future grazing/ conserving (Monsanto, 2009).

Selective control of tall emerging weeds in all crops
Weed wipers can be used in any situation in arable or horticultural crops to control weeds that emerge at least 10cm above the crop (Monsanto, 2007). This allows control of weeds related to crops; Weed beet in Sugar beet, Charlock (*Sinapsis arvensis*) in Oilseed rape, volunteer potatoes in vegetable crops; tall weeds like Fat hen (*Chenopodium album*) or Common orache (*Atriplex patula*), docks, nettle and thistles.

Selective control of Common bracken
Bracken infests 8% of the UK, some 11,000km^2, and is spreading faster than it can be controlled. Bracken is host to ticks that transmit Louping *(Ovine encephalomyelitis)* and Lime disease (*Borrelia* spp.) to humans and causes 'Bracken staggers' in cattle. Previous control methods only gave partial control and their use was restricted by cost, the need to keep a barrier to water, accessibility in the case of asulam (Azulox) or concerns of widespread spraying. However, use of glyphosate in modern weed wipers, in particular the Logic Contact 2000 or Micron WeedSwiper (Mabbett, 2008) on an ATV, has enabled faster cost-effective selective control with low environmental risk compared to spraying. Application at full frond extension in July - August provides full control over 2-3 years.

Logic weed wiper on Bracken in Scotland

One year after treatment for Bracken in Wales. Foreground wiped with glyphosate using a WeedSwiper, background untreated. Photograph courtesy of Micron sprayers.

Selective control of invasive weeds
Whilst spraying is useful on large dense areas, the likely effect is to leave bare ground. Use of weed wipers or stem injection provides a selective way of controlling invasive weeds, including Common bracken as above, whilst leaving desirable vegetation untouched.

For the control of Japanese knotweed glyphosate can be applied neat though stem injection or by weed wipers as a 2:1 dilution (Monsanto, 2004, 2008a and 2008b; Cornwall Japanese Knotweed Forum). Injection of a 10% solution of glyphosate below the first node of Giant hogweed provides effective control (Environment Agency, 2007).

Stumps of cut trees and invasive plants can be treated with a 10% solution of glyphosate when they are dormant to prevent regrowth (Monsanto, 2007, 2009b)

Treat specific weeds or make a tree planting spot
Use a spot gun and a narrow cone TG-3 or TG-5 nozzle to apply 5ml of spray over a 0.3 or 0.6m spot (Monsanto, 2007) provides a clean start for planting a single tree/ bush.

Directed inter-row control of weeds in vegetable crops

Micron produce a range of shrouded controlled droplet application (CDA) equipment including the single unit Vegedome and multiple variable spaced Varidome (Micron, 2009) which allow the use of herbicides between crop rows of vegetables like onions, leeks, and parsnips, etc. Generally these have been used with contact herbicides, however, these do not control perennial weeds although do further minimise the risk of crop damage. In the US there are approvals for the use of glyphosate inter-row in a wide range of crops (Oregon State University, 2008) including Brassicas (Cabbages, Kale, Broccoli), Cucurbits (Courgettes, melons, pumpkins, cucumbers), bulb vegetables (Garlic, Leek, Onions and Shallots) legumes (beans and peas), leafy vegetables (Lettuce, Celery, Fennel, Swiss Chard), root and tuber vegetables (Beetroot, Carrots, Parsnips, Celeriac and Sweet potato), fruiting vegetables (Peppers, Eggplant - but not tomatoes). Approval exists for inter-row spraying in maize in Spain and cotton in Greece. Work is on-going in UK and other European counties to register this valuable use of glyphosate that can provide directed weed control in crops where many products are losing registration and being withdrawn.

Safety to operator, environment and consumer
Glyphosate, particularly formulated in one of the modern products like Roundup Biactive, provides minimal risk to the operator, environment and consumer when used as directed and is classified as non-hazardous under COSHH.

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12 <u>Agricultural non-crop</u>

Primary benefits

- Broad-spectrum weed control prevents build up of scrub, invasive weeds or annuals
- Flexibility of use for management of agricultural non-crop
- Support wild bird and small mammal populations

Introduction/ situation:

This sector includes; agricultural land that is not in agricultural production, green cover on land voluntarily removed from agricultural production, land previously under compulsory set-aside that covered 3.7 m ha in EU-14 (IEEP, 2008) that was enforced up to 2008, environmental stewardship buffer strips along hedgerows and dry ditches, fallow land covered 9.98 m ha in EU-27 (Eurostat, 2003), fence lines, areas round farm buildings, yards, tracks and paths. Such land can quickly become infested with weeds, including noxious/ invasive and woody species, which are great colonisers of open space/ bare ground, particularly in the absence of crop competition and especially over 5 years.

The environmental benefits of longer term set-aside were felt to be so important (IEEP, 2008) that DEFRA, Natural England, the NFU and CLA are working on a plan to maintain 5% of farm land as non-cropped for the environment (DEFRA, 2009b; Natural England 2009; NFU, 2009), including grass buffer strips alongside water courses, reverted arable plots, previously cultivated land taken out of production long-term, game strips, farmland bird plots and winter stubbles (Boatman and Gosling, 2009).

Land not in agricultural production should be maintained so it can be put back into production to be eligible to receive payment under the Single Farm Payment Scheme (Monsanto, 2009; DEFRA, 2009a) and this means growers must control weeds.

Planting a grass/ leguminous cover crop is desirable in non-crop areas to protect the soil and suppress weeds (Arnold and LaBarge, 1994). Sown green covers of grass/ un-harvestable crop mixtures/ wild seed mixtures to manage weed species often succumb to weed ingress albeit at a slower rate.

Nuisance agricultural weeds like Brome grasses (*Bromus* spp.) as well as Wild oats (*Avena* spp.) and Black-grass (*Alopecurus myosuroides*) are often resistant to selective herbicides and Common couch (*Elytrigia repens*), Bent grasses (*Agrostis* spp.) also take advantage of non-cropped open spaces as do Groundsel (*Senecio vulgaris*) and perennial broad-leaf weeds like Docks (*Rumex* spp.), Thistles (*Cirsium* spp.), Dandelion (*Taraxacum* officinale), Perennial Sow-thistle (*Sonchus arvensis*), Rosebay willow herb (*Epilobium angustifolium*) and Coltsfoot (*Tussilago farfara*), which all spread both vegetatively and by seed. Seed production from annual weeds is massive; one Black-grass plant can shed 250-1000 seeds, a brome grass some 40-400 seeds (Merritt, 1994).

Needs:

- Comply with cross compliance rules for; weed control, agricultural land which is not in agricultural production to be maintained as eligible (DEFRA, 2005, 2009a), environmental buffer strips (Monsanto, 2009a)
- Establish and maintain green cover on land temporarily removed from agricultural production, whilst proving cost effective weed control (DEFRA, 2009a)
- Minimise weed seed production
- Control of noxious and invasive weeds is a legal requirement of all agricultural land owners (local weed control legislation); you must take all reasonable steps to prevent the spread on your land and on to adjoining land of 'injurious' weeds; Common ragwort (*Senecio jacobaea*), Spear thistle (*Cirsium vulgare*), Creeping or Field thistle (*Cirsium arvense*), Broad-leaved and Curled Dock (*Rumex obtusifolius* and R. *crispus*) and of the invasive weeds: Rhododendron (*Rhododendron ponticum*), Japanese knotweed (*Fallopia japonica)*, Giant Hogweed (*Heracleum mantegazzianum*) and Himalayan Balsam (*Impatiens glandulifera)* (Monsanto,2009a; DEFRA ,2009a)
- Maintain non-crop land for the benefit of wildlife
- To be able to control all vegetation on non-cropped agricultural land to return it to production
- NOTE: requirements for weed control take precedence over those of maintaining green cover

Alternative practices:

- Mowing to maintain grass cover and minimise weed ingress by cutting species before flowering, tends to delay, but not stop flowering, so does not fully meet the need to control noxious weeds.
- Selective herbicides like metsulfuron-methyl can be used to control problem weeds like thistles and docks to maintain grass cover weed free, however, this removes the wildlife value of broadleaf species unless used selectively as a spot treatment. Metsulfuron-methyl + 2,4-D or trichlopyr provides best control of Hoary willow herb *(Epilobium parviflorum*) and Fireweed/ Rosebay willow herb (*Epilobium angustifolium)* (SAC, 2006), but there are restrictions on use of many alternative herbicides on buffer areas near water.

Fit for glyphosate:

- broad-spectrum long-term control of both perennial/ annual grass and broad-leaved weeds
- manage annual weeds that show resistance to selective in-crop herbicides
- selective treatment of problem weeds
- safe to environment with low leaching potential, broken down in mineral soils
- non-residual so no delay to planting a cover crop or when land returned to production
- translocated and can be used in low water volumes to control the whole plant including roots
- part of an environmental management programme to minimise nitrogen/ soil movement
- return land from fallow/ green cover to production with a single treatment
- modern glyphosate formulations are tank mixable

Benefits of using glyphosate:

Excellent broad-spectrum weed control for many situations (Monsanto, 2009; Robinson, 1985)

- translocated so controls even large weeds/ deep rooted weeds left by non-chemical methods
- opportunity for controlling major annual and perennial weed problems outside the crop, as well as volunteer cereals, oilseed rape and potatoes (SAC, 2006)
- optimum control of perennial weeds by being able to spray at the best physiological growth stage which is at/ near flowering
- control seeding of problem annual weeds like black-grass and brome species at 1.08 kg ae/ ha
- prevent the build-up of established perennial weed/ scrub problems at 1.44-2.16 kg ae/ ha
- clearing weeds before planting trees, or use post-planting to control weeds round newly planted trees
- plant free areas paths, roads, fence lines, yards and around buildings
- rates of 1.08-2.16kg ae/ ha depending on target; annual weeds or light-moderate Common couch to well established difficult perennial broad-leaved weeds like Rushes (*Juncus* spp.), *Clover (Trifolium* spp.) Yellow rattle (*Rhinanthus minor)* and invasive woody species that can become established over 5 or more years out of production (Monsanto, 2007)
- Glyphosate is the most effective treatment on most species

Control even difficult species less susceptible to glyphosate
Adding MCPA at 1L/ ha or mecoprop-P at 0.5L/ ha to glyphosate aids control of large established oilseed rape volunteers, whilst addition of metsulfuron-methyl can help control some large perennial broad-leaved species, however, control of grass species may be reduced (Monsanto, 2004).

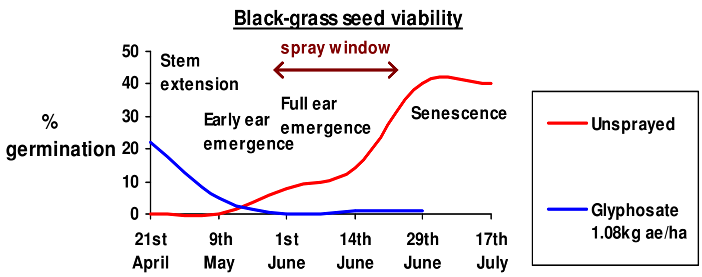
Manage the population of volunteer crops
Cereal and oilseed rape volunteers can be a problem in a continuous winter arable rotation and hard to control as there is insufficient time between crops to allow germination and control. However, in the non-crop situation such weed problems can quickly and cost effectively be used to provide green cover before their control with glyphosate at 0.54-1.08kg ae/ ha and seeding with a cover crop. Volunteer potatoes can be a challenge to control in arable rotations, but a programme of treatments, including glyphosate at 1.44kg ae/ ha at or after flowering in summer can clear land in non-crop situations (SAC, 2006).

