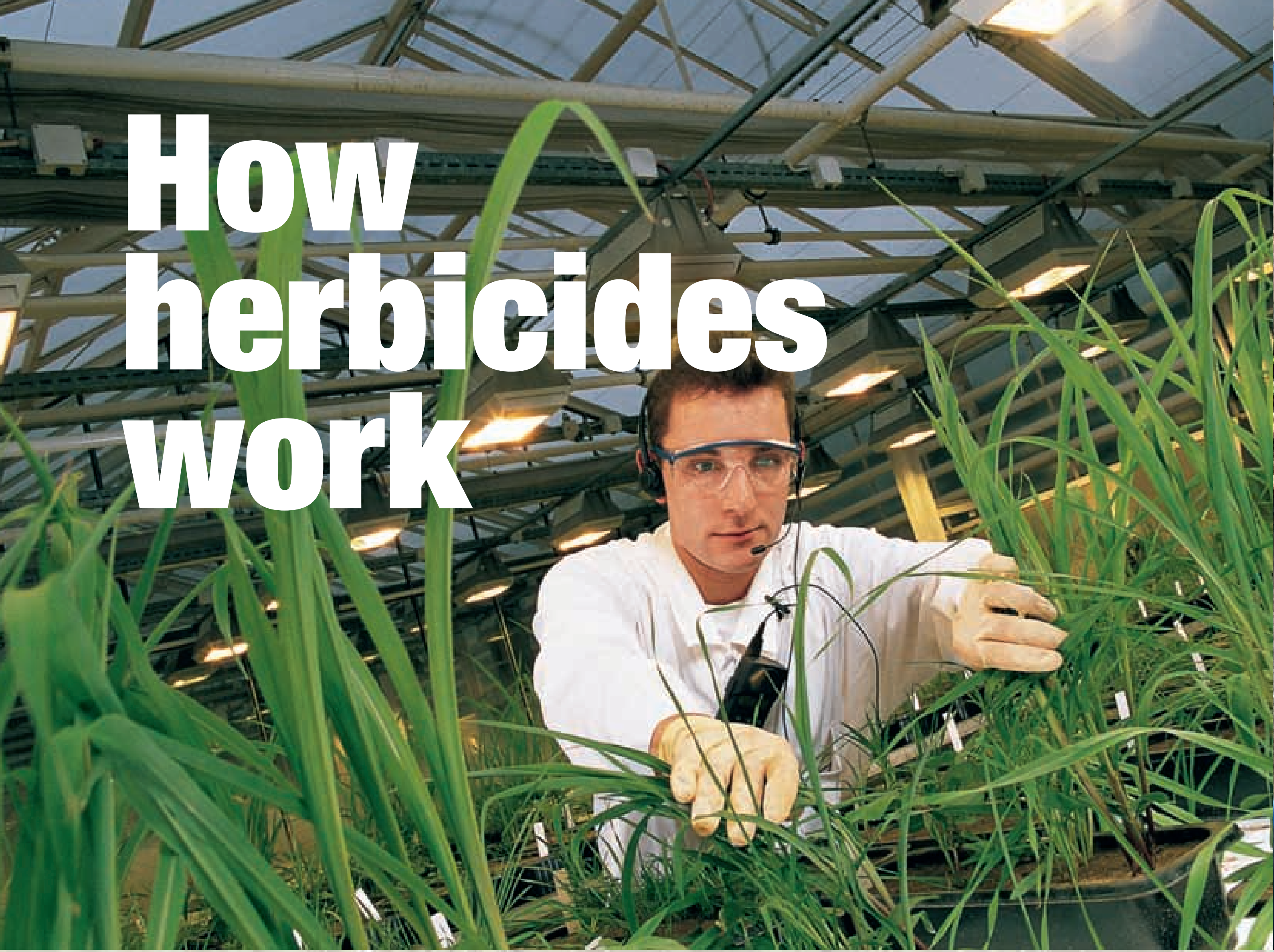
How herbicides work



The effects of crop protection agents are tested in the greenhouse.

Without the means to control weeds, neither the required yield nor the desired quality of the products deriving from a crop can be guaranteed. Under most circumstances, herbicides are the cheapest and most reliable form of weed control. However, they should be used only after other, cultural options for weed control have been considered and put into practice.

