CHOOSING AND MANAGING COVER CROPS IN ORGANIC AGRICULTURAL SYSTEMS

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Mustard, blue tansy, oat, clover, buckwheat, rape, lentil, foxtail millet...these key cover crops offer multiple benefits. Within the strict regulatory environment governing cover crop use, each has its place. However, the reasons for using cover crops extend far beyond just following regulations.

During the fallow period (between the harvest of one cash crop and the sowing of the next), cover crops are established, using regrowth or newly planted seedlings. Different types of cover crops have different functions. Some—catch crops—limit nitrate leaching. Others act as green manure, providing nutrients to the following cash crop and enriching the soil. Relay crops provide cover while producing winter forage or grains.

When properly managed, cover crops provide numerous agricultural and environmental benefits. In particular, they can

- limit nitrate leaching
- improve farm nitrogen self-sufficiency
- limit erosion
- suppress weeds
- increase the activity of beneficial soil biota
- contribute to soil organic matter and carbon stores
- allow for a second harvest (sometimes)

Cover crops serve two main functions in organic agricultural systems: they enhance soil fertility and control weeds and pests (pathogens or insects). Farmers should plant cover crops not just because the law requires it, but also because they provide real benefits when managed effectively.

It is not necessarily easy to use cover crops. If done improperly, the growth of the following cash crop may be harmed. Care must be taken at each step of the process, from cover crop establishment to cover crop termination. However, even before a single seed is sown, farmers must carefully choose the species they will use based on management objectives, farm type, and field type.

This guide lays out essential information that will help organic farmers successfully use fallow-period cover crops. The guide's different sections are interrelated but occur in chronological order for the sake of text flow—we start with a discussion of how to select suitable cover species and end with a section on termination. Each section, each stage, and each choice play an important role in successful cover crop use.

This guide is the fruit of discussions that took place as part of a French national working group that brought together agricultural advisors, coordinators, and other professionals in the field of organic agriculture. They came up with a method for choosing the right cover crop species and recommendations for establishing and terminating cover. This guide seeks to answer major questions related to cover crop use.

THE NITRATES DIRECTIVE: CONSTRAINTS ON FALLOW-PERIOD MANAGEMENT

Written by: Charlotte Glachant, Seine and Marne Chamber of Agriculture

Passed in 1991, the EU nitrates directive seeks to protect groundwater and surface waters from agricultural nitrate pollution. In France, a series of action programmes were implemented to modify farming practices in vulnerable zones. The fourth such programme, which ran from 2009 to 2013, expanded on previous programmes by establishing major requirements related to the planting of cover crops during periods of high leaching risk. Specifically, it defined levels of autumn soil cover and catch crop management procedures. This programme was implemented via prefectural order, and thus exact regulations vary among French administrative departments. To find out the regulations for a given department, it is necessary to contact the local Departmental Directorate of Land (DDT). Autumn cover can be provided by winter crops, catch crops, rapeseed regrowth, grain regrowth (some departments only), and grassland species.

Catch crops must be established before spring cash crops (except when coming after maize). Establishment and termination deadlines (in most cases, cover crops must remain in place for at least two months) as well as authorised species are defined at the departmental level. In general, legumes can only be used as part of mixtures. However, in certain departments, pure legume covers may be specifically authorised on organic farms.

Some DDTs grant exemptions when catch crops are involved, depending on the circumstances (e.g., when a late-season cash crop [maize] is followed by a spring cash crop, the presence of perennials that can only be eliminated after September 15, the need to mechanically remove annual weeds, or the presence of high-clay soils).

SECTIONS:

1 – Choosing the right species
2 – Species Mixtures
3 – Establishing cover crops
4 – Terminating cover crops
5 – Method for choosing cover crops

Reference for guide: *Guesquière J., Cadillon A., Fourrié L., and Fontaine L., 2012. Choosing and managing cover crops in organic agricultural systems. ITAB.*

Linseed (ARVALIS)

CHOOSING THE RIGHT SPECIES

Choosing the right cover crop species can be challenging. Each plant family and species has specific traits that are useful under different circumstances. Therefore, the goal is to identify the cover crop species that is the most appropriate for a given situation; either a single species or a species mixture may be used.