Effective control of noxious and invasive weeds
Under legislation certain weeds need to be controlled including; Japanese knotweed, Giant Hogweed, docks, thistles and Common ragwort. Land owners have a legal duty to manage such weeds to prevent

them spreading to neighbouring land. Good control is achieved through spray application of glyphosate at 1.8kg ae/ ha (Willoughby, 1996). For the control of Japanese knotweed glyphosate can be applied neat though stem injection or by weed wipers at a 1:2 dilution (Monsanto, 2004b, 2008a and 2008b; Cornwall Japanese Knotweed Forum). Spot treatment with a spot gun with glyphosate at 1.08-1.8kg ae/ ha depending on target species can be used to treat small patches of weed or individual weeds, or a weed wiper can be used with glyphosate at 1:2 dilution in water to treat such weeds selectively as long as there is more than 10cm height differential whilst leaving underlying vegetation (Monsanto, 2007), thus leaving underlying flora unharmed.

Allows land to be removed from production without fear of land being infested with scrub
Selective or wide scale use of glyphosate to control problem weeds, as outlined above, means growers can remove land from production to meet environmental requirements of governments with no fear of weeds and scrub preventing a return to production in the future. Although compulsory set-aside has been withdrawn by the EU in 2007, growers in long-term set-aside previously had land out of production for 5-10 years and successfully managed weeds over that period whilst providing enormous environmental benefit to birds and insects. It is likely to be a requirement of UK farmers that they voluntarily set-aside some land for environmental benefit under an expanded entry level stewardship scheme promoted by the NFU and CLA, or alternatively that under new cross compliance rules they manage 4-6% of their cultivated land for environmental benefit (Farmers Guardian, 2009).

Prevent build up of annual grass weeds and weeds resistant to selective herbicides
In many countries, annual grasses like Black-grass and Rye-grass have become resistant to selective herbicides used in crop. Together with Brome grasses these weeds can rapidly build up in non-crop situations as they seed prolifically, but are easily controlled by glyphosate during the non-crop period, with a cover crop being established afterwards when needed. Alternatively, growers can take a programmed approach to reduce such annual weeds by repeatedly controlling successive flushes of such weeds thereby reducing their seed population over a period of years before returning the land to agricultural production. Sprays of glyphosate are most effective at early tillering or full ear emergence, typically in mid-late May, but not at stem extension, and provide full control of the plant and green seed at label rates of 1.08kg ae/ ha. Untreated/ mowing would leave seed heads to mature and shed viable seed thus increasing the weed seed burden (Monsanto 2002).



Facilitate a decline in arable crop disease and pest levels and break the 'green bridge'
Disease and pest levels build through a tight arable rotation and increase cost of control with pesticides, as well as likely risk of the development of resistance. In a non-crop situation the use of glyphosate to manage volunteer crops and grass weeds means certain pest and disease levels will fall as their host plants are removed. Importantly, all vegetation should be sprayed out and left to dry out before cultivating and planting a following crop, thus breaking the green bridge and transfer to the crop (SAC, 2006, 2009).

Support nesting/ fledging birds and small mammals
The use of glyphosate for weed control in May-June means growers don't have to resort to cultivation or mowing to manage annual grass weeds in March-May period when birds are nesting and fledglings growing up. Delaying management means Sawfly larvae can emerge and disperse through April and May to provide food for young game birds and Skylarks. Weed/ green cover controlled by glyphosate application in mid-May to June at flowering leaves standing 'brown cover' which provides excellent cover for nesting wildlife and young birds. Glyphosate can be used to destroy the cover and the benefits to Sawfly emergence can still be obtained (Sotherton, 1994). Contrast this with the detrimental effects of mowing such vegetation at this time of year.

Spraying is the preferred management technique over cutting/ mowing as it leaves birds and nests unharmed (RSPB, 2002).

The numbers of voles, harvest mice, brown hares and bats increased due to increased food and improved habitat on long-term non-cropped land compared to surrounding arable land (Natural England, 2009).

Facilitate effectiveness of fence lines and safe working environment around buildings, tracks
By controlling weeds along electric fences, voltage is maintained to restrain animals in the fields as opposed to shorting through foliage. Sight lines are maintained and yards and tracks kept clear for safe vehicular or pedestrian passage.

Cover crops can be sown to minimise over winter environmental damage
Agricultural non-crop land left without cover is more prone to water run-off, soil erosion and movement of soil, phosphate and nitrogen to watercourses causing pollution.

Cover crops can be safely established that minimise soil and water movement directly to watercourses in the knowledge that they can be controlled through application of glyphosate prior to returning the land to agricultural production.

Flexibility of use

- timing: can spray through the year so it is possible to spray only when really necessary
- safety to operator, water and the environment
- broad-spectrum: control both annual and perennial grass and broad-leaved weeds
- inactivated on contact with soil so non-residual, no delay to planting and no risk to unsprayed areas
- selective/ spot application; avoid drains/ desirable or rare plants/ control invasive and noxious plants
- suits application through new low volume applicators: Rotary atomisers at 40L/ ha volume, CDA at 7.5-15L/ ha volume (Nomix Enviro), Mantis ULV (Lange et al, 2008) and weed wipers to control drift, improve precision, speed and cost effectiveness
- shielded spray head minimises drift and avoids damage to surrounding vegetation or young trees

Efficient use
Use of rotary atomisers, CDA or weed wiper applicators maximises performance and efficiency of operation, whilst minimising water and chemical use.

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13 Forestry and Christmas trees

Primary benefits

- Most cost effective weed control option
- Broad-spectrum long-term weed control
- Faster growth rate of trees
- Flexibility of use

Introduction/ situation:
Wooded/ forested land represented 42% of the EU-27 land area in 2007, some 177m ha, one of the most valuable resources in Europe which comprised of 25% coniferous and 75% broad-leaved species with some 73% available for use in wood supply or timber production. In 2006 some 111 billion m^3 of sawn timber was produced in Europe (Eurostat, 2009).

Conifers used to be the main forestry/ woodland species due to their rapid growth; however, there is renewed interest in planting broad-leaved and mixed forests of coniferous and broad-leaved trees. Established weeds and natural tree regeneration can compete aggressively with young trees resulting in poor establishment and slow or distorted growth which is bad for the establishment of forest/ wood/ amenity planting but disastrous for lucrative Christmas tree production where shape is crucial to sales.

Scrub growth and invasive perennial broad-leaved species like, Rhododendron (*Rhododendron ponticum)* (Edwards, 2006), Brambles (*Rubus* spp.), Common bracken (*Pteridium aquilinum)* and Japanese knotweed (*Fallopia japonica)* can cause major problems in forested areas smothering establishing trees. These are very aggressive competitors, rapidly colonising areas to create a dense thicket that is expensive to clear; reducing biodiversity, restricting re-planting. Rhododendron is also a host for the damaging Phytophthora diseases (*Phytophthora ramorum* and *Phytophthora kernoviae)* which are subject to plant health regulations (Edwards, 2006) that infect Oaks (*Quercus* spp.), Beech (*Fagus sylvatica)* and Horse Chestnut (*Aesculus spp.*) in broad-leaved forests and woodlands causing cankers and subsequent death of trees.

When commercially managed forests reach maturity they are often clear felled and replanted. Cut stems, stumps and roots of many broad-leaved tree species regrow, producing 1m growth in their first season (Lund-Hoie, 1988). This, or natural regeneration from seedlings, can rapidly swamp the cleared area and newly planted trees with brushwood. Exposure of forest soil on clearance causes massive weed problems, particular on richer soils of more productive sites. With the high cost of labour, herbicides are in great demand (Lund-Hoie, 1988). Common practice after felling is to replant exposed upland areas as soon as possible which puts such plantations at particular risk of intense competition (Lund-Hoie, 1985).

Arable land used for Christmas trees is often productive and full of competitive annual weeds, whilst commercial forestry is often heavily infested with perennial grass, rush or perennial broad-leaved species.

Dense trees compete with each other producing more slender specimens and lower profits, so selective thinning is carried out leaving the best specimens to increase girth and value (Woolfenden, 1988).

Many upland forests are near water watercourses (streams, rivers, lakes) in water catchments.

Problems:

- Land infested with competitive weeds or scrub that is going to be planted with trees
- Competition from weeds, invasive plants and natural regeneration for light, moisture and nutrients
- Establishment and growth of new trees will be slow and stunted so production is lost or delayed
- Mechanical/ manual thinning of plantations is labour intensive and thus expensive and opens forest to increased risk of wind blow in upland areas
- Close proximity to water course and ponds/ lakes with need for environmental protection
- Many forested areas are open to public access for recreation so techniques must allow for this

Needs:
Economic control of tough weed species, natural regeneration/ brushwood and regrowth of cut stumps/ roots as well as thinning of established trees whilst protecting the natural environment and public access.

Alternative practices:
Mechanical clearance of weeds, scrub and Rhodendron by flailing and chain saws is only partially successful due to regrowth (Edwards, 2006). Use of weed membrane/ thick plastic sheeting to suppress weeds on new plantations is effective but expensive in materials (Willoughby & Palmer, 1998) and time and larger weed species can benefit from the retained moisture and manage to grow over and compete with planted trees. Mechanical/ manual tree thinning is labour intensive, but on exposed/ upland sites can increase the risk of wind blow (Woolfenden, 1988).

Other herbicides, notably hormones, sulfonylureas and trichlopyr are effective on broadleaved weed species but not grass species. Unfortunately these herbicides are prone to persistence and/ or to mobility in soil and are potentially harmful to aquatic life so posing a threat to the environment. Various active ingredients (e.g. atrazine, simazine and ammonium sulphamate have been banned in Europe and were replaced by herbicides such as glyphosate based products.

Fit for glyphosate:
- Excellent fit on grounds of broad-spectrum performance on grass and broad-leaved weed species (Jones, 1988) and excellent safety in or near water
- Translocated in phloem and xylem of woody species
- Pre-plant site preparation, post-planting directed sprays, and post-planting overall sprays as well as selective application by weed wipers, stem injection, 'hack and squirt' and cut stump treatments
- Degraded by micro-organisms in soil and silt
- Approved for use on or near water in some countries like UK
- Hazard free label on Roundup Pro Biactive and some other modern glyphosate products. This is very important when applied in public places and when hand-held equipment is used.

Benefits of using glyphosate:

Cost effective
Herbicides are more efficient, cost-effective and require less labour than non-chemical methods (Lund-Hoie, 1985; Willoughby, 1996). For Christmas tree growing plastic membrane can cost £950/ ha (approx. €1330/ ha) compared to herbicides costing £50-£250/ ha (approx. €70-350/ ha) (Willoughby and Palmer, 1998).

