SYNERGIES OF CONSERVATION AGRICULTURE IN WEED CONTROL

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ABOUT AEACSV

The Spanish Association of Soil Conservation Agriculture (AEACSV) is a non-profit association founded in 1995, independent from other organizations or groups and commercial brands. It is open to any natural person (farmers, technicians, scientists, government staff) or legal person (companies, public bodies) who is interested in conservation agriculture and the conservation and improvement of agricultural soils and their biodiversity in a sustainable agricultural context.

The aims of the AEACSV are

• To promote information for farmers, agricultural technicians and society in general on techniques that make it possible to conserve agricultural soil and its biodiversity in the context of sustainable agriculture.
• To promote the development, teaching and research of any aspect related to conservation agriculture / biodiversity of agricultural soil.

DISCLAIMER

This study has been co-financed by AEACSV and Bayer. The authors state that the research was conducted independently. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the report or in the decision to publish the results.
Since the beginning of agriculture, one of the key factors for the success of the crops has been the control of the so-called “weeds”, which are nothing more than unwanted plants growing spontaneously on the land. They are characterized by their high dispersion capacity, great persistence and by being very competitive with the crop stealing its water, light and soil nutrients.

For decades, this control has depended on an intensive use of tillage, in relation to the primary tasks and those associated with the preparation of the seedbed and the work between the rows. The appearance of hormonal herbicides in the 40s and, subsequently, of a wide range of selective herbicides, allowed us to eliminate most of the mechanical and manual weeding techniques. The introduction of paraquat in the 50s and, subsequently, glyphosate and glufosinate in the 70s, have allowed to completely or partially eliminate the primary tasks and the preparation of the seedbed, encouraging soil management systems such as Conservation Agriculture (CA), where no-tillage technique in herbaceous crops and groundcovers in woody crops is mostly used.

The change of paradigm that CA implies in land management systems and the application of the three fundamental principles on which its practice is based, such as the suppression of tillage, the maintenance of groundcovers and rotation and/or diversification of crops, in addition to a series of environmental, economic and social benefits, represent a method of weed control.

Even so, CA faces significant challenges with respect to weeds and their control. The change in philosophy that involves no-tillage or groundcovers affects the population dynamics of the adventitious flora and its interaction with crops. Therefore, the use of plant protection products in CA continues to be a necessary tool to control weeds and numerous studies show how, in addition, the environmental benefits provided by these practices allow an optimization in the use of these products.

**Conservation Agriculture: Fundamental principles**

According to the FAO, CA includes a series of techniques whose main objective is to conserve, improve and make more efficient the use of natural resources, through integrated management of soil, water, biological agents and external inputs. The fundamental principles on which CA is based, and which are universally applicable to all agricultural areas and land uses, always adapted to local conditions, are:

- Suppression of soil tillage operations.
- Maintenance of groundcovers throughout the year, occupying at least 30% of its surface.
- Plan of rotations or diversification of crops in annual crops.

CA will report benefits on the agricultural ecosystem, if the three principles are applied jointly and not separately. With the application of these principles, CA improves biodiversity and natural biological processes above and below the soil surface, which contributes to greater efficiency in the use of water and nutrients and to an improved and sustained agricultural production.
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**Importance of weed control in Conservation Agriculture**

Integration of Conservation Agriculture principles as a strategy to control weeds

The implementation of the CA systems, including the three basic principles of their application, supposes that a series of modifications of the physic chemical properties of the soils takes place, varying the conditions in which the weeds develop with respect to the conventional tillage. These modifications have an impact on the population dynamics of the adventitious flora, having repercussions in many cases, in its greater control (Table 1).

**Tilling suppression**

The most notable effect produced by the suppression of tillage on the population dynamics of weeds, is the distribution of seeds in depth, leading to an accumulation of them in the upper layer of the soil. This accumulation of seeds in the superficial horizon of the soil, increases the probability of germination, causing greater density of weeds in the first years of adoption of no-tillage techniques, although it can probably decrease over the years, as a consequence of its greater exposure to predation and meteorological variability. In relation to the diversity and type of weeds present in the seed bank, the results obtained showed a reduction in the diversity of weed species in soils under CA and a transition of the weed population towards perennial species.

In any case, the suppression of tillage in crops management, rather than controlling weeds present in the seed bank, produces a displacement of arvense flora, which only corroborates the importance that must have the control of mentioned flora in these systems, having to face a new situation after the change from a system based on tillage.

