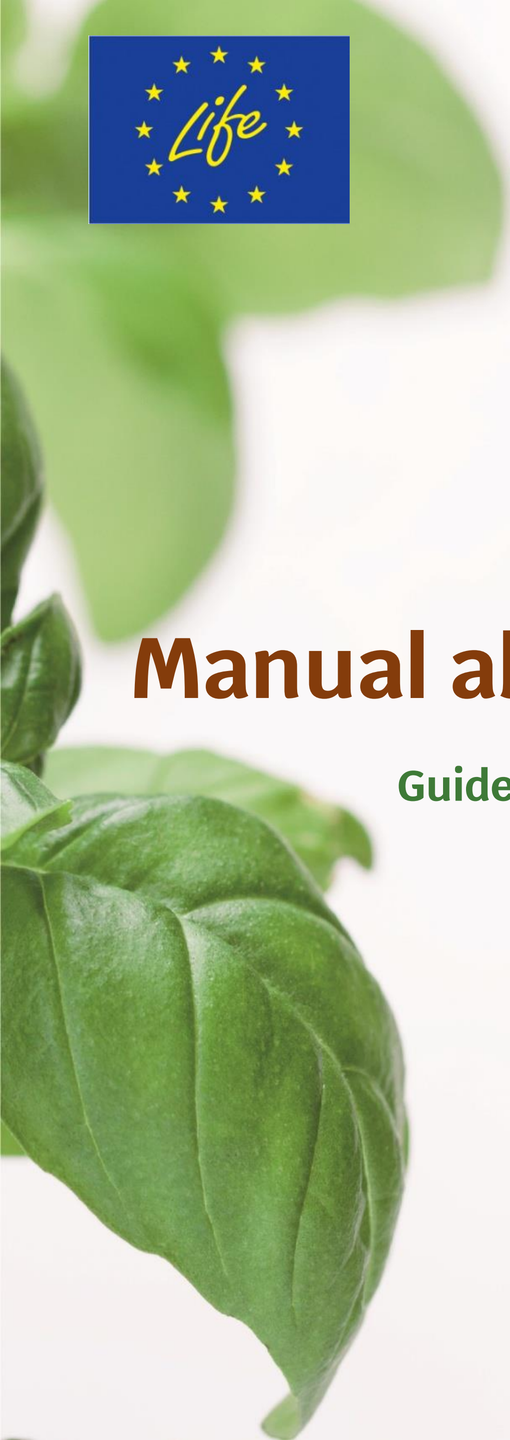

Manual about Best Management Practices

Guide on practical application of Conservation Agriculture techniques

About this manual

Climate change is one of the challenges the agricultural sector is facing nowadays. Agriculture is responsible for approximately 10% of greenhouse gas emissions in Europe, so it is necessary to provide farmers with tools that would allow them to contribute to climate change mitigation, without decreasing the profitability of their farms.

This manual offers answers to these issues. Various studies around the world, based on Conservation Agriculture, either using No-tillage in arable crops or Groundcovers in woody crops, have developed crop management techniques capable of sequestering carbon and reducing CO_2 emissions in the atmosphere.

With this guide, it is intended to offer the farmer, in a simple and enjoyable way, the main guidelines for the implementation and development of these management practices, thus favoring the migration of unsustainable management systems based on tillage and helping the farmer to fulfill the increasingly demanding requirements of the CAP and European regulations on climate change.

Life

agromitiga

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Conservation Agriculture and Climate Change