Excellent broad-spectrum weed control
Glyphosate is a very useful tool in forestry both pre- and post-plant to release trees from competition from brush and weed species (Lund-Hoie, 1985). This is the best approach for Christmas trees.

- Pre-plant (complete or spot treatment*)* and post-plant directed *g*lyphosate at 1.8-3.6g ae/ ha
  - Perennial grasses: Bent grasses (*Agrostis* spp.), *Holcus* spp., Rushes (Juncus spp.) and the tough Wavy hair grass (*Deschampsia flexuosa*) …
  - Perennial broad-leaved: Creeping thistle (*Cirsium arvense*), Rosebay willow herb (*Chamaenerion angustifolium*) and Heather (*Calluna vulgaris*) plus Common bracken (*Pteridium aquilinum*)…
  - Brushwood species: Birches (*Betula* spp.), *Prunus* spp, Elder (Sambucus spp.), Rowan (Sorbus aucuparia), Willow (Salix spp), Ash (Fraxinus spp) and Rhododendron…
  - Tree species: Larch (*Laris* spp.), Mountain and Lodge pole pines (*Pinus montana and P. contorta*)…

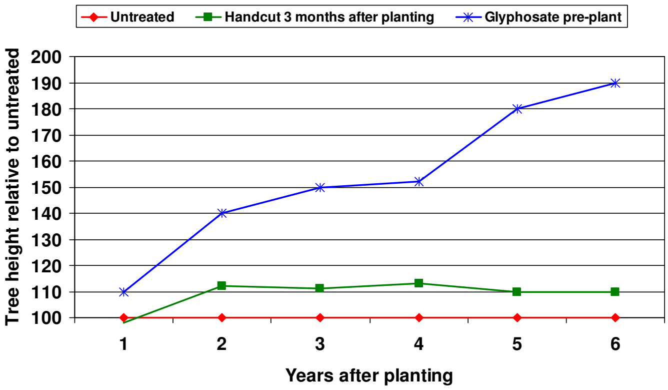
Reduced death rate of planted Norway spruce (Picea abies) from competition (Lund-Hoie, 1988)*;*

Years after planting	Vegetation management method		
	Untreated	Hand cutting	Glyphosate pre-plant
1	14%	10%	3%
2	36%	14%	6%

The competitive effects of weeds are evident in the data above. The application of glyphosate prior to planting reduced mortality in planted Norway spruce from 36% in untreated, or 14% hand weeded, to just 6% 2 years after planting. Weed control is highest pre-plant providing biggest benefit to tree growth.

Faster growth rate of Norway spruce

Removal of all vegetation, through the use of glyphosate, before planting Norway spruce dramatically boosted tree growth by ensuring trees were exposed to maximum light with minimum competition for moisture and nutrients. In these ten experiments hand weeding had relatively little effect, presumably as weeds were still competing for moisture and nutrients.



After Lund-Hoie (1988)

- Post-plant overall treatment with glyphosate at 0.36-1.08kg ae/ ha is possible due to selectivity in some conifers to control weeds and release conifers, with use rate depending on local conditions, species and approval (Lund-Hoie, 1985). Efficacy is restricted by dose rate that is selective and so is insufficient to control tougher species like Rhododendron, Heather and most brushwood scrub.

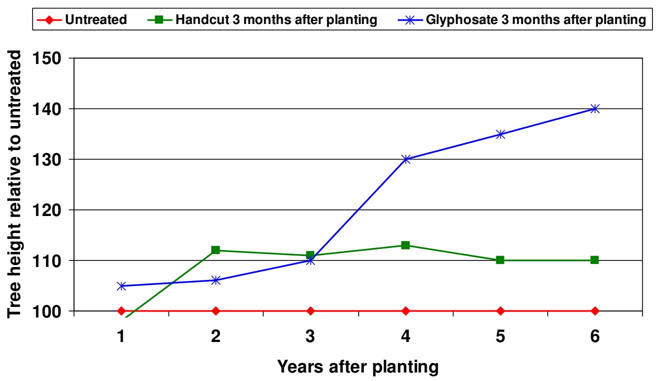
  During the winter dormant season (when needles on leaders have hardened and buds are tightly closed) glyphosate can be applied over the top of approved coniferous species used for timber production; Corsican, Lodge pole and Scots pines (*Pinus nigra*, P. *contorta* and P. *sylvestris*), Norway and Sitka spruce *(Picea abies* and P. *sitchensis*), Lawson cypress (*Chamaecyparis lawsoniana*), Western red cedar *(Thuja plicata*), Douglas and Noble firs *(Pseudotsuga* menziesii *and Abies procera*) to release them from competition (Monsanto, 2008c).

  This treatment is very useful in Christmas trees where good weed control is essential to achieve a saleable tree, but is rarely approved as many growers are non-professional the risk is too high. Although effective, timing is difficult and great care must be taken as costly damage can result. Off-label approvals have been used successfully for years by big growers (Garnett, 1988).

  Generally it is best to keep Christmas tree plantations weed free at all times firstly with a pre-plant glyphosate treatment, followed by directed post-plant applications, although it is safe to apply glyphosate overall care must be taken to avoid damage (Willoughby & Palmer, 1998; Palmer 2007).

  Trials on Norway spruce, Nordman fir and Serbian spruce showed excellent safety and efficacy up to 2.2kg ae/ ha, but damage occurred at higher doses (Garnett, 1988, Redened Research, 2001 and 2002).

  Faster growth rate of planted trees
  Control of weeds post-planting released conifers and allowed increased growth, although this effect took at least 3 years to show significant benefit. Weed control was better than hand weeding as shown by this work on Norway spruce (Lund Hoie, 1988). It should be noted the benefits were not as great as application pre-plant as trees had to compete with weeds at planting, but would be cheaper than directed post-planting treatment.



After Lund-Hoie (1988)

Nitrogen release boosts tree growth
Plants controlled by glyphosate release large quantities of organic matter. As this breaks down ammonium nitrogen and other nutrients are released into the soil, especially two years after treatment. This nitrogen boosts tree growth by 20-30% after 2 years and 50% after 5 years. Due to the acidic

nature of forest soils, and further acidification by use of glyphosate, nitrogen leaching is minimal (Lund-Hoie, 1985).

Control of noxious weeds under legislation
Glyphosate at 1.8kg ae/ ha controls weeds like Japanese knotweed and Giant Hogweed as well as thistles, docks and Common ragwort that are subject to control through legislation (Willoughby, 1996).

Removing weeds prior to planting and directed/ overall use after planting reduces competition for light nutrients and water and improves the survival and growth rate of trees.

Selective removal of invasive weeds
For the control of Japanese knotweed glyphosate can be applied neat though stem injection or by weed wipers as a 2:1 dilution (Monsanto, 2004 and 2008b; Cornwall Japanese Knotweed Forum). For the control of Rhododendron and brushwood apply a 20% solution through cut stump application or neat by stem injection (Lund-Hoie, 1988; Edwards, 2006), or to control cut brushwood as a 10% solution ideally using the Enso saw (Lund-Hoie, 1988; Monsanto, 2007). Glyphosate is translocated to control roots and prevents regrowth whilst not affecting surrounding foliage/ trees.

Control of Rhododendron and thus restricting spread of the damaging Phytophthora fungi
Glyphosate is an essential part of the management programme to control Rhododendron, the host of *Phytophthora*, by either cut stump (20% solution) or foliar treatment (at 3.6kg ae/ ha) prior to removal and burning of dead plant material under plant health regulations (Edwards, 2006; Monsanto, 2008a).

Chemical thinning of trees
Glyphosate can be applied using the 'hack and squirt technique', applying 2ml of neat product per axe cut per 10cm girth to selected trees using a spot gun fitted with a solid stream nozzle (Monsanto, 2007). Alternatively, in some countries a glyphosate - containing shell can be pushed into the tree. The chemical thinning technique is more cost effective than traditional thinning and maintains the tree canopy thus minimising the risk of wind-blow in exposed plantations or on unstable soil types (Woolfenden, 1988).

Flexibility of use;
– Non-residual so planting is possible after the minimum period of time
– As it is not absorbed through bark it can be safely used round established trees, although a guard should be used for trees of 1-3 years old as bark is green and too thin to protect from uptake
– Can even be used safely over the top of certain conifers in dormant season, so reducing application costs over hand-sprayed directed use.
– Use over or near water is approved in some countries making it cheaper and easier to apply broadcast treatments
– High levels of safety to operators, public and environment (Lund-Hoie, 1988; Monsanto, 2009).

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14 Amenity and industrial weed control

Primary benefits

- Safest most cost and time effective weed control technology option
- Broad-spectrum long-term weed control
- Flexibility of use

Introduction/ situation:
Open spaces can be rapidly colonised by weeds from wind-blown seed. Less disturbance means bigger and more numerous weeds that spread seed rapidly to neighbouring land.

Pavements, particular those with cobbles or paving stones with soil filled cracks are most at risk of weed invasion, particularly those with less foot traffic, where-as tarmac used commonly in the UK is more often weed free. Common weeds in pavements include grasses like Annual meadow grass *(Poa annua),* Procumbent pearlwort *(Sagina procumbens)*, Knotgrass *(Polygonum aviculare),* Canadian fleabane *(Conyza canadensis),* Common dandelion *(Tarax*acum *officinalis*) and Greater plantain *(Plantago major*) all weeds that produce large numbers of seeds and establish quickly and are tolerant of being walked on (Hipps*,* 2008*).* Poor site preparation when laying a pavement, leaving perennial weeds in place, leads to weed regrowth through the paving or tarmac.

Weeds rapidly colonise new plantings of ornamentals or trees on bare sites and if existing perennial weeds and grass vegetation is not cleared before planting they can severely hamper establishment.

On industrial sites, largely left undisturbed, weed vegetation can take over rapidly creating potential security, safety and fire hazards.

Problems:

- Surfaces and land infested with weeds or scrub present a hazard to public and industry
- Buildings and industrial complexes are at risk of structural damage, whilst dead dry vegetation presents a fire hazard around installations (Murphy, 2001)
- On hard surfaces weeds break up tarmac, enlarge cracks, make paths slippery or cause a trip hazard. These larger cracks encourage build up of organic matter and more weeds that impede water run-off and block drains thus increasing flooding. Large vegetation growth can block/ reduce visibility on sight lines and of signs on roads and increase the risk of accidents and can make an area look run-down/ uncared for (Kristoffersen et al, 2008)
- Weeds like Stinging nettle (*Urtica dioca*), Thistles (*Cirsium spp.*), brambles (*Rubus spp.*) and Giant Hogweed (*Heracleum mantegazzianum*) can cause injury and weed scrub can harbour vermin like rats causing a public health hazard (Murphy, 2001)
- Weeds and invasive plants compete with ornamental and tree plantings for light, moisture and nutrients
- Establishment and growth of new trees/ shrubs will be stunted affecting amenity improvement
- Mechanical and manual operations are very labour intensive and thus expensive
- Hard surfaces offer no chemical binding and thus a high risk of run-off of pesticides to water courses, pollution of surface water and increased cost of treatment to remove pesticides from drinking water
- Public access is required in many amenity areas so techniques must allow for this

Needs:
Weeds must be removed for aesthetic and safety reasons;

- to minimise fire hazard around industrial installations or buildings
- to reduce damage to hard surfaces (tarmac, and paving slabs), permeable surfaces (gravel/ aggregate/ sands/ block paving) and buildings
- to reduce maintenance costs
- to maintain good drainage to minimise flooding
- to keep up good well maintained appearance of an area

There is a legal requirement on land-owners to control invasive and noxious weeds.