**Groundcovers**

The presence of groundcovers is another element that affects the population dynamics of weeds present in the soil seed bank. Thus, the groundcovers do not allow light to arrive in the place where seeds and seedlings cohabit in their first stages of growth and they reduce the maximum daily temperature of the soil. Since most weeds and crops require light and soil temperatures above a certain threshold to germinate; the presence of groundcovers delays and reduces the rate of germination. On the other hand, in a soil covered by plant remains, soil moisture is better preserved, favoring the germination of seeds in semi-arid zones.

Plant remains present on the surface of the soil also cause allelopathic effects, having a special incidence on small seeds. Therefore, the allelopathic activity of plant remains has been demonstrated mainly in laboratory and, although the results of these studies are not easily conducted in the field, there are studies that show that allelopathy reduces the appearance of weeds in the field.

**Crops rotation**

Crop rotations control weeds better and more effectively than any other principle in CA. The different crops that are part of a rotation and

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**Table 1. Effects of each of the principles of CA on weeds.**

<table>
<thead>
<tr>
<th>Effect on weeds</th>
<th>Tilling suppression</th>
<th>Groundcovers</th>
<th>Crop rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed bank size</td>
<td>Without conclusive results.</td>
<td>Reduced.</td>
<td>Reduced.</td>
</tr>
<tr>
<td>Vertical distribution of seeds</td>
<td>Accumulation on the surface horizon.</td>
<td>No effects.</td>
<td>No effects.</td>
</tr>
<tr>
<td>Seed germination</td>
<td>Greater in the first years.</td>
<td>It is reduced, although in semi-arid areas it can be increased.</td>
<td>Reduced.</td>
</tr>
<tr>
<td>Seed predation</td>
<td>Increased.</td>
<td>Increased.</td>
<td>Without conclusive results.</td>
</tr>
<tr>
<td>Growth and establishment</td>
<td>Reduced.</td>
<td>Reduced.</td>
<td>Reduced.</td>
</tr>
<tr>
<td>Seed dispersion</td>
<td>Reduced.</td>
<td>Reduced.</td>
<td>Reduced.</td>
</tr>
<tr>
<td>Seeds composition and diversity</td>
<td>Greater predominance of perennial species.</td>
<td>No effects.</td>
<td>Increased.</td>
</tr>
</tbody>
</table>
their different agronomic management, subject the weeds to many and varied types of pressures that hinder their development. Thus, the fact of having crops that explore different depths of soil to obtain water and nutrients, with different growth patterns, use of herbicides of different spectrum and action methods, as well as, in some cases, segregation of allelopathic substances, favor the control of weeds. It has been shown that in four or more years long crop rotations, the use of herbicides in conventional agriculture as well as in CA is highly optimized. In addition, crop rotation, by promoting a greater composition and variety of weeds, leads to a variation in herbicide programs, which helps to reduce the risk of development of resistances because of weeds.

**Sustainable use of herbicides in Conservation Agriculture**

Generally, the use of herbicides in annual crops under CA does not have to be greater than in conventional tillage, thanks to the control exercised by the three principles on which the implementation of this management system is based. To give an example of what this would represent in the typical crops of a rotation under the Mediterranean climate, between the harvest of a sunflower crop and the planting of a wheat or rapeseed crop, it may be necessary to apply a single non-residual herbicidal treatment, except in the case of autumns with early and very rainy precipitations. In the same way, between winter cereal harvesting and sunflower planting, 2 to 3 non-residual herbicidal treatments are usually needed, although the possibility of early sowing would reduce the number of treatments.

Among the products used in the pre-seeding period of the crop, glyphosate alone or in a mixture with other types of herbicides, such as hormonal ones, is the most common choice among farmers. Glyphosate controls many of the weeds in the fields under CA and does not leave residues on the soil that could impede or delay sowing. The low toxicological profile of this active substance, its excellent control of weeds and its wide availability in numerous brands of many companies, since its patent expired in the year 2000, makes the treatments with this base inexpensive and widely spread, therefore it is highly recommended product to control weeds.

An interesting perspective regarding the management of herbicides in CA is offered by the economic section. A vast majority of the farmers...
decision to change from a management system based on tillage to CA in order to reduce expenses. The economic saving produced by the suppression of the works on the field, compensates for the increased costs of herbicides and their applications, what are the common activities during the first year of CA. Taking as an example a wheat crop and taking into account only the preparation operations of the sowing bed, which are the ones that basically make the difference between a management system based on tillage and no-tillage, show the savings of € 12.96/ha, or in other words 68% savings using no-till techniques.