DECIDING WHICH COVER CROP TO USE

There are three steps to choosing a cover type. First, farmers must identify field constraints. Second, they must prioritise their management objectives. Third, they must adapt their species choices based on farm resources (e.g., equipment, seeds, available work hours).

FIELD CONSTRAINTS

CROP ROTATION

When planting fallow-period cover crops, farmers should seek to alternate plants with different characteristics (e.g., different taxonomic families, winter vs. spring vs. summer crops, crops with different root systems), just as they do when designing the cash crop sequence/rotation. Indeed, cover crops enhance rotation diversity. For example, if the rotation includes sunflower, then other asters should be avoided when the rotation is short. The use of legumes as cover crops depends on their representation within the rotation (currently around 30% in organic systems).

It is also important to take pests into account. Indeed, crop sequences may increase pest pressure. For example, it is a bad idea to plant oat or rye if the stem and bulb nematode (*Ditylenchus dipsaci)* is present. Also, in fields contaminated with root-rot fungi (*Aphanomyces*), it is better to avoid the use of sensitive legume species like pea, vetch, or lentil. That said, in many cases, cover crops can have positive effects on the following cash crop. For example, it is commonly known that legumes provide nitrogen to future crops. However, crucifers also have benefits, particularly when planted between two wheat crops. They are a rich source of glucosinolates, organic compounds that inhibit the development of certain soil fungi, such as the pathogen responsible for take-all disease. This phenomenon is known as allelopathy.

SOWING DATES

The window of opportunity for planting cover crops will vary depending on species and regional precipitation patterns. If springs tend to be dry, cover crops should not be undersown in grain crops. Instead, it is better to delay planting until late summer, to take advantage of seasonal rain storms. In contrast, if summers tend to be dry, it is better to undersow. That said, certain cover crops are drought resistant, and their seedlings can emerge even if summer conditions are very dry. Late seedling emergence is not a problem: plants can still develop properly and yield good-quality cover. General recommendations are slightly different if a farmer has access to an irrigation system—a single pass can encourage seedling emergence and enhance growing conditions for cover crops.

Different cover crop species display different degrees of drought tolerance and vary in their sowing dates.

Blue tansy

FALLOW-PERIOD DURATION

The duration of the fallow period varies depending on the identity of the cash crops coming before and after. Cover crop developmental speed must match fallow-period duration. For example, if the fallow period is short (e.g., occurs between two small-grain crops), legumes planted post harvest cannot be used because they develop too slowly. However, if climatic conditions allow it, legumes such as white clover or red clover can be undersown in the spring.

In certain cases, it is simply impossible to plant cover crops. For example, when sunflower is followed by a small-grain crop, the fallow period is far too short and undersowing in sunflower is rarely successfully.

The length of a species' developmental period must correspond to the length of the fallow period.

SOIL TYPE

Cover crop choice will also be affected by soil type. Some species are better adapted to certain soil textures and pH levels. Moreover, different species respond differently depending on soil water availability.

UNDERSTANDING FIELD CONSTRAINTS MAKES IT POSSIBLE TO IDENTIFY THE RIGHT COVER CROP SPECIES

MANAGEMENT OBJECTIVES

Once field constraints have been considered, farmers must think about their management objectives, which will define species selection criteria. It should be noted that the functions described below are only displayed by successfully established cover crops.

NITROGEN CAPTURE

Some species are better than others at capturing nitrogen. Crucifers are good catch crops—they develop rapidly, generate abundant biomass, and quickly absorb soil nitrogen. While less effective than crucifers, legumes are still decent catch crops. They take up soil nitrogen before starting to fix atmospheric nitrogen. However, farmers must pay close attention to departmental regulations. Often, legumes can only be planted as part of mixtures. Consequently, a good alternative is mixing legumes with crucifers or grasses.

PROVIDING NITROGEN TO THE FOLLOWING CROP

For cover crops to effectively provide nitrogen to the following cash crop, they must be able to fix nitrogen (nitrogen content of 2–4%, depending on the species) and release captured nitrogen at the right moment. On average, one ton of aboveground biomass can provide dozens of units of nitrogen to the following cash crop. The exact quantity depends on plant family (legumes: 20-30 U/t of dry matter [DM], crucifers: 15-20 U/t of DM, and grasses: 10-15 U/t of DM); it is also affected by such factors as soil type and climate.