The whole plant should be controlled including deep tap roots to prevent regrowth and re-treatment.

Operations must be safe with respect to the public as well as presenting a good image.

Safety to environment should be maximised and ongoing costs e.g. chemical removal from drinking water minimised.

Alternative practices:
Several residual herbicides that were used on hard surfaces have been withdrawn or restricted by the EU, these include atrazine, simazine, diuron and imazapyr.

Public concern over water pollution from the use of agrochemicals has lead to restrictions on use in Denmark, Sweden, Netherlands and Germany. In some of these countries glyphosate is the only approved herbicide for pavement weed management, but even this is restricted (Hipps, 2008). A range of alternatives have been developed in these countries including hot water, hot foam, flame, infra red and brushing techniques, but these are much more labour intensive and expensive than the use of glyphosate due to lower efficacy particularly on bigger / perennial weeds (Garnett, 1993).

New integrated systems have been developed, like SWEEP (DOB) under the Clean Region InterReg IIIC project (www.dob-verhardingen.nl) and new ultra low use rate applicators (spot spraying based on optic weed sensors, ULV, CDA and brush or roller drum system) to minimise glyphosate dose applied whilst maximising performance.

Fit for glyphosate (Monsanto 2009)

- Excellent fit on grounds of broad-spectrum performance on annual/ perennial grass and broad-leaved species (Robinson, 1985)
- Translocated to roots and shoots providing complete weed control
- Can be applied in very low water volumes saving labour, time and money
- Pre-plant site preparation to create allotments, before planting ornamentals/ grass/ trees/ mulching
- Post-planting directed sprays around amenity trees and ornamentals
- Selective treatment of invasive/ noxious weeds by weed wipers, stem injection and cut stump
- Spot treatment on pavements (plus sweeping) and hard surfaces or for planting individual trees
- Non-residual weed control along roadside kerbs and drains integrated with road sweeping
- Edge/ band spraying to create a grass mowing margin, to maintain fence lines weed free, keep weeds away from where hard surfaces meet buildings, or around industrial installations
- Certain formulations like Roundup Pro Biactive and some other modern glyphosate products are suitable for tank-mixing where approved and needed
- Binds and biodegrades in soil, non-residual, low leaching potential
- Hazard free label on Roundup Pro-Biactive and some other modern glyphosate products like Roundup Ultra make them the only approved agrochemicals in this sensitive market in some countries like Belgium (Flanders region), Netherlands and Denmark.

Benefits of using glyphosate:

Safest weed control technology
Health and Safety studies show the use of herbicides to control weeds is both safer to the operators and the public than non-chemical methods of weed control like hand-weeding, steaming or burning (Murphy, 2001). Brushing and cutting/ flailing risks throwing stones and thorns or branches. There is no need to keep the public away when spraying but there is a need to exclude the public during mechanical operations involving burning or spraying hot water/ foam/ steam due to risk of injury.

Excellent broad-spectrum weed control for many situations (Monsanto, 2009; Robinson, 1985)

- Translocated so controls even large weeds/ deep rooted weeds left by non-chemical methods
- Clearing weeds before planting trees or amenity vegetation; ornamentals/ shrubs/ trees in parks, shrubberies, street plantings & roundabouts

- Maintenance of;
    - Plant free areas on amenity and industrial sites: paths, roads, fence lines, car parks and around buildings
    - Natural surfaces not intended to bear vegetation; soil, grass path edges, open soil and around buildings and fences
    - Permeable surfaces over soil: gravel, aggregate, sand and porous parking
    - Hard surfaces: tarmac, concrete, block and crazy paving
    - Amenity trees/ woodland: post-planting weeds around newly planted trees

- Control of weeds post-planting around newly planted amenity trees/ woodland

Flexibility of use

- timing: can spray throughout the year so it is possible to spray only when really necessary
- safety: user can show choice of the safest method for the public, operators, water and the environment so fulfilling regulatory obligations
- broad-spectrum: control both annual and perennial grass and broad-leaved weeds
- inactivated on contact with soil so non-residual, no delay to planting and low risk to unsprayed areas
- selective/ spot application; avoid drains/ desirable or rare plants/ control invasive and noxious plants
- suits application through new low volume applicators: CDA at 7.5-15L/ ha (Nomix Enviro), Mankar ULV at 2L/ ha (Amenity machinery and equipment, 2008) and Mantis ULV (Lange et al, 2008) and brush and wiper systems to dramatically reduce drift, improve precision, speed and cost effectiveness and reduce water use by 90+% and chemical use by 50-80% over conventional sprayers and thus risk of run-off to watercourses.

Cost and time effective

The use of glyphosate was shown to be the most effective treatment for controlling weeds on hard surfaces as regards performance, cost and time effectiveness requiring 50% fewer treatments a year and costing 25-50% of the alternatives. The new SWEEP (DOB) programme of integrated use of glyphosate cost 6-12% more but appeared to do a similar job whilst using 35% less herbicide and cutting run-off to drains by 90% (Kempenaar & Saft, 2006; Kempenaar and Van Dijk, 2006).

Operations to achieve <5% bare ground cover by weeds & no clumps	Ranked performance (1 is best)	Relative cost/ m^2 (1 is best)	Relative time taken (1 is best)	# passes required for season long weed control
Brushing	4	3 - 4	3 – 5	4 - 6
Flame	3	2 - 4	5 – 7	4 - 5
Hot water/ hot foam	2	4	10 - 21	3 - 4
Glyphosate standard	1	1 (€0.05-0.10)	1	2 - 3
SWEEP (DOB) low	1-2?	1.06-1.12	-	2 - 3

After: Kempenaar and Saft (2006), ? = provisional data

Work in France confirmed foliar spraying to be the cheapest alternative (Marque and Chabaux, 2006). Weed control in UK is dependent on spraying with glyphosate (Hipps, 2008) where cost comparisons show glyphosate based weed control at £0.0175-0.0375/ m^2 (approx. €0.025-0.053/ m^2) versus the repair of pavements at £6.37-16.50/ m^2/ year (approx. €8.92-23.1/ m^2/ year) (Goldsworthy, 2002) and show glyphosate use is greatly cheaper than manual methods (Garnett, 1993).

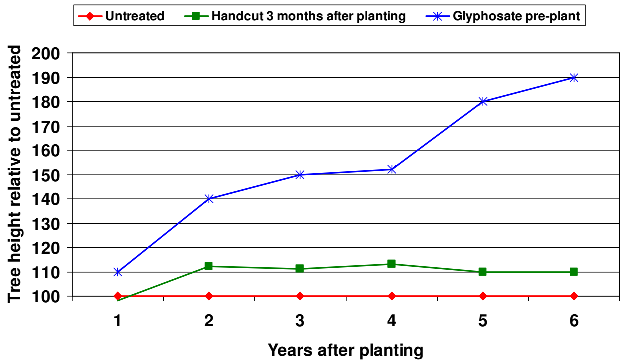
In ornamental shrub plantings a residual herbicide plus 2 glyphosate applications cost 0.065 / m^2 / year (approx. €0.09/ m^2/ year) compared to £1.14 / m^2 / year (approx. 1.6/ m^2/ year) for 4 hoeing operations to achieve similar weed control (Goldsworthy, 2002).

Tank mixable to provide extended weed control

Some formulations like Roundup Pro Biactive can be tank mixed with flazasulfuron to provide residual weed control through the season on natural and permeable surfaces over soil not intended to bear vegetation (Monsanto, 2009). This saves time by cutting the number of applications needed to keep ground weed free.

Improve establishment and growth of amenity trees/ woodland
Pre-plant preparation to clear a site of competitive weeds leads to faster growth rate of planted trees;

Removal of all vegetation, through the use of glyphosate, before planting Norway spruce dramatically boosted tree growth by ensuring trees were exposed to maximum light with minimum competition for moisture and nutrients. In these ten experiments hand weeding had relatively little effect, presumably as weeds were still competing for moisture and nutrients (Lund-Hoie, 1988).



After Lund-Hoie (1988)

Alternatively, the use of a 1 to 1.5m sprayed spot around trees in their first 5 years was found sufficient to maximise growth (Davies, 1987; Willoughby and Dewar, 1995).

Effective control of noxious and invasive weeds
Under legislation certain weeds need to be controlled including; Japanese knotweed, Giant hogweed, docks, thistles and Common ragwort *(Senecio jacobaea).* Local councils and other land owners have a legal requirement to manage such weeds to prevent them being a public nuisance. Good control is achieved through spray application of glyphosate at 1.8kg ae/ ha (Willoughby, 1996).

Selective removal of invasive weeds and stumps
For the control of Japanese knotweed glyphosate can be applied neat though stem injection or by weed wipers as a 2:1 dilution (Monsanto, 2004, 2008a and 2008b; Cornwall Japanese Knotweed Forum). Stumps of cut trees and invasive plants can be treated with a 10% solution of glyphosate when they are dormant to prevent regrowth (Monsanto, 2007, 2009). Glyphosate was shown to give best control of stumps under power lines with no regrowth compared to competitors (Darrall, 1988).

Low risk of resistance development
When glyphosate is used as part of an integrated programme with mechanical weed control methods and improved surface design the risk of resistance development is low.

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15 Railway track vegetation management

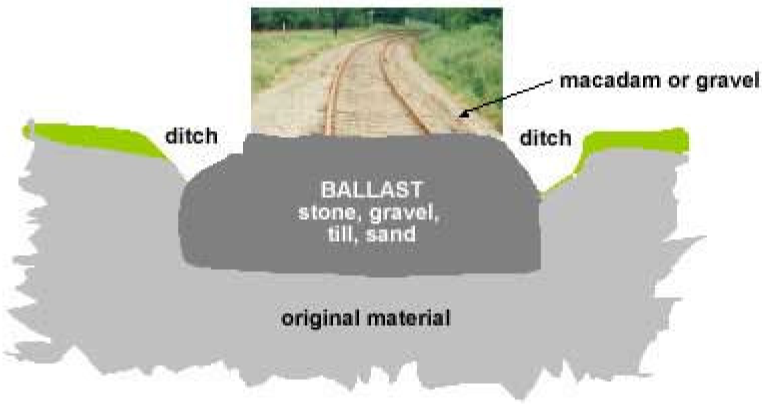
Primary benefits

- Broad-spectrum control of weeds as a 1 or 2 pass system
- Excellent safety profile
- Best weed control option (safe, flexible, fast and effective)

Introduction/ situation:

The ballast used to support the railway track whether on main lines, sidings, or marshalling yards left undisturbed can quickly be overrun by weed growth from neighbouring trackside vegetation or weeds growing from seed. Signalling, cabling and cabinets can also be affected by vegetation growth as can hard surfaces on platforms, walkways or paths to installations.