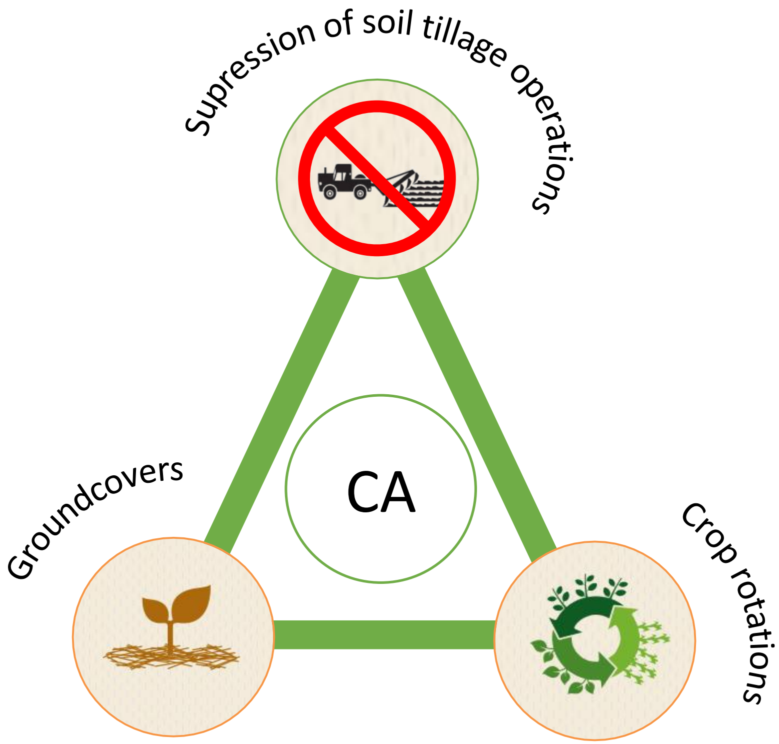
Principles and fundamentals

According to FAO, Conservation Agriculture includes a series of techniques that have as a fundamental objective to conserve, improve and make more efficient use of natural resources, through integrated management of soil, water, biological agents and external inputs. There are three fundamental principles on which Conservation Agriculture (CA) is based, and which are universally applicable to all agricultural areas and land uses, always adapted to local conditions:

Suppression of soil tillage operations. In Conservation Agriculture the soil is conceived as a living entity capable of providing numerous ecosystem services to agriculture. By not disturbing it mechanically, we increase its resilience and the content of organic matter, favor edaphic biodiversity, improve its structure and ultimately improve its quality.

Maintaining Groundcovers throughout the year. This means to maintain stubble in herbaceous crops and plant or maintain groundcovers between rows of trees in woody crops. In this way, the soil organic matter will increase, some weeds will not grow, there will be better infiltration of water into the soil and the evaporation of water from the soil will be limited. At least 30% of the soil must be covered after tillage, to protect it effectively against erosion. However, 60% of coverage will allow having almost total control over this soil degradation process.

Crop rotations or diversification of crops in annual crops. In this way, pests and diseases are better controlled, breaking cycles that remain in monocultures, and planting crops that can improve the natural fertility of the soil and biodiversity.



Main practices

No-tillage

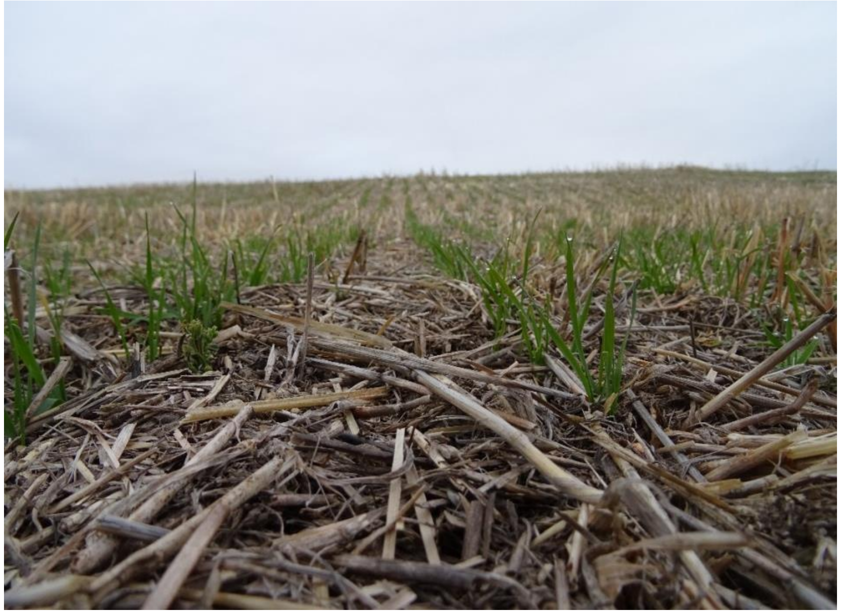
No-tillage is the most representative agronomic management practice of Conservation Agriculture in annual crops, which is especially implanted in winter cereals, spring cereals, legumes within a rotation with cereals and oilseeds (sunflower).

It is an agronomic management practice in which no work is done; At least 30% of soil surface is protected by plant remains, and planting is done using machinery enabled to plant on the plant remains of the previous crop. No-tillage is the best option to achieve a high degree of conservation in annual crops, in which there is a complete suppression of mechanical work on the soil.

Groundcovers

Groundcovers are the most representative agronomic practice of Conservation Agriculture in woody crops, highlighting its implantation in olive, citrus and almond crops. In this case, the soil surface between the rows of trees remains protected against erosion generated by the direct impact of raindrops. At least 30% of the soil surface is protected by groundcovers.

Groundcovers can be made up of live vegetation or plant remains, always taking care to manage it properly to avoid the competition for water and nutrients between groundcovers and the crop.