In order to avoid the problems that arise if an active substance is over-used, it is necessary to select a rotation in which herbicides with different modes of action can be applied. Knowledge of the mode of action of herbicides can help towards developing a successful strategy for controlling weeds.

How are herbicides taken up by the plant?

In order to be effective, herbicides must be able to move from the spray deposit (foliar herbicides) or the soil solution (soil herbicides) into the plant. Products are classified as contact or systemically-active herbicides, depending on the extent and nature of uptake, redistribution and activity within the plant.

1. Foliar herbicides

The contact herbicides belong to this group. They penetrate into the plant exclusively or predominantly via the leaf, and are then redistributed only to a limited extent. They therefore cause damage to the weed plant at, or near, the point of penetration. This means that contact herbicides tend to be effective mainly against species that lack stored reserves, such as annual weeds.

The uptake of systemic foliar herbicides occurs mainly via the leaf, and is followed by extensive redistribution within the plant. The best-known examples are the growth substances, which interfere with the balance of growth hormones in the plant. Most grass herbicides and bindweed products also work via the leaf.

Foliar herbicides are redistributed in the plant mainly via the transpiration stream that flows through the plant's vascular bundles. The assimilates produced by photosynthesis in a particular leaf are only exported if it is producing more than it needs for growth and respiration within its own tissues. The greatest export of assimilates occurs in fully developed, photosynthetically-active leaves when weather conditions are optimal. Young, still-developing leaves do not export sugars – and herbicides applied to them are not re-distributed to any extent. Temperature is important for herbicide efficacy: at temperatures below 10°C, activity is usually low; whereas at temperatures greater than 25°C, there may be scorching of the crop plant, or reduced activity against the target species.

Special additives protect crop plants against the effects of herbicides. These are called „safeners“. Bayer CropScience is recognized as one of the world leaders in this technology.

2. Soil herbicides
The uptake of these active substances occurs via the roots, and is followed by re-distribution within the plant. The herbicides tend to be active in the leaves, or other above-ground parts of the plant, where they disrupt respiration processes and photosynthesis. The active substances reach the soil through the medium of water, and can remain there for some time. Soil herbicides should therefore only be applied to moist soils: under dry conditions, these products may lose their activity altogether. Soil herbicides play an important role in the control of weed grasses and dicotyledons during the pre-seeding and pre-emergence periods, or sometimes in the early post-emergence period. Examples include active substances such as metazachlor in oilseed rape and flufenacet (in Cadou®) in cereals.

3. Foliar and soil herbicides
Some herbicides are active via both the leaf and the soil. Examples include the ALS-inhibitors, e.g. Atlantis® and Husar®. The relative degree of uptake via leaves and roots of products within this category of herbicides determines the timing of application – whether pre-emergence, early post-emergence or from the 3-leaf stage onwards. Combined foliar and root uptake can be achieved using a mixture of active substances: a typical example of this type of mixture is the sugar beet herbicide Betanal® Expert.

4. Safeners
Safeners are herbicide additives that accelerate the breakdown of the active substance within the crop plant. In contrast, they do not interfere with the intended action within target grass weeds, which apparently possess different variants of the relevant target enzymes. The product Atlantis, for example, has excellent activity against grasses. It would not be possible to use Atlantis in cereals – which, strictly speaking, are also grasses – if the product didn’t contain a safener. The safener activates an enzyme in cereals that accelerates the breakdown of the active substance, thus making the cereal plant insensitive to it. The secret is that the safener does not activate the corresponding enzyme in weed grasses – they remain sensitive and are killed off.

Mode of action

The mode of action describes the way in which physiological processes within the plant are influenced by the herbicide. In most cases, the active substance binds to a protein, thereby blocking one of the plant’s essential metabolic processes. The protein is usually an enzyme that regulates a particular biochemical reaction within the metabolic chain. However, the inhibition can also take place at structural and regulatory binding sites. Herbicides tend to possess a single main mode of action, but many also have secondary sites of action at which they can also disturb the plant's metabolism.