Figure x1. An intersection of a railway embankment.



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Problems:

Weeds and decaying plant material can build up on and in the ballast under the track. This can restrict drainage from the track encouraging more weeds and the retention of more water within the track bed. Excess water destabilises the ground making track movement more likely. Lying water can increase the speed of decay of wooden railway sleepers. In countries with low winter temperatures the water can freeze and swell as ice to damage the track and destabilise the whole structure (Torstensson, 2001).

Weeds can make the track and pathways slippery and growth of trailing species like Brambles (*Rubus* spp.) presents a trip hazard for railway workers thus increasing the risk of accidents (Network Rail, 2007; Conroy, 2006).

Weeds can grow across rails causing train wheels to slip thus restricting acceleration and worse increasing breaking distance for trains with consequent risk of accidents if trains fail to stop at signals or in an emergency (Torstensson, 2001).

Dead vegetation on the trackside presents a fire hazard in drier regions or summers when sparks from the metal wheels rubbing against the rails ignited plant material. Thus there is a risk of fire damaging vital signalling and communication equipment (Torstensson, 2001) as well as spreading to neighbouring land and property.

The stone ballast structure of the track, designed for good drainage and support of the sleepers and rails, means there is a low organic matter content and minimal binding of any herbicides increasing the risk of off-site movement through leaching and run-off and contamination of nearby watercourses.

Needs:

It is important for safety reasons to maintain track ballast, walkways, platforms, signalling and communication equipment free of vegetation but also protect the environment. It is vital to do this with minimum disruption to busy railway timetables and ensure the safety of railway workers.

Alternative practices:

Mechanical clearance through regular track bed tamping and changing ballast on busy lines restricts weed growth, but less so on wider tracks or less busy lines (Heeler, 1979). Cutting, although appropriate for the trackside/ banks, is not appropriate for the track itself. Manual or mechanical methods are slow, labour intensive and dangerous operations (Torstensson, 2001).

The use of flames, steam, radiation and liquid nitrogen has been tested for weed control, but the use of herbicides has been the most cost effective and reliable management technique found. Plastic membrane laid under surface ballast/ gravel to protect basal material from water can also restrict weed development (Torstensson, 2001). Use of flaming was tested in Germany but shown to be inferior for weed control to glyphosate and produced a large number of polycyclic aromatic CN compounds and aldehydes in the air (Garnett et al, 2004).

The use of certain older herbicides have now become restricted due to their long persistence (atrazine, diuron) or tendency to move off site (atrazine, diuron, imazapyr, and trichlopyr) and damage surrounding vegetation or enter watercourses. However, such herbicides both added useful residual activity and/ or broadened the spectrum to control certain weeds less susceptible to glyphosate such as Common horse tail (*Equisetum arvense)* and some woody species which is useful in certain situations.

Fit for glyphosate:

- part of an integrated programme of railway track vegetation management to ensure full control of vegetation and provide a resistance management strategy
- broad-spectrum control of most weed species including noxious and invasive weeds
- excellent safety profile: operators, wildlife, water
- can be applied rapidly by spray trains, or more slowly by weed wipers
- only controls what is treated
- translocated
- slow acting
- modern glyphosate formulations like Roundup Pro Biactive that combine improved environmental safety with improved efficacy are ideal for railway use
- largely immobile in track bed through binding to iron (Torstensson, 2004)

Benefits of using glyphosate:

Broad-spectrum and tank mixable - controls a wide range of species in one annual treatment.
Trials in continental Europe showed that glyphosate at 2.88kg ae/ ha provided 95% control and could be used as a single spray that provided excellent long-term control, whilst 2.52kg ae/ ha provided 90% control over 2-3 months so would need a re-spray (Wolińska J R, 2003). In UK a rate of 1.8kg ae/ ha provides equivalent control.

Best weed control option: Glyphosate provided excellent weed control in German railway trials compared to use of flaming and infrared weed treatment (Garnett et al, 2004);

% weed control 3 weeks after treatment on	*Soil*	*Ballast*	*Sleepers*
Glyphosate	*99*	*99*	*99*
Infrared	*6*	*8*	*8*
Flaming	*29*	*35*	*32*
% weed cover in untreated	*20*	*19*	*19*

Translocated – controls the whole plant, including roots, so minimising regrowth thus making control longer lasting and more cost effective

Control of noxious and invasive weeds under legislation
Glyphosate at 1.8kg ae/ ha controls weeds like Japanese Knotweed (*Fallopia japonica)* and Giant Hogweed (*Heracleum mantegazzianum*) as well as thistles (*Cirsium* spp.), docks (*Rumex* spp.) and Ragwort (*Senecio jacobaea*) that are subject to control through legislation (Willoughby, 1996).

Only controls what is treated – no risk of offsite damage so long as drift is controlled.

Rapid spray application – fits in with railway timetable – so minimal delays.

Slow acting – wildlife can move from treated areas unharmed (Network Rail, 2007).

Excellent safety profile – stays within track bed (Torstensson, 2001) – minimal risk of leaching (Gustin, 2000) – no contamination of neighbouring watercourses – flexible use. Products like Roundup Pro Biactive and Roundup Ultra present low risk to operators, bystanders and wildlife during and after application due to the combination of low hazard active ingredient and surfactants.

Use of glyphosate:

- UK – 85,000 litres of Roundup Pro Biactive was applied in 2005 on 17,000 track miles (ha), compared to 140,000 litres of diuron and 3,000 litres of trichlopyr (Network Rail, 2005).
- Germany – glyphosate has been sole approved herbicide since 1997 for railways since the others were found in groundwater near railways (Schweinsberg et al, 1999).
- Sweden – glyphosate is now the only approved herbicide (Cederlund, 2008) at preferred maximum rate of 1.08kg ae/ ha if a new safe mixture partner can be found.

The use of glyphosate is the responsible choice for weed control on railway tracks (Gustin, 2000).

“While the railways are doing their utmost to minimise the use of pesticides, the use of plant protection products still remains necessary to ensure the safety and efficiency of the network…” (CER Executive Director, Johannes Ludewig, 2009)

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16 Aquatic vegetation management

Primary benefits

- Broad-spectrum long-term control of emergent/ floating weeds is still possible
- Excellent safety profile and flexibility of use
- Most cost effective weed control practice
- Enables habitat management to improve water flow whilst increasing waterfowl

Introduction/ situation:

Whether in ditches, channels, streams, rivers, lakes, reservoirs, canals or wetlands or the bank side of the watercourse, management of aquatic vegetation may be required in a wide variety of situations;

• Water management	drainage, flood defence, irrigation, drinking
• Recreation and tourism on water	angling, boating, sailing, sail board, swimming etc
• Industrial uses	power generation, abstraction, effluent disposal, transport
• Food production	fish farms, harvesting vegetation for food
• Wildlife and biodiversity	wildlife conservation, meeting Biodiversity Action Plans, landscape, education
• Recreation near water	rambling, cycling, bird-watching

Problems:

Water, particularly shallow slow flowing water, provides the ideal habitat for emergent and floating aquatic plants to colonise. These plants including introduced ornamental species are very invasive growing rapidly in to produce huge volumes of biomass in a season through vegetative growth.

Such emergent and floating aquatic plants can rapidly cover open water and block water flow of ditches, canals and rivers. Restricted water flow can cause water supply problems but particularly drainage problems with consequent flooding. Siltation in slow moving water makes further flooding even more likely in future.

Such large masses of plants can prevent access to the water for pleasure/ recreation by boats/ fishing and even stop birds visiting wetland habitats. Floating masses can cause hazards for navigation and fishing

A monoculture of tall dense emergent plants can smother smaller emergent, floating or submerged species thus dramatically reducing habitat diversity reducing invertebrate and fish numbers.

Excessive plant growth often results in the partial or total deterioration of leisure, fishing and sporting activities. At this stage aquatic plants become weeds that need to be controlled on either a regular or occasional basis (Spencer-Jones and Wade, 1986).

Mankind's activities have further worsened the problem;

- soluble chemical fertilizers and disposal of sewage effluent and use of washing powders contribute nutrients to water courses that boost aquatic plant growth
- greater urbanisation, with more hard surfaces, means rain water gets to ditches quicker causing greater risk of flooding
- introduction of alien plant species like Japanese Knotweed (*Fallopia japonica*), Himalayan Balsam (*Impatiens glandulifera*) and Giant Hogweed (*Heracleum mantegazzianum*) that have a competitive advantage over indigenous plants
- recent economic downturns have meant less money is spent on clearing drainage ditches, with blockages causing flooding, so more cost-effective methods are needed

Needs:

Improve water flow in water-courses, maintain open water, and improve biodiversity, control noxious/ invasive or alien weeds. Techniques need to provide cost effective, safe, targeted, long-term integrated management of mixed emergent and floating plants. Ideally provide a balanced habitat with a mix of open water, emergent, floating and submerged species through careful management. In the UK the Environment Agency has statutory responsibility for controlling invasive weeds in/ near water as well as minimising the risk of flooding from inland waterways - the need for good weed control is obvious.

Alternative practices:

For hundreds of years man has managed aquatic plants by hand cutting, most recently by mechanical cutting and dredging. Such practices can be very destructive, creating large amounts of material for disposal and can cause ecological instability. As root systems are left intact repeated cutting is required which can be expensive in terms of both labour and machinery. Dredged material left next to the water course can re-establish and also be washed down-stream spreading the weed problem further.

There are a small number of other aquatic herbicides, mostly for control of submerged species. Those used for control of emergent/ floating species have a narrow spectrum and limited activity.

Fit for glyphosate:

- part of an integrated programme of aquatic vegetation management
- habitat management
- broad-spectrum control of emergent and floating species of mono and dicots
- no effect on submerged, mostly submerged or algal species
- excellent safety profile and activity of the Roundup Biactive formulation with improved safety to the aquatic environment; low – moderate toxicity to fish, invertebrates and green algae (Czepó, 2004)
- only controls what sprayed
- translocated
- can be applied selectively
- slow acting

Benefits of using glyphosate:

Before treatment

After treatment

- broad-spectrum control of emergent and floating species of mono and dicots (Seddon,1981; Barrett, 1985) - glyphosate controls a wider range of species in one treatment than other herbicides; fewer problems of taking out one species and leaving the niche for another invader (Barrett, 1985), more cost effective than many alternatives. Rates of 1.8kg ae/ ha were effective on broadleaved species and Flowering rush *(Butomus umbellatus),* Hard rush *(Juncus inflexus)*, Narrow leaved water plantain *(Alisma lanceolata)* and Reed sweet grass *(Glyceria maxima)*, but 2.1kg ae/ ha was needed on Common reed *(Phragmites australis) and* Common bulrush *(Typha latifolia)* in Hungary (Czepó, 2004)

- translocated – controls the whole plant, including roots, rhizomes or stolons, so minimising regrowth thus making control longer lasting and more cost effective
- can be applied in lower water volumes down to 100L/ ha on floating species or even by weed wiper at 50% solution – more cost effective application than higher volume herbicides/ uses and much more effective than mechanical weed control by cutting or dredging that often spread the problem.
- excellent safety profile – water can be used for irrigation, drinking, fishing and watering animals; minimal risk to non-target organisms when applied according to best recommended practice
- slow acting – plant material takes time to die and breakdown meaning there is little risk of deoxygenating water reducing the risk of affecting invertebrates and fish (Barrett, 1985)
- only controls what sprayed – applications can be targeted by spraying specific areas to create channels for water-flow, or swims, or treat specific noxious plants, or selectively weed wipe taller emergent plants leaving lower bank vegetation to protect against erosion (Barrett, 1985)
- targeted and phased use of glyphosate has less effect on wildlife than mechanical weed control which often involves cutting and removal of vegetation along with much of the invertebrate and vertebrate fauna (Garnett, 2008)
- habitat management with carefully targeted use of glyphosate can create a wider range of habitats, increase bio-diversity, whilst maintaining and boosting existing invertebrate and fish and birds populations and maintain a more balanced ecosystem – minimising the risk of algae and submerged plants taking over from emergent ones. All this whilst reducing the risk of flooding too.