Basis of climate change mitigation

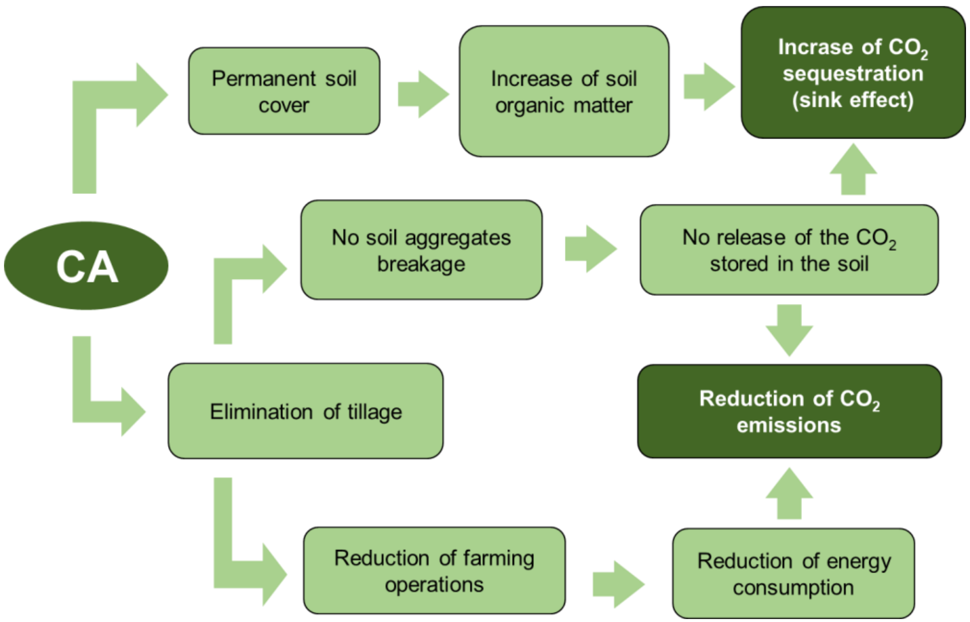
The change in the management philosophy implied by the practice of Conservation Agriculture, induces changes in the Carbon dynamics in the soil, increasing its concentration and quantity because of two reasons:

Carbon sequestration

By leaving groundcovers on the soil, the atmospheric CO_2 fixed in its vegetative structures, through photosynthesis, becomes part of the soil as organic matter thanks to the decomposition processes carried out by soil microorganisms.

Emission reduction

Suppression of soil tillage, improves its structure, increasing the stability of the aggregates against disaggregation processes, allowing greater protection of organic matter against attacks of edaphic microfauna, and maintaining CO_2, resulting from the processes of mineralization of organic matter, "trapped" in the porous space of the soil, contributing to a reduction in emissions of this gas. In summary, Conservation Agriculture increases the amount of CO_2 in the soil thanks to the presence of groundcovers and reduces the outflows of this gas as a result of the reduction of work, which ultimately results in an increase in the sink effect.

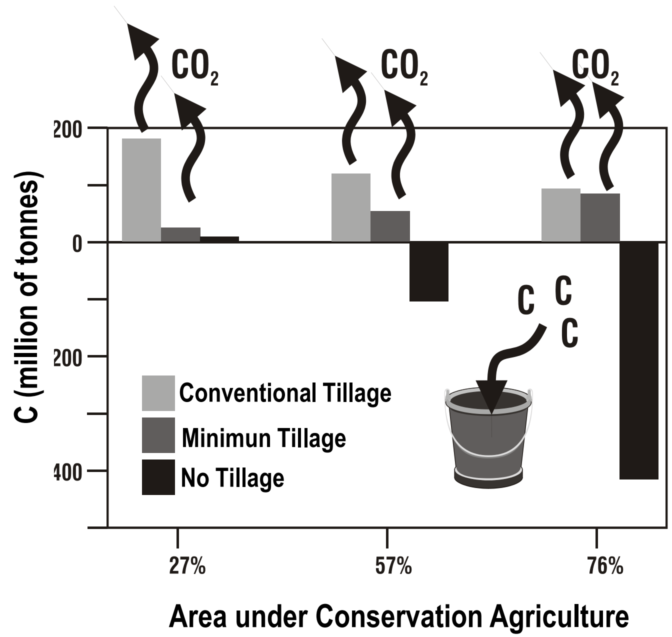


Carbon sequestration potential

There are numerous international studies that support the mitigating capacity of Conservation Agriculture practices in relation to carbon sequestration in the soil.

Thus, González-Sánchez *et al.* (2012)[1], after reviewing 29 studies carried out in Spain, concluded that, in the first 10 years of implementation of Conservation Agriculture techniques; No tillage and Groundcovers were capable of sequestering 0.85 t of carbon/ha and 1.54 t of carbon/ha respectively compared to conventional tillage per year. Aguilera *et al*. (2013)[2], in a review that included 79 studies worldwide in Mediterranean climate zones, obtained that No tillage and Groundcovers were capable of sequestering 0.44 t of carbon/ha and 0.27 t of carbon/ha respectively compared to conventional tillage.