Herbicides are classified into different groups according to their main site of action within the plant's metabolism. Here is a list of the various modes of action:

- Photosynthesis inhibitors
- Pigment synthesis inhibitors
- Amino acid synthesis inhibitors
- Fatty acid synthesis inhibitors
- Cell division inhibitors

Photosynthesis is among the plant's most central metabolic processes, and is thus a particularly suitable target for herbicidal action. Photosynthesis inhibitors can disrupt the electron transport system of Photosystem II, or they can inhibit the formation of radicals in Photosystem I. Both have fatal consequences for the target weed, the cells of which are no longer able to store the energy derived from light.

Herbicides can also disrupt photosynthesis indirectly, by inhibiting the synthesis of compounds that are important to it – pigments such as carotenoids, chlorophylls and cytochromes. The carotenoids, for example, have a protective function within photosynthesis, and it is this very function that is shut off by herbicides. Products possessing this property include soil and foliar herbicides that can be used at an early development stage in autumn or spring against both mono- and dicotyledons (e.g. Mikado®).

Among the most well-known herbicides are those that inhibit the synthesis of amino acids and thus disrupt the production of proteins, including enzymes. Here, three important target enzymes can be affected: glutamine synthetases (target of glufosinate in Basta®), 5-EPSPS-Synthase (target of glyphosate) and acetolactate-synthase (target of ALS-inhibitors). The latter enzyme is the target of action for sulfonylureas and the imidazolinones. With Husar, Atlantis und Maister®, the Bayer CropScience portfolio has some well-proven herbicides from this class.

Fatty acid metabolism is important to the process of cell membrane formation. Disturbance of this process through the action of a herbicide leads to the development of a thinner cuticle, and thus to a disruption of water uptake: this type of action is characteristic of FOPs (e.g. Puma® Super) and DIMs. But compounds from other groups can attack fatty acid metabolism too: another example is ethofumesate (Betanal® Expert).

Other herbicides act like plant hormones (auxin herbicides) and set off uncontrolled cell growth. This is why the term growth substances is also applied to representatives of this group. Examples include the phenoxyacetic acids such as the well-known MCPA-, MCPP-P- and 2,4-D compounds.

The process of cell division is vitally important. Some herbicides inhibit the system that regulates cell division – the microtubule system – such that cells can develop with several nuclei or too many chloroplasts. The grass herbicide flufenacet belongs to the group of substances that prevent cell division in plant tissues.

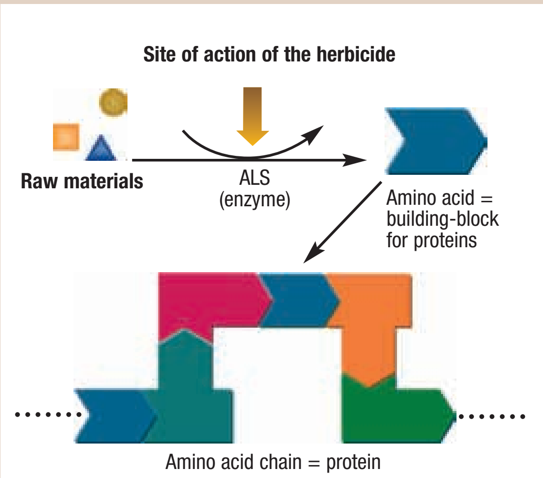
Decision criteria

Herbicides should be applied according to the principles of Good Agricultural Practice and Integrated Crop Protection. This means that local conditions, rotation, and possible cultural methods should all be considered when developing a strategy for controlling weeds. Rotation is particularly important, and it has a direct influence on soil cultivation, the incidence of weeds and the ability of a crop to compete with them, and it determines the spectrum of herbicides that is available for weed control.