Habitat management using glyphosate:

Although initially just used for weed control the broader refined use of glyphosate for aquatic habitat management started in the 1990's. This use is now part of planning and implementation of Local Biodiversity Action Plans under the Convention on Biological Diversity, 1992. Targets are to maintain biodiversity of inland and marine/ coastal water habitats and to manage invasive alien species.

Here are a few examples together with the benefits that were observed:

- *Clearance of dense rush to improve a fishery (Caffrey, 1996)*
  A single application of glyphosate removed obstructive stands of reeds to create clear areas and swims for three years. A large-scale trial on 3 km of a salmonid fishery clearly demonstrated the ability of glyphosate to provide long-term control of very dense Club rush (*Schoenoplectus lacustris)*

  This allowed unobstructed fishing on a previously un-fishable stretch of river.

  Scouring cleared much of the silt from the cleared areas, and more diverse vegetation was recorded. Two winters after treatment brown trout and salmon spawned on exposed gravels, and quality trout returned for the first time in 15 years.

- *Management of invasive weeds (Tweed Invasives project, Tweed Forum 2006)*
  Co-operative £382,000 (approx. €535,000) management project on the river Tweed in Scotland supplied advice, Roundup Pro Biactive, sprayers and even contractors to help landowners manage Giant Hogweed and Japanese knotweed that had grown rampantly for many years and was restricting bank side access to this well known Salmon fishery and adversely affecting the local ecology.

  Biannual treatment over an initial 3 year period along the river dramatically reduced populations of flowering plants by at least 90% thus stopping the endless cycle of seeding and further spread. The work will continue to eliminate these invasive species.

- *Increased settlement of migrant waterfowl* (Dies Jambrino and Fernández-Anero, 1997)
  Use of glyphosate to control the explosive spread of introduced Common reed (*Phragmites australis)* and other invasive weeds that were smothering native plants in the Albufera de Valencia Natural Park in Spain has resulted in increased settlement of migrant waterfowl.

- *Creation of open areas for birds on tidal areas infested with Spartina (Garnett et al., 1992)*
  Common cordgrass *(Spartina angelica)* was introduced to coastal areas primarily to prevent erosion or to reclaim grazing land, but spread rapidly. It has impoverished the botanical diversity of

colonized areas and lead to a loss of feeding areas for waders and ducks. Mechanical control was found to be difficult, time consuming and showed little success.

Trials with glyphosate by English Nature and the Royal Society for the Protection of Birds showed that Common cordgrass could be cleared for at least two years, allowing scouring of the silt in some areas and encouraging a more diverse flora in others.

- *Enhancement of the wildlife value of wetlands (*Linz *et al.*, 1996, 1999)
  Many wetlands in North Dakota are overgrown with Bulrush (*Typha latifolia*) providing habitat for crop-depredating blackbirds and impeding use by waterfowl. Thousands of hectares have been treated with glyphosate to reduce blackbird populations.

  Following removal of Bulrush many insects such as Midges (Chironomidae) and gastropods increased in numbers, while populations of other aquatic invertebrates remained unchanged. Using glyphosate to create a mosaic of open water and live and dead vegetation increased the number of ducks using the wetlands.

- *Create open channel for water flow whilst maintain bank side protection and habitat (BAA 1999)*
  Pip Barrett, the Aquatic weed control unit and Environment Agency showed how a two stage channel could be created through dense Reed by spraying glyphosate with a long reach hand lance to clear a central channel that once free of vegetation allowed fast water flow to scour out silt, leaving shallower edge for overflow and reducing the risk of flooding, improving habitat diversity where the rarer Water Crow foot (*Ranunculus aquatilis*) colonised the open channel.

- *Maintenance of drainage channels (Aquatic Weeds Research Unit, 1992-96)*
  Early season applications of glyphosate to drainage channels in May on Common reed (*Phalaris australis)*, Reed canary grass *(P. arundinacea)* and Reed sweet grass (*Glyceria maxima*) prevented further growth during the same season and reduced regrowth in subsequent years.

  The advantages of treating early in the season are that some vegetation is retained in the channel for bank protection and habitat value, while the total biomass and the consequent risk of flooding are reduced.

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17 Invasive and noxious weed control

Primary benefits

- Broad-spectrum long-term control of noxious and invasive weeds
- Remove impacts of these weeds on fisheries, other species, water flow, humans
- Most cost effective and practical weed control solution that also does not create waste

Introduction/ situation:
In the 1800's plant collectors were keen on finding new exotic and rare species that they subsequently introduced to gardens across Europe. Unfortunately some of these were very well adapted to local conditions and thrived to the extent they are now classified as invasive species. They have colonised well beyond gardens to road sides, watercourses, arable land, industrial land, waste land, hard-standings and around buildings such that they threaten drainage, building stability and damage roads and paths. These include Japanese knotweed (*Fallopia japonica),* Himalayan balsam (*Impatiens glandulifera)*, Pampas grass (*Cortaderia selloana*), Rhododendron (*Rhododendron ponticum*) and Australian swamp stonecrop *(Crassula helmsii)*.

Other weeds are such a nuisance through explosive seed spread and human/ livestock damage they are classified as noxious weeds. These include docks (*Rumex* spp.), thistles (*Cirsium* spp.) and Common ragwort (*Senecio jacobaea*) that can infest farmland from adjacent waste land (Willoughby, 1996).

A few native species in the wrong place cause huge problems for example the explosive spread of Common bracken (*Pteridium aquilinum*) in upland Britain or Rugosa rose (*Rosa rugosa*) forming dense thickets on coastal fringes of Europe (DAISIE, 2008).

Many of these species spread vegetatively (Japanese knotweed, Rhododendron, Australian swamp stonecrop, thistles and Common bracken) and/ or by seed. They are tolerant to a wide variety of conditions are often very vigorous and are thus weeds par excellence.

In many cases legislation exists to force land owners to control listed weeds.

Problems:

- Smothering native vegetation: invasive weeds are often very vigorous and form dense stands/ populations that out compete or cover native vegetation; Rugosa rose (*Rosa rugosa*), Pampas grass, Japanese knotweed, Himalayan balsam and Australian swamp stonecrop, Rhododendron and Bracken.
- Blocking drainage channels that increases flood risk; Japanese knotweed, Himalayan balsam and Australian swamp stonecrop (Environment Agency, 2007).
- Restricting access to water with dense stands of foliage; Japanese knotweed, Giant Hogweed (*Heracleum mantegazzianum*) (Tweed forum, 2006) and Rugosa rose (DAISIE, 2008)
- Damage to hard surfaces like roads and pavement, foundations of buildings and even floors by growth of Japanese knotweed (Argyll and Bute, 2009)
- Fire hazard from dead foliage and stems of Pampas grass and Japanese knotweed
- Human hazard: Common ragweed (*Ambrosia artemisiifolia*) is a potent allergen causing hay fever across continental Europe. In Italy 26% of the allergic population are allergic to pollen from Common ragweed. Giant hogweed sap is very irritating to human skin causing blistering and photo-sensitization that results in skin pigmentation that last 5-6 years. Kids think the stems make ideal 'blow-pipes' (Environment Agency, 2007), but the effects on lips and facial skin are devastating
- Obscured sight-lines on roads by large vegetation growth increases the risk of traffic accidents; Japanese knotweed, Pampas grass (DAISIE, 2008) and Rhododendron
- Litter traps caused by vegetation growth; Japanese knotweed (Argyll and Bute, 2009)
- Hazard to grazing animals; Common ragwort produces a liver toxin that causes a slow and painful death to herbivorous animals that eat it

- *Phytophthora* fungal attack on forestry trees due to spread of Rhododendron that hosts this damaging fungus
- Damage pastures and farm productivity: docks and thistles
- Invasive plants taken off site are classified as controlled waste and need a special license and approved contractor and site for disposal so costs can be very high. Japanese knotweed and Giant hogweed are classified as pollutants in the UK

Needs:
To control these invasive and noxious weeds whilst minimizing cost without creating further problems to ensure native vegetation and inhabitants are not compromised.

Many countries have obligations to preserve biodiversity after signing up to the Rio Convention on biological diversity. This states "Each contracting party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" (Convention on Biological Diversity, 1992).

To prevent flowering of the following species so as to minimize population spread and persistence as seeds can survive up to 40 years in the soil; Himalayan balsam, Japanese knotweed, Giant hogweed, Pampas grass, Common ragweed, Rhododendron, Common ragwort, thistles and docks.

Funding for major control programmes; In UK £1.5-2.6 billion (approx. €2.1billion) and £150-300 million (approx. €210-420 million) are the estimated costs of eradicating Japanese knotweed and Himalayan balsam respectively (Environment Agency, 2007). To control invasive weeds on the river Tweed in Scotland cost £300-400 million (approx. €420-560 million) (Tweed forum, 2006).

Alternative practices:

Mechanical cutting practices are not that effective for most of invasive/ noxious weed species as they often reproduce vegetatively from broken roots or stems, so the problem gets worse. However, cutting Himalayan balsam just prior to flowering in June over a period of 3 years until growth stops works well (Environment Agency, 2007) although earlier cutting promotes more flowering and seed formation.

Mechanical cutting of Giant hogweed is dangerous due to the risk of irritant sap being sprayed over operators (Environment Agency, 2007).

Cutting Common ragweed is expensive as 3-5 passes a year are needed to significantly reduce pollen levels. This slow expensive process cannot keep up with the rapid spread and flowering of this weed.

Dredging is effective, but expensive, for the control of Himalayan balsam (DAISIE, 2008) and Australian swamp stonecrop (Environment Agency, 2007). However, the Centre for Aquatic Plant management does not recommend mechanical removal of Australian swamp stonecrop as fragments left behind float downstream and create bigger problems (Newman, 2000), so glyphosate is the only treatment chemical remaining now that EU rules have meant the withdrawal of registration for diquat.