Furthermore, the higher a plant's carbon-to-nitrogen (C/N) ratio, the less nitrogen it will release to the soil. For example, peas (C/N ratio = 11) will release 60–80% of the nitrogen they capture. In contrast, mustard in flower (C/N ratio = 35) will harm the growth of the following cash crop because its decomposition by soil microorganisms results in a temporary nitrogen deficit.

The Poitou-Charentes Chamber of Agriculture has come up with a way to estimate the amounts of nitrogen, phosphorus, and potassium available after cover crop termination. It is called the MERCI method.

WEED CONTROL

To fight weeds, farmers can use cover crops that excel at light competition, like mustard. They act to "smother" weeds. In this method of weed suppression, proper cover crop establishment is crucial. Care must be taken when sowing. If the cover is heterogeneous or plant development is poor, weeds will thrive rather than perish—they will have good access to light, water, and nutrients. Using species mixtures can help ensure or even enhance weed control efficacy. Certain cover crop species can suppress weeds via allelopathy: they produce toxins that prevent other plants from germinating and growing. When the weed is a perennial species, mechanical tilling is more effective.

MAINTAINING SOIL ORGANIC MATTER

Cover crops can be used to maintain levels of soil organic matter. Those with high C/N ratios are especially helpful. Grasses are also a good choice.

Bird's-foot trefoil: tasty forage

COMPLEMENTARY FORAGE

Many forage species (e.g., millets and clovers) can be used as relay crops and serve as a significant source of complementary livestock forage. Mixtures of grasses and legumes can also furnish high-quality forage.

SOIL STRUCTURE

Species with different root systems will have differential effects on soil structure. Species mixtures can enhance soil structure across several soil layers by combining species with complementary root systems (e.g., those with taproots vs. fibrous roots).

PEST CONTROL

Cover crops can also help farmers deal with pests. Certain species have disease-fighting effects. Others promote biodiversity and thus encourage the establishment of beneficial insects. For example, blue tansy attracts ground beetles, along with other aphid predators.

WHEN CHOOSING COVER CROPS, FARMERS MUST KEEP THEIR MANAGEMENT OBJECTIVES IN MIND

Red clover

COVER CROP SOWING AND TERMINATION

The availability of certain types of farming equipment also influences cover crop choice because it determines which sowing methods and termination methods can be used; it is especially important in the latter case. We delve into this topic in greater detail later in the guide.

COVER CROP VARIETIES

It is important to understand that there are different varieties of cover crop species, just as there are different varieties of cash crop species. Furthermore, different varieties may functionally contribute in entirely different ways. For example, the different oat varieties respond differently to day length; some can develop even when days are shorter, meaning they can be planted in the autumn. There are also anti-nematode varieties of crucifers. In general, varieties display variability in such traits as drought tolerance, developmental sensitivity to day length, and root structure. Such differences must be accounted for when selecting a cover crop.

SPECIES MIXTURES

We have already mentioned several ways in which species mixtures can be useful. It can be broadly beneficial to combine species with different advantageous traits.

BENEFITS OF MIXTURES *(from a special report on cover crops, TCS issue no. 33)*

HIGH-QUALITY PLANT COVER

Regardless of conditions, establishing several cover crop species at the same time improves the chances of obtaining quality cover. Since plants vary in their development depending on that year's climatic conditions, such an approach limits the effects of variability. The impact of pests can also be diluted because slugs, sawflies, and aphids each target specific plants, ignoring others.

GREATER BIOMASS PRODUCTION

By combining several complementary species, positive competitive dynamics are established that promote biomass production. Biomass will be further enhanced if legumes are included in the mixture. At first, the legumes will exploit soil nitrogen, and all the cover species will be in competition. However, once soil nitrogen stores have been depleted, the legumes will further develop their root systems, which harbour nitrogen-fixing symbiotic bacteria. They will become autonomous and accumulate even more biomass.