	Carbon sequestration rate (t / ha and year)	
Agricultural Practice	González-Sánchez *et al.* (2012)[1]	Aguilera *et al*. (2013)[2]
No tillage	0,85	0,44
Groundcovers	1,54	0,27



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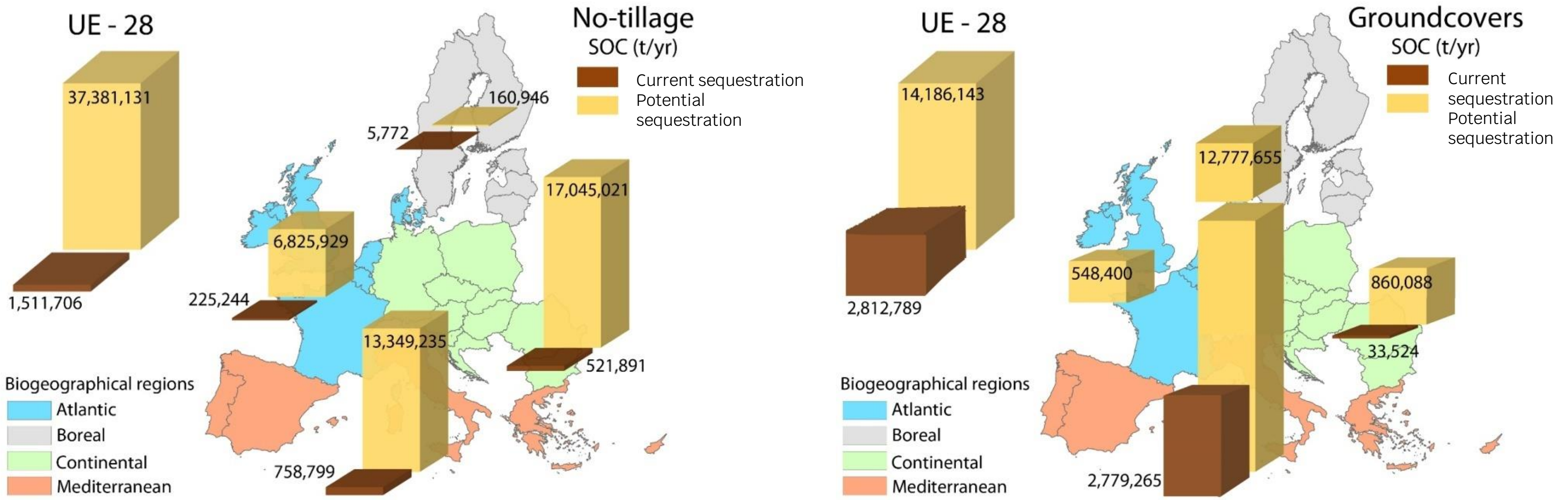
Carbon sequestration potential

One of the studies carried out worldwide[3], estimates the potential in carbon sequestration that global migration would have towards Conservation Agriculture systems, concluding that if 1.5 billion passed from a system based on tillage to Conservation Agriculture systems, between 0.6-1.2 billion carbon would be set a year.

In a study conducted by ECAF on the potential of Conservation Agriculture to sequester carbon in Europe[4], in which the carbon sequestration results of Conservation Agriculture in different biogeographic regions of Europe were analyzed, it was estimated that the current capacity sequestration, thanks to these practices, is just over 2.8 million tons of carbon per year in the case of No tillage and almost 2 million tons in the case of Groundcovers. This study estimated the potential of European agricultural soils to sequester atmospheric carbon. If the entire agricultural area was under Conservation Agriculture, this potential would be just over 14 million tons of carbon per year in the case of No tillage and 7.6 million tons in the case of Groundcovers.



[3]Lal, R. (2004). "Soil carbon sequestration impacts on global climate change and food security". *Science* (304); pp. 1623–1626.
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No tillage

Five steps to proper implementation

1 Management of crop remains

In No tillage, the success of the technique begins in the harvest of the previous crop, where is essential to place homogeneously the straw on the ground.

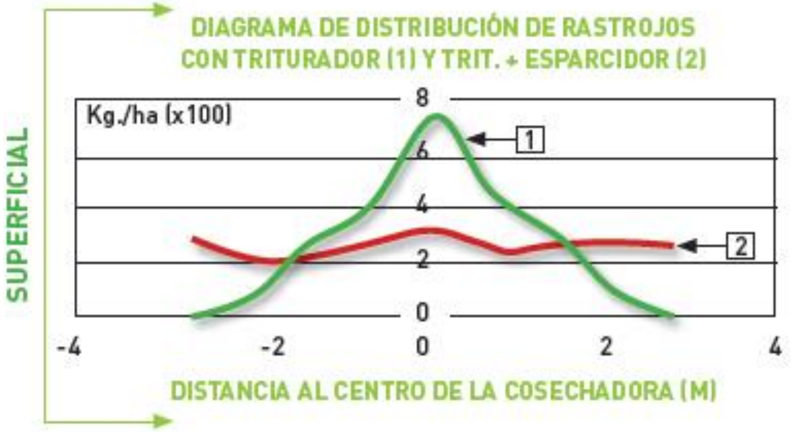
Therefore it is advisable, in most cases, to leave the stubble on the ground after harvesting, which is the most economical and effective way to execute it using the implements installed in the combine.