Fit for glyphosate:

- translocated so controls roots, shoots and stops flowering and seed production
- approved for use in or near water in some countries where many of the most vigorous invasive weeds colonise
- modern glyphosate products have an excellent environmental operator and public safety profile

Benefits of using glyphosate:

Control of noxious weeds under legislation
Glyphosate used at 1.8kg ae/ ha controls weeds like Japanese knotweed and Giant hogweed as well as thistles, docks and Common ragwort that are subject to control through legislation (Willoughby, 1996) and it also provides excellent control of Australian swamp stonecrop (Environment agency, 2007). Local legislation from the Commune of Milan in NW Italy forces land owners to control Common ragweed. See details below ##.

Selective removal of invasive weeds
For the control of Japanese knotweed glyphosate can be applied neat though stem injection or by weed wipers as a 2:1 dilution (Monsanto, 2004 and 2008b; Cornwall Japanese Knotweed Forum). For the control of Rhododendron and brushwood a 20% solution should be applied through cut stump application or neat by stem injection (Lund-Hoie, 1988; Edwards, 2006), or as a 10% solution using the Enso saw (Lund-Hoie, 1988; Monsanto, 2007). Injection of a 10% solution of glyphosate below the first node of Giant hogweed provides effective control (Environment Agency, 2007). Weed wipers allow the control of Bracken on upland extensive grazing whilst leaving permanent pasture to regenerate. Glyphosate is translocated to control roots and prevents regrowth whilst not affecting surrounding foliage/ trees.

Improve the survival and growth of native plants
Many invasive weeds are so vigorous they smother native plants. Mechanical cutting methods often encourage invasive weeds or remove all vegetation (dredging) or create further problems in disposal. Selective use of glyphosate controls the weed on site and can release native flora from suppression.

Control invasive weeds even in or near water
The excellent safety profile of glyphosate means it can be used to effectively control Japanese knotweed, Himalayan balsam, Giant hogweed, Bracken and Australian swamp stonecrop that grow in wet ground near watercourses. Other herbicides cannot achieve this.

Controls flowering
Correct timing of use of glyphosate to control the plant and stop growth prevents flowering and seed shed. This is vital for invasive weeds like Ragweed, Himalayan balsam and Japanese knotweed as well as noxious weeds like docks, thistles and Common ragwort that produce huge quantities of seed. Mechanical cutting only delays flowering and can even increase seed shed.

Better reduction in Common ragweed pollen and hay-fever risk
A single application of glyphosate at 500 g a.i./ ha- 720g a.i/ ha depending on the population applied before plants grow bigger than 20cm high can stop flowering and provide 97-100% control, where-as repeated cutting or cultivation only restricts flowering and pollen production and cannot be used in areas inaccessible to machines.

Control of Rhododendron and thus restricting spread of the damaging Phytophthora fungi
Glyphosate is an essential part of the management programme to control Rhododendron, the host of *Phytophthora*, by either cut stump (20% solution) or foliar treatment (at 3.6kg ae/ ha) prior to removal and burning of dead plant material under plant health regulations (Edwards, 2006; Monsanto, 2008a).

Regain access to a world famous salmon fishing river
Co-operative £382,000 (approx. €535,000) management project on the river Tweed in Scotland supplied advice, Roundup Pro Biactive, sprayers and even contractors to help landowners manage Giant Hogweed and Japanese knotweed that had grown rampantly for many years and was restricting bank side access to this well known Salmon fishery and adversely affecting the local ecology. Biannual treatment over an initial 3 year period along the river dramatically reduced populations of flowering plants by 90+% thus stopping the endless cycle of seeding and further spread. The work will continue to eliminate these invasive species (Tweed Forum, 2006).

Increased settlement of migrant waterfowl
Use of glyphosate to control the explosive spread of Common reed (*Phragmites australis)* and other invasive weeds that were smothering native plants in the Albufera de Valencia Natural Park in Spain has resulted in increased settlement of migrant waterfowl (Dies Jambrino & Fernández-Anero, 1997).

Use fewer passes and thus save time and money
To manage Ragweed with mechanical cutting takes 3-5 passes a year compared to just a single spray of glyphosate to control the weed and stop pollen production. Himalayan balsam needs 3 years cutting just before flowering, whilst control of Giant hogweed can take 5-10 years cutting with the associated operator risk and cutting only serves to spread Japanese knotweed (Environment Agency, 2007), where-as spraying can be carried out any time once a year for a few seasons.

More practical and efficient control solution
Ragweed like Japanese knotweed, Giant hogweed and Himalayan balsam often colonises places inaccessible by machines, but possible with hand sprayers, so spraying with glyphosate is a more effective solution. Mechanical operations are slower and more expensive in diesel and labour.

No waste to dispose of
Use of glyphosate controls weeds in situ without creating a waste problem that needs disposing of, or without spreading the weed further.

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18 Roundup Ready/ glyphosate tolerant crops

Primary benefits

- Flexible broad-spectrum selective control of weeds even those closely related to crop
- Encourages adoption of Conservation tillage enabling increased CO_2 sequestration
- Reduced herbicide use with fewer passes and increased gross margin

Introduction/ situation:
Most crops in the world rely on selective herbicides for weed control with the addition of inter-row cultivation and/ or hand-weeding when necessary in some beet crops or repeated cultivation before planting. Although very effective selective herbicides do have a number of issues;

- not totally selective at higher rates and in adverse weather
- weed control can be difficult with; tough species, larger weeds, dry weather
- control of closely related weeds; weed beet infests 70% of UK sugar-beet (Sweet et al, 2004)
- narrow application window
- soluble maize herbicides used at high rates on highly cultivated fields

Roundup Ready (glyphosate tolerant) crops are currently not authorised in Europe, but use of these crops is growing rapidly across the world, such that 90% of transgenic crops are glyphosate tolerant (Duke and Powles, 2008).

Problems:

- weeds can rob 34% of maize yield if left untreated (Zaragosa, 1986)
- dry weather can mean pre-emergence herbicides do not work
- need higher rates, many active ingredients mixed or used sequentially and repeatedly to control a broad range of weeds/ larger/ more difficult species
- crop damage at higher rates or in freezing or very dry weather
- expense of hand-weeding and inter-row hoeing of large or closely related weeds
- soil damage from excessive cultivation
- pollution of water courses with residual herbicides increases costs of cleaning drinking water

Needs:
Simple, cost effective, easy to use and reliable selective weed control, with minimal effect on the environment and minimal risk of development of weed resistance.

Alternative practices:

- tillage pre-plant or inter-row hoeing in crop
- conventional non-selective pre-plant herbicides and selective herbicides in crop
- glufosinate tolerant crops

Fit for glyphosate/ Roundup Ready:

- selective use of a non-selective herbicide when crop approved
- at approved timings is completely selective with no crop damage
- broad spectrum herbicide controlling annual and perennial grass and broad-leaved weeds
- translocated to roots
- tank mixable
- bound in mineral soil, readily degraded in soil and water – very low risk of leaching
- safe to environment and consumers

Benefits of using glyphosate in Roundup Ready crops:

Broad-spectrum selective weed control
Glyphosate provides excellent weed control of most annual or perennial grass and broad-leaved weeds.

Average % weed control in French maize trials (Dewar, 2009, in press)

Herbicide programme	Roundup Ready 2+2L	Conventional 0.5+0.5/ 0.5+0.5
Annual broad-leaved weeds (202 trials)	97	97
Annual grass weeds (70 trials)	95.4	81

Brookes (2003) and Kleter et al (2008) report glyphosate provided greater weed control than glufosinate or standard selective herbicides in Romania, in particular control of difficult weeds like Johnson grass (*Sorghum halepense*) that conventional herbicides struggle to control, leading to large yield increases.

Greater timing flexibility as controls larger weeds
The BRIGHT project in UK found weed control with herbicide tolerant crops, in particular glyphosate tolerant; to be more flexible as regards management and timing on larger weeds and glyphosate was better on grasses weeds and Field pansy (*Viola arvensis*) than glufosinate (Sweet et al, 2004). Trials in Denmark on Fodder beet showed more flexibility in timing of weed control as glyphosate could control large weeds with no loss in crop yield (Strandberg and Pedersen, 2008). Although glyphosate allows a wide application window, application is best made before weeds reach 10cm in crops most sensitive to competition like maize, sugar beet and soybeans (Costa, 2007; Kleter et al, 2008).

Simplified weed control (Devos, 2007; Gianessi, 2005; Cerdeira and Duke, 2006)
With Roundup Ready crops a grower would mostly need one and occasionally two active ingredients and 1-2 applications of glyphosate plus an occasional residual partner herbicide perhaps pre-emergence where there is a risk of prolonged weed germination or to minimise glyphosate weed resistance.

Compare this to normal use of conventional selective herbicides where the minimum programme is a pre-emergent and post emergent timing, which with easy to control weeds might be just 2-3 active ingredients. However, with tough weeds, or a broad spectrum, this can easily increase to 3 timings and 4-5 active ingredients and in sugar beet where crop tolerance is limited 4-5 timings and 5-6 active ingredients (Costa, 2007) requiring the services of a trained agronomist.

More reliable weed control
Teagasc noted improved weed control in sugar beet trials compared to conventional herbicide programmes (Mitchell, 2008) and Strandberg and Pedersen (2008) noted more reliable weed control in fodder beet. The UK BRIGHT project trials found better weed control in most situations compared to conventional treatments (Sweet et al, 2004). The reasons include the fact that glyphosate performance is less influenced by weather conditions and weed size, where-as pre-emergent herbicides don't work if the soil stays dry and post-emergent broadleaved herbicides won't work when weeds exceed a certain size. Tough weeds, a broad-spectrum of weeds, or weeds with common herbicide resistance require multiple passes and multiple active ingredients mixed to control them.

Control of weeds closely related to crop
Herbicide tolerant crops like Roundup Ready allow the control of weeds closely related to crops; weed beet in sugar beet and Charlock *(Sinapsis arvensis*) in Oilseed rape (Sweet et al, 2004). These weeds are expensive, if not impossible to control with selective herbicides in crop, although the use of weed wipers with glyphosate has been used to control weed beet in sugar beet.

Removes requirement for expensive mechanical/ hand-weeding in beet crops
Above a certain size weeds are no longer susceptible to post-emergence herbicides in sugar beet. Weed beet and other tough species that are difficult to control, or escape the herbicide programme, are very competitive to this valuable crop. Consequently growers would resort to expensive hand/ mechanical weeding. However, with Roundup Ready, glyphosate controls all weeds regardless of size, including weed beet, so there was no need for hand/ mechanical weeding saving 35 hours/ ha (Kleter et al, 2008). However, as part of integrated use of this technology it could be advisable to include an element of mechanical weed control to prevent the development of glyphosate resistance.

Decreased risk of crop injury leading to higher crop vigour
Devos et al (2007) comment that glyphosate tolerant crops suffer less risk of crop injury compared to conventional crops. Teagasc trials in Ireland showed higher crop vigour in glyphosate tolerant crops than conventional sugar beet due to a lack of phytotoxicity from glyphosate use (Mitchell, 2008). Due to narrow selectivity in sugar beet a low dose programme of 4-5 applications and 3-5 active ingredients is common with resultant high cost and complexity (Costa, 2007).