Some people recommend including non-nitrogen fixers in the plant mixture—such species help deplete soil nitrogen more quickly, thus forcing legumes to switch over to and develop their nitrogen-fixing roots more quickly. Legumes must never make up more than 75% of cover composition.

BETTER WEED CONTROL

When different species are grown together, competitive intensity and biomass are enhanced. A higher overall level of biomass is thus produced. As a result, the cover is more effective at controlling and suppressing regrowth and weeds; the cover crops have a competitive advantage.

EFFICIENT USE OF SOIL NUTRIENTS

Cover crop mixtures can better exploit the soil's range of nutrients by bringing together species with different types of root systems.

IMPROVED SOIL STRUCTURE

When mixtures are used, above- and below-ground biomass may be better balanced. For example, annual plants produce little below-ground biomass. Consequently, the inclusion of other species with deeper, more expansive root systems is beneficial. Furthermore,

Mustard, radish, flax, vetch, and sunflower

high levels of water consumption in the late summer help break up deep clay soil layers by drying them out. When cover crops are terminated, their root networks remain and can be used by future crops.

REDUCED SEED COSTS

Sometimes farmers do not use certain beneficial cover crop species because the seeds are expensive. By combining more expensive species with less expensive species, mixtures allow farmers to exploit the advantages of pricier species while still paying a reasonable cost overall.

COMPOSING A MIXTURE *(approach recommended by the Meurthe and Moselle Chamber of Agriculture)*

First, for cover crops to develop properly, it is necessary to choose species whose characteristics match with preferred sowing and termination methods. Second, it is important to keep in mind the identity of the following cash crop and any potential threats to plant health, even if such risks are reduced by using mixtures rather than single species. Third, even if it is theoretically possible to mix seeds of all sizes, different seeds may have different sowing requirements. For example, planting depths vary. Consequently, farmers may have to make two passes with the seed drill: once to sow seeds with deeper planting depths and once to sow seeds with shallower planting depths. This approach is necessary, for instance, when planting mixtures of faba bean and mustard.

Mixture type in and of itself does not affect the probability of successful cover establishment and biomass production. However, following a few guidelines can optimise the results that farmers obtain:

- Combine plants with different, complementary development strategies that share space and do not compete for resources
- Combine plants with different morphologies (e.g., slender, bushy, low-lying, climbing)
- Use species with diverse root systems
- Use species that flower rapidly in the autumn to provide pollen and nectar to beneficial insects at a time of the year when such resources are rare
- Adjust the sowing density of each species to limit overrepresentation by any one plant or excessive competition, both of which could prevent optimal, balanced cover crop development

MANAGEMENT GOALS

If the goal is to modify soil structure, it is important to combine species with different root systems. If the goal is to retain nitrogen over the winter so that it can be passed along to the following cash crop, it is helpful to use mixtures of legumes and grasses or of legumes and brassicas. In both cases, cover, and thus weed suppression, can be maximised.

CALCULATING SOWING RATE

To calculate sowing rates for species mixtures, you must multiply the monoculture sowing rate for each species by the proportion desired in the mixture*:

→ Here is a sample calculation for a mixture of spring faba bean (50%), blue tansy (25%), and radish (25%):

spring faba bean = 100 kg*0.5 = 50 kg/ha
blue tansy = 12 kg*0.25 = 3 kg/ha
radish = 15 kg*0.25 = 3.8 kg/ha

**In some cases, the sowing rate can be increased by 20% to ensure proper cover development.*

There are no established types of mixtures; many combinations are possible. The overall goal is to maximise the complementary benefits of different species.
When calculating sowing rates, it is crucial to take **regulatory standards** into account. The proportion of legumes allowed in mixtures varies by department. Farmers must check departmental regulations to verify the maximum allowable proportion.

Oat and vetch: nitrogen capture and release + good soil cover

SOME EXAMPLES

Black oat (Brazilian cultivar) and spring vetch
These two species take up nitrogen in complementary ways. Black oat absorbs nitrogen from the soil, while spring vetch fixes atmospheric nitrogen. They then make this additional nitrogen available to the following cash crop. Furthermore, these two species develop rapidly and produce abundant biomass, which means they quickly provide soil cover and suppress weeds.