Conservation Agriculture, herbicides and the environment

In the scientific literature there are numerous studies that study how the management system affects the behavior of herbicides once they enter the soil, without obtaining truly conclusive results in this regard. Most of them confirm that this behavior depends on many more factors than the soil management system itself, with other variables such as the physicochemical properties of the soil, the meteorological conditions and the intrinsic characteristics of the used herbicide.

Thus, and as regards the soil, parameters such as the amount of OM, pH, cation exchange capacity, texture and soil structure, among others, determine the behavior of the movement of herbicides in the edaphic profile, conditioning its concentration in the soil solution and in its solid phase and, therefore, its transport through infiltrated water and runoff water. In one way or another, the CA, which is the management system that directly affects the soil, influences all these parameters, favoring in some cases the processes that reduce the concentration and loss of herbicide in water, and in others, favoring the processes that motivate greater mobility of the herbicide through the edaphic profile, resulting in higher concentrations in groundwater. Thus, the increase in OM, provoked by the adoption of CA, increases the capacity of adsorption of herbicides by soil and microbial activity, which results in greater degradation of the herbicide and in a reduction of leachate and pollution in groundwater. On the other hand, the improvement of soil structure which is under CA, with a higher proportion of macropores, increases preferential channels of water flow, being able
in some cases and under certain conditions, to increase the transport of herbicides.

In addition to soil, the transport capacity of the herbicide, both in the runoff water and in the water that flows through the edaphic profile, as well as through the eroded sediments, is influenced by the intrinsic characteristics of the used product. Thus, there are herbicides that can be highly adsorbed by the soil, which are normally transported only by erosion. Therefore, glyphosate is vastly used in CA and easily absorbed by the soil. Its main form of transport and potential contamination through the eroded sediments, are greatly reduced, thanks to the reduction of erosion rates that the application of practices such as no-tillage implies.

Occasionally, there were cases in which the concentration of herbicide in runoff water produced by no-tillage techniques was higher than in crops under conventional tillage. In these cases, the meteorological conditions could have a determining role. Thus, the combination of groundcovers and strong precipitation events occurring just after applying the product, helps the herbicides intercepted by the vegetal remains on the soil surface, to be “washed” easily by water from rainfall. This fact, together with the fact that CA reduces the amount of runoff water, increases the concentrations, no matter how low the amounts of herbicides dragged by water are.

In any case, the analysis of the existing information in the scientific literature regarding the influence of the CA systems on the dynamics of the herbicides in the soil, yields a great variability of results, due precisely to the large number of factors that intervene in the processes of adsorption and entrainment of the active materials in the edaphic profile. As a result, to date, it is not possible to determine with certainty whether CA reduces the risk of water contamination produced by herbicides with respect to the management systems based on tillage, because the obtained results are uneven.

**Conclusions**

There is evidence that the adoption of CA optimizes the use of herbicides with respect to the management systems based on tillage. According to some of the existing studies in the scientific literature, over the time, it is possible to reduce the doses and the number of applications on crops. Therefore, CA is based on three very important principles which include crop rotation and groundcovers. The synergies generated by these principles provide, in addition to environmental benefits for soil, water and air resources, an adequate weed control strategy, for the effects they have on the seed bank and the growth and establishment of the arvense flora.

The extensive study has shown that if these three principles are not implemented simultaneously, problems with weed infestation are more likely to arise in CA systems. However, the chemical control of weeds in CA is necessary for its implementation and development. The chemical control has to respect regulations currently in force, what guarantees the safe use of these products.

The study has also shown that the behavior of herbicides in the agricultural ecosystem depends not only on the management system, but also on variables such as the physico-chemical characteristics of the soil, the characteristics of the used active material and the meteorological conditions at the time of application. The results found in this regard, show a great variability what makes it difficult to draw conclusions about how the CA affects the dynamics of the movement of herbicides in the soil and runoff water. Despite this, some studies suggest how its implantation can reduce the concentrations of these products in water and soil compared to conventional tillage, although this depends to a great extent on the weather conditions, and this situation can be reversed. The scientific evidence shows that herbicides with high adsorption capacity, as is the case of glyphosate, are less mobile and more rapidly degradable in soils with high OM contents, such as that obtained in CA.

Therefore, the adoption of CA, with all the benefits that this entails, constitutes, through its three principles, an appropriate strategy for the optimized use of herbicides, resulting in a reduced risk of impacts on the environment, leading to a safer use of these products. The positive results, measured by the decrease in phytosanitary presence in surface waters, can demonstrate to society, legislators and regulators in general, the capacity of agriculture to respond to environmental concerns using only the necessary amount of herbicide products, respecting the regulations in force.
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