This operation can be carried out by attaching to the harvester a system to chop and scatter the straw, which can be attached on its back in the case of wheat or barley, or on the cutter bar in the case of corn or sunflower crop.

Depending on the type of seeder which is used in the sowing operation, it will be more or less appropriate to chop the stubble. Thus, some experiences show that if the seeder that is going to be used has a disc groove opening system, it is better not to chop, it while if the opening system is grating, it is advisable to chop the straw.

An irregular distribution of the stubble, can lead to an uneven establishment of the crop, because when regulating the seeder for a certain depth, there is a risk that in the areas of greater stubble accumulation, the seed is not implanted correctly causing a reduction of the emergence in the crop.

stubble distribution with shredder and spreader



Five steps to proper implementation

Percentage of groundcover

0%	9%	34%
		
1.350 kg/ha	5.760 kg/ha	11.160 kg/ha

Five steps to proper implementation

2 Weed, pest and disease control I

During the time between the harvest of one crop and the next one of the rotation, it is necessary to keep the soil without weeds. Part of that control is carried out by the crop remains of the previous crop present on the soil. However, treatments with non-residual herbicides need to be done before planting.

It is usual to make a herbicide application before planting after the autumn rains in the case of winter crops and one to two applications in the case of spring crops. The applications to be used are usually a mixture composed of broad-spectrum herbicides, at doses not greater than 1-1.5 l/ha with hormonal herbicides at doses between 0.5 to 0.75 l/ha.

After sowing, the treatments performed do not differ much from those carried out in a management system based on conventional tillage, the application of a pre-emergence herbicide may be necessary in spring crops, to prevent germination of weeds after planting.

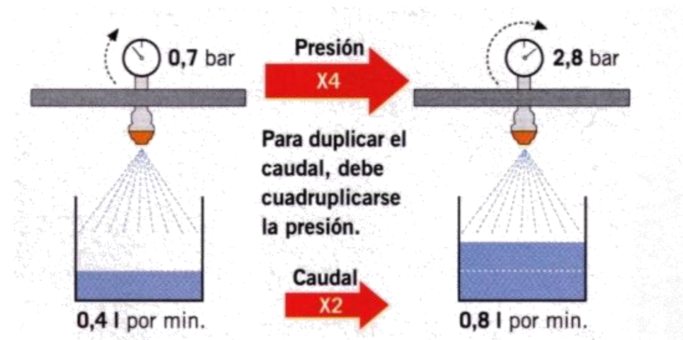
Once the crop has germinated successfully, it is convenient to monitor its development, to make the appropriate decisions about the necessary treatments to be carried out, either to control weeds, or to control pests and diseases, what will depend on each agricultural season.

Five steps to proper implementation

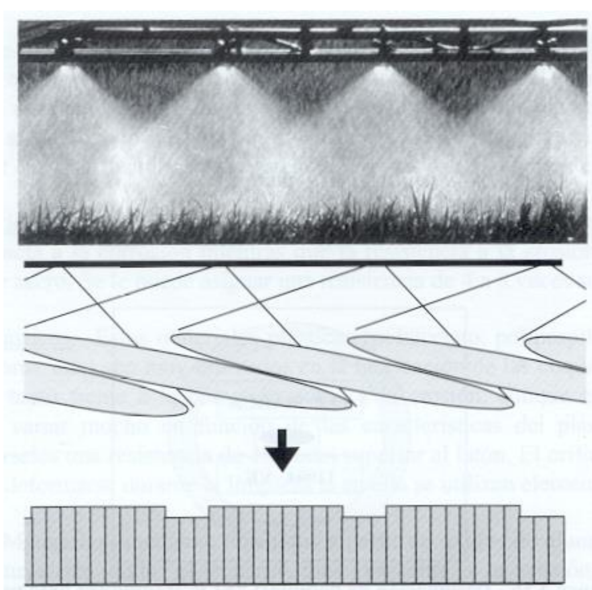
2 Weed, pest and disease control II

For the application, treatment bars are used, which must be perfectly calibrated and at a suitable height above the ground (50 cm) to make a correct application. Therefore, it is essential to use nozzles in perfect condition, preferably anti drift ones, and the pressure recommended by the manufacturer (2-3 bar) to use an appropriate drop size and an application angle that allows a homogeneous distribution of the product (110º). In addition, their orientation with respect to the front of the trailer must be such that a homogeneous application on the ground is guaranteed.

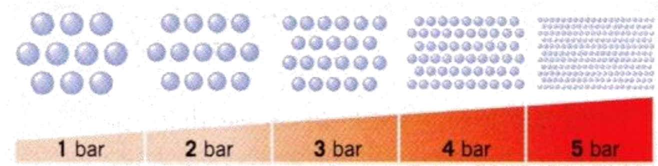
FLOW
It varies according to the size of the outlet orifice, but the spray pressure plays a fundamental role.