Winter turnip rape and rye
Winter turnip rape and rye have different root systems (taproots vs. fibrous roots, respectively). Consequently, when the species are combined, they make efficient use of soil nutrients and mechanically affect soil structure in a complementary way. Furthermore, winter turnip rape produces a significant amount of cover and thus helps control weeds.

Crimson clover and Italian ryegrass
Together, crimson clover and Italian ryegrass provide excellent forage.

Farmers can use mixtures to accomplish several objectives at once. It is up to them to create and customise a mixture that will fulfil their needs.

COVER CROP MIXTURES: THE EXPERIENCE OF A FARMER IN THE HAUTE MARNE

Interviewer: Vincent Lefèvre, ISARA Lyon

The Cathelat family farms cash crops on 280 ha in Colmier-le-Haut (Department of Haute Marne). Their farm has been fully organic since 1999; they began the transition in 1989. On their farm, calcareous clay soils predominate; there is great heterogeneity in depth (near the surface on hillsides/deeply buried on plateaus and in valleys).

Over the past seven years, cover crops have been a crucial part of the family's cropping system because they maintain soil fertility and promote farm nitrogen self-sufficiency. The family uses multispecies mixtures that include vetch (20 kg/ha), buckwheat (5 kg/ha), mustard (3 kg/ha), camelina (2 kg/ha), forage radish (2 kg/ha), sunflower (2 kg/ha), and blue tansy (2 kg/ha). This mixture precedes a grain crop and is winter killed if the fallow period is long or mechanically terminated if the fallow period is short. The mixture used before a protein crop is composed of oat, mustard, and camelina.

The family sees mixtures as reducing the risk that cover crops will fail to establish themselves or develop properly: *"...even if we experience unexpected climatic events (heat wave, rainfall), the cover crops are unlikely to fail entirely. Moreover, because soil depth is variable on the farm, we have noticed that each species does better under different conditions: the brassicas are more successful in deep soils, but the sunflower and buckwheat are better adapted to shallow soils."*

ESTABLISHING COVER CROPS

The chosen cover crop species must be properly established for farmers to benefit from its presence. First, it is important to confirm the species' sowing date. Second, an appropriate seedbed must be prepared. Third, the seeds must be planted using the right method.

WHEN TO SOW

The period during which sowing should take place is determined by cover crop species, water availability (e.g., in the case of spring drought, spring planting should be avoided), and field status (e.g., prevalence of weeds, identity of the following cash crop).

LATE-SUMMER SOWING

If cover crops are sown in the late summer, it is advisable to initiate the process as soon as possible post harvest. The idea is to take advantage of residual soil moisture and to give the cover crop enough time to develop and produce sufficient biomass before it is terminated. However, if perennial plants are present or there is a high risk of annual weeds emerging, this ideal may be impossible. In such cases, farmers should use mechanical means (e.g., stubble ploughing) to first control weeds. Seeds should be planted by late August to take advantage of summer rains.

Many species have sowing dates that occur around August 15. However, some species must be planted a bit earlier because they deal poorly with short days and freezing temperatures. It is better to sow such species, which include foxtail millet, buckwheat, and nyger, in July.

Certain small-seeded legumes, such as the clovers, must also be sown before August 15 to have enough time to develop.

However, other species need to be sown later. For example, it can be a problem if mustard is planted too early because it develops quickly and goes to seed. Of course, all the above recommendations may need to be adapted depending on local climatic conditions.

UNDERSOWING

By undersowing, farmers can avoid leaving fields bare and, consequently, limit weed growth. Undersowing has many benefits. Unfortunately, only a few species can be undersown, namely those that develop slowly and that do not bolt while the cash crop is still present. Furthermore, species must also have small seeds with a shallow planting depth (e.g., clovers, lucerne). The identity of the cash crop in place must also be considered. For example, undersowing will be less successful in barley or triticale (which are "aggressive"). In this case, it is recommended that cover crops be planted early, when the grain crop is just beginning to produce tillers.

Nyger: a plant adapted to July sowing

MANAGEMENT OBJECTIVES

The timing of sowing may also need to be modified based on management objectives. For example, if the goal is to provide nitrogen to the following cash crop, maintain soil organic matter, or suppress weeds, it is better to plant cover crops earlier to ensure that they have enough time to develop.