Same/ increased yield
Improved weed control and crop safety compared to that provided by conventional selective herbicides lead to improved crop yields in sugar beet trials, significantly so compared to 2n rates of conventional herbicides (Mitchell, 2008). Much improved weed control and reduced crop injury resulted in an average 33% increased yield in Romanian soybeans (Brookes, 2003; Brookes and Barfoot, 2006) or 3 - 3.5t/ ha

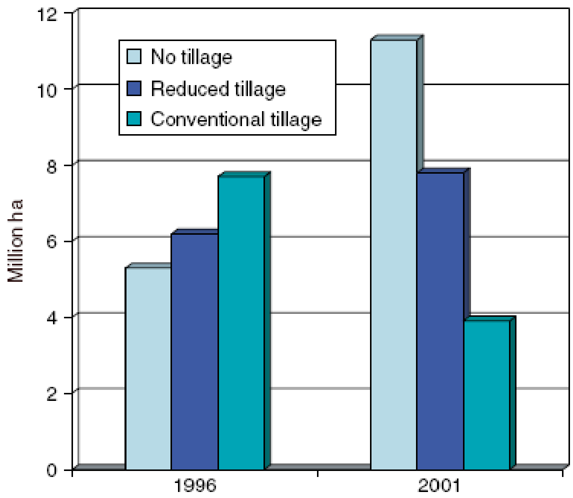
versus 2t/ ha in conventional soybeans in 2006. However, in the US, Canada or Latin America Roundup Ready crops yielded similarly to conventionally produced crops which already had good conventional weed control (Paun, Badea and Buzdugan, 2008).

Improved seed quality brings higher sale value
Most farmers in Romania found Roundup Ready soybeans commanded a 2-3% increased price due to improved quality from lower weed admixture (Brookes, 2003).

Allows development of early weed flora to support insects and birds
As glyphosate can be applied to larger weeds and still achieve full control, spray timing can be adjusted to allow weed growth early in a crops life to support arthropods and birds and still control weeds before irreversible weed competition reduces yield in crops like sugar-beet (Baylis, 2000). Trials in Denmark showed a 10-fold increase in weed biomass and arthropod numbers just prior to delayed glyphosate treatment, 48 days after conventional herbicides, with no loss in fodder beet yield and the increase in arthropods remained after treatment. Where-as a shorter delay increased initial numbers, but these were not maintained after treatment. Such an increase was likely to benefit insectivorous birds (Strandberg and Pedersen, 2002). UK farm scale trials measured increased invertebrates including ground dwelling detritivores, herbivores and seed eating beetles due to increase seeding of dicots and early weed volume (Hawes et al, 2003).

Greater adoption of CA and less tillage
The ease and reliability of use of Roundup Ready crops means tillage is no longer needed for weed control and can be significantly reduced (Dill, Cajacob and Padgette, 2008).

The chart shows the change in tillage use from 1996 to 2001 for US soybeans with increased adoption of various forms of conservation agriculture like reduced tillage and no-tillage as growers adopted Roundup Ready. Conservation agriculture results in reduced soil erosion, increased carbon sequestration, increased biological activity of the soil, increased moisture conservation, reduced tractor and fuel use and reduced compaction (Devos et al, 2007).



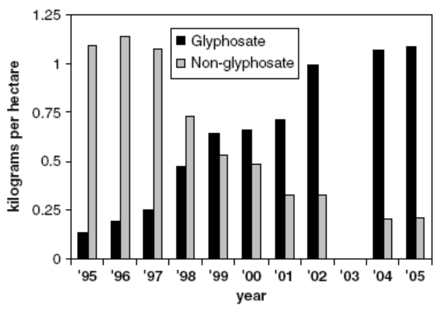
(Duke and Powles, 2008)

As part of an integrated weed management strategy to reduce the risk of weed resistance to glyphosate it is becoming important to include tillage as an additional weed control measure on a rotational basis when growing Roundup Ready crops (Duke and Powles, 2008).

Reduced $C0_2$ emissions and greater sequestration
Use of Roundup Ready requires less herbicide and fewer applications and so produces less $C0_2$ and through increased adoption of conservation agriculture there is more CO_2 sequestration into soil organic carbon. In 2005 it was estimated that glyphosate resistant crops had reduced carbon emissions and sequestered carbon equivalent to taking 4 million cars off the road (Brookes and Barfoot, 2006).

Tank-mixable if needed
Tank mixing can be useful to extend the weed spectrum and period of protection against weeds thus decreasing the number of applications whilst protecting yield (Dewar, 2009 in press). Tank-mixing glyphosate and a soil residual for application in soybeans to extend the spectrum and protect against repeated weed germinations saves an application pass, saving 1.3-1.8L diesel/ ha (Costa, 2007).

Reduce use of prophylactic pre-emergence herbicides
Use of glyphosate in Roundup Ready crops avoids the prophylactic use of pre-emergence soil residual herbicides (Baylis, 2000). In sugar beet, there was no benefit to applying a pre-emergence residual before glyphosate;



instead it was better to just apply glyphosate earlier if weed pressure dictated (Sweet et al, 2004).

Herbicide use in US soybeans shows the clear impact of adoption of Roundup Ready by growers in 89% of the crop bringing increased use of glyphosate for weed control and a corresponding decrease in use of conventional selective pre- and post-emergence herbicides (Kleter et al, 2007). Residual herbicides commonly used in maize and soybean are often detected in watercourses increasing the cost of drinking water treatment (Scientist Live, 2008).

Lower rates of active use and fewer herbicide applications
In the UK BRIGHT project the total amount of active ingredient used in weed control in sugar beet was reduced and trials showed that herbicide tolerant weed control required fewer passes on average; 1 pass in oilseed rape compared to 1 - 2 passes required for conventional herbicides or glufosinate; 1.3 passes in sugar beet compared to the usual 2.7 passes (Sweet et al, 2004).

In UK farm scale trials total herbicide use (kg ai/ ha) was reduced 36% in sugar beet, 42% in fodder beet, 42% in maize and 3% in oilseed rape (Hawes et al, 2003; Squire et al, 2005). The rates and use of conventional pre-emergence selective herbicides are reduced and post-emergence selective herbicides replaced by glyphosate use (Devos et al, 2007). Commercial experience in US showed a 20% drop in total active use in Roundup Ready soybean, 30% drop in Roundup Ready Oilseed rape and 33% drop in Roundup Ready maize (Kleter et al, 2007). In Romania Roundup Ready soybeans needed an average of 1.9 sprays applications compared to 4.3 in conventional crops (Paun, Badea and Buzdugan, 2008).

Lower fuel and energy use to apply herbicides
In Spain spraying a herbicide uses 1.3 - 1.8L diesel/ ha compared to 32.7 - 39.5L/ ha for intense tilling (IDAE, 2006), bringing an overall energy saving of 7-15% if energy used in herbicide manufacture is included (Hernánz, 1995).

Decreased financial costs of weed control
In Romanian soybeans growers using full rates have seen an average €61.5/ ha or 29% reduction in variable costs on farms up to 5,000 ha and €44.4/ ha or 28% on larger farms (Brookes, 2003).

In Irish sugar beet conventional low dose programmes can cost £125-200/ ha (approx. €175-280) depending on weed spectrum, making up 15% of sugar beet production costs. However, a glyphosate programme including technology fee might cost just £30-50/ ha (approx. €42-70) (Mitchell, 2008).

The UK BRIGHT project found the cost of weed control in sugar-beet and oilseed rape was reduced by £20-30/ ha (approx. €28-42) through use of herbicide tolerant crops compared to conventional production, and use of tolerant crops allowed control of closely related weeds thus cutting out the need for costly hand weeding or mechanical hoeing (Sweet et al, 2004). Roundup Ready removes the need for hand weeding sugar beet saving 35 hours/ ha (Kleter et al, 2008).

Increased gross margin (GM)
Although few studies have gone this far, commercial use of Roundup Ready Soybeans in Romania showed a 127% and 185% increase in GM on large and small farms respectively with certified seed that came from a 29% saving in herbicide costs and 33% increase in yield (Brookes, 2003).

Increased crop value
The value of Romanian soybeans increased 14-19%, by €8.23 – €8.62m, in 2003-3 (Brookes, 2003).

Reduced herbicide loss and concentration in water courses so reduced water purification costs
Use of glyphosate tolerant soybeans dramatically reduced herbicide loss to water over a 4 year period, such that glyphosate loss was 14% the level of metribuzin and 50% that of alachlor, two residual herbicides it would replace. The maximum concentration of glyphosate never exceeded the drinking water limits where-as conventional herbicides regularly did (Scientist Live, 2008).

Lower environmental risk and more environmentally benign
Glyphosate has an excellent safety profile (Costa, 2007). A review of the environmental impact of Roundup Ready compared to conventionally produced crops of oilseed rape, maize, cotton and soybeans showed a 39-59% drop in the total environmental impact in 2004 (Kleter et al, 2007).

Roundup Ready technology has been found to be more environmentally benign than alternative chemical and mechanical weed control techniques; less injurious to soil than intensive tillage, glyphosate is safer than conventional herbicides and less likely to move to water and to persist in water than other herbicides (Duke and Powles, 2008).

Use of glyphosate:
90% of the world's transgenic crops are tolerant to glyphosate and the adoption of these crops is increasing rapidly (Duke and Powles, 2008) as they offer low cost, simplified, more flexible and selective weed management options (Gianessi, 2005; Cerdeira and Duke, 2006).

"Glyphosate has become the world's most widely used herbicide because it is efficacious, economical and environmentally benign" (Powles, 2008).

Roundup Ready should be used as part of an integrated programme to minimise the risk of resistance development and maximise weed control benefits. Such a programme should include diverse methods such as crop rotation, sequences and mixture of herbicides, use of robust rates and different modes of action as well as mechanical controls (Powles, 2008).

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19 Annex 1: Overview of registered uses of glyphosate by European country

Usage situation by country	Belarus	Belgium and Luxemburg	Bulgaria	Czech Republic	Denmark	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Kazakhstan	Netherland	Norway	Poland	Portugal	Romania	Russia	Slovakia	Spain	Sweden	Switzerland	Turkey	UK	Ukraine
Pre-plant	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
Pre-emergence / Post plant	Y	Y	Y		Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y			Y	Y		Y	Y
Pre-Harvest (cereals / other crops)	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y		Y	Y	Y		Y			Y	Y
Harvest aid / Desiccation	Y	Y	Y	Y	Y			Y		Y	Y		Y	Y	Y	Y		Y	Y		Y	Y			Y	Y
Post-Harvest / Stubble	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Vines / Orchards / Olives	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Grassland renewal	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
Set-aside		Y				Y	Y	Y		Y	Y	Y		Y		Y	Y	Y			Y	Y	Y	Y	Y	
Forestry / Christmas tree	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	
Crop inter-row		Y				Y	Y	Y	Y			Y		Y			Y	Y			Y		Y			
Railway / Amenity / Non crop use	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Aquatic use / Water ditches	Y			Y					Y		Y		Y						Y	Y	Y				Y	

Note: 'Y' indicates the use is registered in that country, but there will be specific restrictions by formulation, crop/ use, dose rate and timing