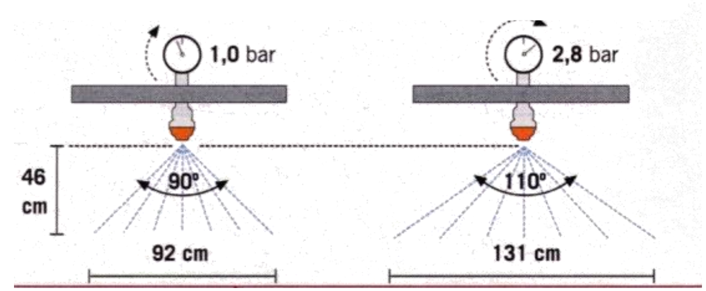
ORIENTATION
Orienting the nozzles obliquely with respect to the front of the trailer guarantees a homogeneous treatment that covers 100% of the soil.



DROP SIZE
The sprayed liquid is formed by drops, which generally do not exceed 0.8 mm in diameter. Its size is regulated by pressure.



SPRAY ANGLE
It is characteristic of the tablet, but the working pressure can increase or reduce the angle.



Five steps to proper implementation

3 Sowing I

After preparing the seedbed, the next step is to sow the crop. Seeders used in No tillage differ in their design and structure from seeders used in conventional tillage when sowing on the soil covered with plant remains. In general, they must have the following characteristics:

Enough weight to go over the plant remains.

Ability to open a groove wide enough (several cm) and deep (4-6 cm) to place the seed properly.

- Rigidity and resistance of their elements to withstand the greatest loads.
- Possibility of regulating the dosage and spreading of seeds of different sizes to ensure their adequate covering.
- To be able to modify their configuration to adapt them to different crops and include fertilizer elements and treatments in order to fertilize the soil in a localized while sowing it.

In the market there are basically two types of direct seeders depending on the type of element used to place the seed in the seedbed:

- Disk seeder.
- Tiner seeder.

SEMBRADORA DE DISCO

SEMBRADORA DE REJA

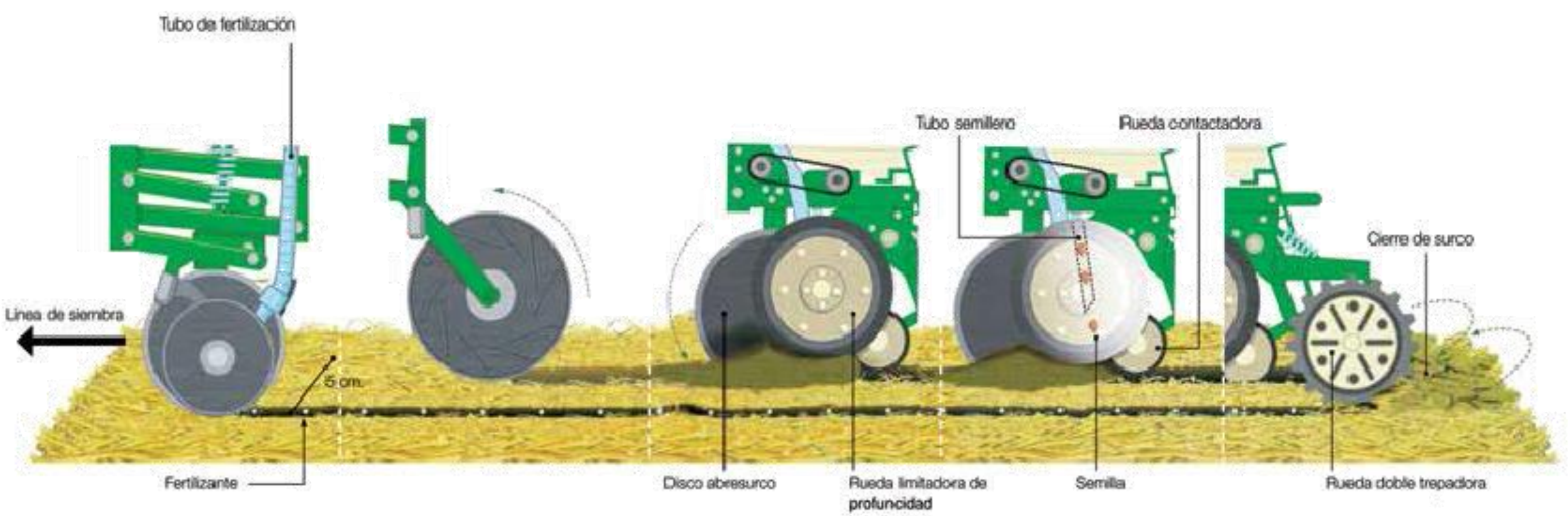
Five steps to proper implementation

3 Sowing II

In order to sow correctly it is advisable to conduct in advance, a brief analysis of the soil conditions and properly regulate the seeder. Unlike the management systems based on tillage, in which the soil is tilled so that it is in the same conditions for planting season after season, in No tillage the characteristics of the soil are different in every season, so the planting depth and the direction of the groove need to be adjusted periodically every year ,

The sowing trailer of a direct disk seeder has a greater number of implements, because it must be able to place the seed in a soil covered by plant remains. The direct disc seeders, are those that more elements incorporate to the trailer, having generally a mentioned cutter (there can be more than one), a disc which opens the groove with the wheel which controls the depth, a compactor wheel and discs which sweep stubble to close the groove.