Modes of action of herbicides

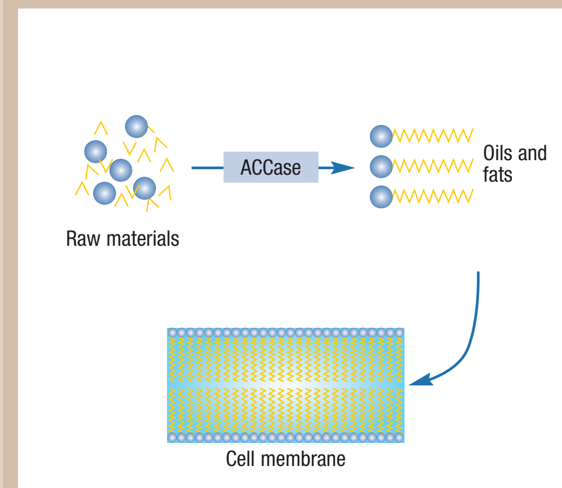
Inhibition of amino acid synthesis

Product examples:
Alister, Atlantis, Attribut, Basta, Husar, Maister



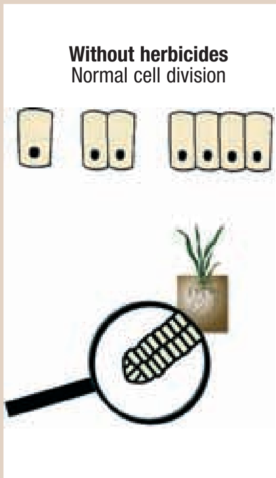
Inhibition of fatty acid synthesis

Product examples:
Betanal Expert, Puma Super



Inhibition of cell di

Product examples:
Cadou, Husky



If herbicide use becomes necessary, the first step towards choosing the most suitable product is to determine which weed species are present – or are likely to appear – and the current and anticipated density of infestation. The prevalent weed flora and the known thresholds of action determine the choice of the best herbicide, based on its spectrum of activity.

The efficacy of a product and the overall success of weed control are influenced by a number of factors, including the growth conditions, the timing and rate of application, the technology used to apply, and other, local circumstances. If all of these factors are considered together, then the product's full potential can be realised. But economic factors also play a role in the decision-making process. Depending on the situation on the farm and the number and types of different crops grown, early treatment of cereals can help to avoid work peaks later in the season. The decision as to whether to treat pre-sowing, or pre- or post-emergence, influences both the choice of herbicide, and the work-regime throughout the season.

Resistance

Limiting the rotation to one or two crops, and intensive use of herbicides with identical or similar modes of action, favour the development of resistance in weeds. Shifts within the weed population always start with single, resistant individual plants – these are universally present in nature. The repeated use of herbicides with a common mode of action creates a selection pressure that promotes the spread within the population of plants possessing the resistance characteristics. Unless the control strategy is changed, these resistant weeds can spread such that they eventually gain the upper hand, and can no longer be controlled effectively.

Thus to be on the safe side, resistance management should be considered in advance, whilst planning which crop to grow. The key to active substance rotation is to design the rotation so that the same mode of action is not used twice in successive crops. ■

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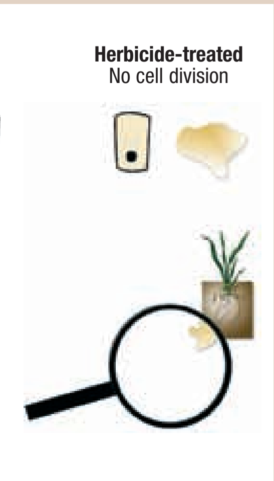
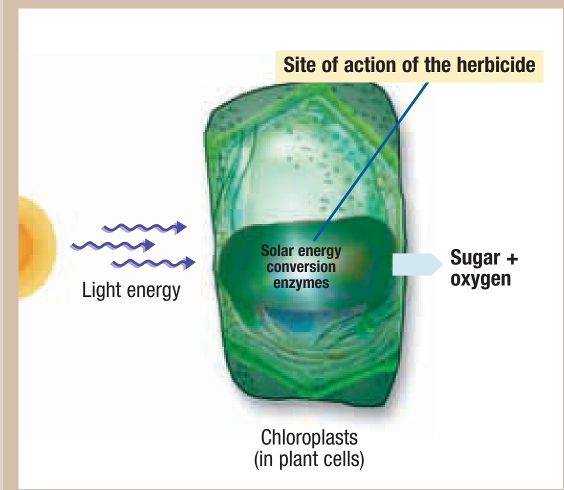


Inhibition of photosynthesis

Product examples:
Betanal Expert, Betanal Quattro, Sencor



Inhibition of pigment synthesis

Product examples:
Alister, Husky, Laudis, Mikado