Direct grid seeders usually have a single element, consisting of an arm which has groove opening elements made from a resistant material (tungsten carbide, ...) and with various shapes depending on the needs of soil.



Five steps to proper implementation

4 Fertilization

Although it is true that the soils under No tillage have different conditions from those under conventional tillage, which modify the nutrient cycle and influence the use of nutrients, in practice, fertilization strategies do not vary substantially between those two management systems.

Nitrogenous Fertilization

At the beginning, no tillage system may require additional doses of nitrogen fertilizer. Therefore, it is advisable to mitigate the lower temperature that occurs in soils covered by plant remains and microbial competition for nitrates, very intense in the first years of the change, by incorporating about 40-50 units in the case of cereals. An option widely used in these cases is to locate the seed fertilizer 5 cm to the side and below the seeds, through fertilizer systems incorporated into the seeder, taking special care that phytotoxicity problems do not appear. The number of top dressings will depend in each case on the type of crop and the needs to be covered in each season.

Phosphorus Fertilization

Phosphorus is one of the least mobile nutrients in the soil and, therefore, one of the most affected by the absence of tillage that occurs in Conservation Agriculture. The superficial application of fertilizers together with plant remains that accumulate in soil surface enrich the first centimeters of the soil profile, causing a stratification of the phosphorus. Despite this, in Conservation Agriculture, the used doses are usually similar to those used in conventional tillage, using any soluble phosphorus fertilizer.

Potassium Fertilization

The accumulation of plant remains and potassium fertilizers on the surface, together with the reduction of erosion, favors the enrichment of the soil surface in potassium. The greater richness in organic matter of the superficial horizon, favors a greater exploration of the roots, so the assimilability of potassium in No tillage is greater. However, and despite all this, no significant differences have been observed between Conservation Agriculture and conventional tillage.

Regarding the application, if the potassium fertilizer is located near the seeds, it is recommended not to exceed 50 kg/ha of N + K and if the fertilizer is applied together with the seed, 20 kg/ha of N + K should not be exceeded. The normal limits are between 20 and 100 kg of N + K.

Five steps to proper implementation

5 Harvest

Once the crop cycle ends, the circle is closed by harvesting and evaluating the progress of the agricultural year, in order to make decisions regarding the strategies to be followed in the next season regarding fertilization, weed, pests and diseases control. This analysis is essential in order to solve the problems that have arisen and overcome the difficulties that may have occurred throughout the implementation and development of the crop using No tillage techniques.

Groundcovers

General aspects

The groundcover constitutes an effective soil maintenance system in sustainable agriculture models. Its effect on the increase of biodiversity, on the improvement of soil quality, on the reduction of the risks of erosion and transfer of agrochemicals to the waters, on the capture of atmospheric CO_2 which is subsequently stored in the soil in organic form and on the limitation of excessive use of agricultural inputs, contributes to the rational and sustainable management of the crop.

There are several options when planting a groundcover. Therefore, it is necessary to take into account several aspects among which is necessary to highlight the management that must be carried out, since a good management of the groundcover will influence its benefits.

Good guidelines to follow when choosing the type of cover would be to choose one that has the ability to stop erosion, that adapts to the climatic conditions of the area and that its management is simple and cheap.

"Ideal" Groundcovers

- Do not grow very high
- Fast implantation in autumn.
- Superficial root development.
- Poorly competitive.
- Do not host insects / pests.
- Low combustibility.
- Able to mobilize nutrients.
- Do not have fast decomposition.
- Self-seeding plant.

Types of Groundcovers

By its origin and maintenance	By their duration	By their physiological state
Not sown	**Temporary**	**Live**
Spontaneous, not selected weed	Winter	Vegetative
Spontaneous, selected weed; grasses	Annual cycle	
Sown	**Permanent**	**Dead**
Grasses	Grass	Plant remains (leaves, pruning remains)
Legumes		No plant remains (stones)
Cruciferous		

Agronomic management

Spontaneous, not selected Groundcovers

This type of cover consists of allowing the growth of spontaneous vegetation between the rows of the crop. The advantage of this cover is the possibility to reduce some costs related to sowing seed, sowing operation and the selective treatment. One of the disadvantages is that the plant species that compose it are frequently very diverse, which makes maintenance more complicated. In case that a mechanical mowing is chosen, there is an inversion of flora towards creeping, quick plants and perennial or easy regrowing plants, and in the case of chemical mowing, high doses of herbicide must be used. In addition, these species decompose rapidly offering poor soil protection.

Agronomic management

Selected, spontaneous Groundcovers; grasses

This type of cover is recommended for soils that have been tilled for years, so that there is a seed bank with a great variety of species and high seed density. In this case, the native flora is cultivated, so that a single species, or a mixture of species from a single family, predominates on the soil. This is achieved by turning the natural vegetation into a grass cover (ryegrass, brome grass, sterile brome ...), very common and very effective species in the fight against erosion.

Tasks

- Letting the autumn pasture to grow.
- Selective treatment against wide leaf, as soon as the cover is 10 to 15 cm high.
- Nitrogen fertilization, 50-60 UF / ha cover
- Repeated herbicide treatment whenever appear weeds which are difficult to control, or when the percentage of stands with weeds, different from those selected one, is high.
- Chemical mowing when it starts competing with the crop for water and nutrients, leaving the vegetation in the center of the row untreated, to favor the existence of self-seeding plants. This can be achieved by covering the nozzles located on a side which goes above the area we want to leave untreated.

Agronomic management

Groundcover planted with grass

It is one of the most widespread types of groundcover and it is an alternative to natural or spontaneous vegetation. It is recommended for very eroded land or with a very poor or very lowly dense seed bank. This usually occurs in woody crops that have been managed with tillage on the bare soil. Uncertified seeds or natural grasses, such as ryegrass, CEBADILLAS, bromine, etc., can be used.

Tasks

- Superficial tillage to prepare the sowing bed (cultivator) (only the first year)
- Sowing: Use of seeder or centrifugal fertilizer with the following doses:
  - Uncertified seeds: 100-110 kg/ha of cover, which is equivalent to 50 kg/ha of land.
  - Natural grass: 15 kg/ha of cover, which is equivalent to 7.5 kg/ha of land.
- Burying the seed (only in the case of uncertified seeds) with superficial harrow or ploughshare. This is not possible in plots with 15% slopes.
- Nitrogen fertilization, 50-60 UF/ha cover.
- Chemical mowing when it starts competing with the crop for water and nutrients, leaving self-seeding plants.

Agronomic management

Groundcover made of legumes

It is an interesting alternative due to its ability to fix atmospheric nitrogen, and save nitrogen fertilizer. However, regarding protection, they are considered less interesting, mainly because of their fast decomposition. In addition, herbicide treatments for their control are difficult and expensive, so mechanical harvesting is the best option used for their maintenance, especially with species with little regrowth capacity such as vetch. This species, besides clover, they are the most interesting plants used as a groundcover.

Tasks

- Superficial tillage to prepare the groove (cultivator) (only the first year).
- Sowing: Use of seeder or centrifugal fertilizer with the following doses:
  - Vetch: 90-100 kg/ha.
  - Clover: 30 kg/ha.
- Burying the seed with superficial harrow or ploughshare. This is not possible in plots with 15% slopes.
- Mechanical harvesting.

Agronomic management

Groundcover made of cruciferous

This type of groundcover is a very valid option to introduce in a rotation with grass groundcovers, because after several years of using the same species as a groundcover, it decomposes, reducing soil protection. Some of the advantages of its use are: they are species known to the farmer, they grow fast and abundant biomass production, covering the soil very quickly. Being species of winter cycle, they coexist with the crop during the rainy season and low evapotranspiration, making the competition very low. In addition, its deep pivoting root can break the work sole and improve the problems of low water infiltration into the soil.

Tasks

- Superficial tillage to prepare the groove (cultivator) (only the first year).
- Sowing: Use of seeder or centrifugal fertilizer.
- Burying the seed with superficial harrow or ploughshare. This is not possible in plots with 15% slopes.
- Mechanical mowing: Two cuts:
    - First cut before flowering, leaving the groundcover at a height of 40-50 cm.
    - Second and final cut at ground level.

Agronomic management

Groundcover of pruning remains

This type of cover consists of spreading the grinding pruning remains, leaving them on the soil surface in the center of the row. While they are decomposing slowly, they are protecting the soil for a long time. It is an alternative that uses remains that traditionally were not used nor valued by the farmer. For its implantation, it is necessary to carry out a previous mechanical treatment of grinding or chopping and, if it is considered necessary, defibration. This last treatment is especially interesting in medium and large caliber trunks and branches. Chopped pruning remains should be small to prevent certain pests, such as ash bark beetles, and not to impede other maintaining tasks, such as harvesting.

Tasks

- Grouping of the pruning remains in the center of the row with liner swathers.
- Chopping of pruning remains with a self-powered chopper in case of not very thick remains (ø <8cm) or manually in case of thick remains.
- Herbicide treatment in case of weeds in the rows (product and dose depend on the species).

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