SOWING DATE IS SPECIES DEPENDENT AND HAS A MAJOR INFLUENCE ON COVER CROP SUCCESS

GETTING READY TO SOW

Since weeds are mechanically removed in the spring, it is fairly straightforward to then undersow cover crops in grain crops. Weed removal loosens the soil, allowing seeds to by planted by lightly covering them with earth.

In contrast, planting cover crops post harvest requires more intensive soil preparation. Cover crop development depends on the degree of residue incorporation. If residue incorporation is light, the sometimes-thick residue layer will delay cover crop development, a fact that farmers must take into account when sowing. When planting large-seeded cover crops, it is better to clear residues away. Otherwise, it will be necessary to plough. The degree of soil preparation will depend on the cover crop species, the type of crop rotation, and soil type.

CHOOSING A SOWING METHOD

Sowing requirements vary among species. Some species are easy to sow (e.g., broadcast sowing is possible, seeds germinate near the soil surface). Others have highly specific needs (drill planting, proper positioning in soil). To undersow cover crops in grains, broadcast or row sowing can be used. It can take place as the grain is being planted or during early tillering. Table A on the following page summarises the advantages and disadvantages of each method.

LARGE-SEEDED SPECIES

Large seeds must be planted 3–4 cm deep and be well covered with soil for germination to proceed properly.

It is ideal to use a seed drill, which ensures proper planting depth. However, it is also possible to employ a pneumatic fertiliser spreader to distribute the seeds and then use stubble ploughing to cover them with soil.

SMALL-SEEDED SPECIES

Centrifugal fertiliser spreaders are the quickest and least expensive tools for broadcasting small seeds. Farmers can then do a pass with a roller, which will increase cover crop establishment success by enhancing contact between the seeds and the soil.

IT IS CRUCIAL TO PROPERLY PLANT COVER CROPS TO TAKE FULL ADVANTAGE OF THEIR BENEFITS

Methods	Advantages	Disadvantages	Tools	Cost (€/ha)
Broadcast sowing	- Low establishment costs - Fast - Limits constraints related to plant residues (if the soil has been properly prepared ahead of time)	- Difficult to calibrate equipment (centrifugal fertiliser spreaders), can lead to heterogeneous cover - Not suited to all species (early-sown species)	Centrifugal fertiliser spreader (e.g., DP12), combine harvester (sow while harvesting)	15–35
Row sowing	- Optimal planting depth, homogeneous seed distribution, and rapid seedling emergence - Suited to all species - No investment needed	- Expensive and slow - Equipment accumulates wear and tear - Residues remain from prior cash crop - Limits on equipment size	Pneumatic seed drill	30–65
Direct sowing	- Seed properly positioned - Only one pass needed - Contact between seeds and soil without the need for intensive soil preparation	- Crop residues can jam equipment - Equipment accumulates wear and tear - Limits on equipment size - No stubble ploughing	Specific seed drill needed (e.g., Unidrill, Semeato, Gaspardo Directa)	25–60

Table A: Advantages and disadvantages of different sowing methods (source: Poitou-Charente Chamber of Agriculture)

MANAGING COVER CROPS

FERTILISATION

Farm fertiliser can be used on cover crops. The use of high-nitrogen manure is not necessarily environmentally unfriendly. Except in the case of legumes, fertilisation levels of 40–60 kg N/ha can be used.

IRRIGATION

In regions where irrigation is possible, a single light pass can help the cover crop get started.

PLANT DEVELOPMENT

Cover crops should not be allowed to become woody or they will have a negative effect on the following cash crop—they will tie up nitrogen during decomposition, leading to nitrogen deficiency. Early-established or fast-growing cover crops can be cut whenever they start to bud or flower to keep them from bolting. In this way, the cover crop is broken down in several steps, reducing the likelihood that the following cash crop will be negatively impacted. Otherwise, early termination will be necessary.

It is recommended that farmers fertilise and irrigate cover crops only under specific circumstances, namely when the additional cost results in clear benefits (e.g., proper cover crop development). Crop rotation type will influence this decision, as will departmental regulations.

COVER CROP UNDERSOWING: ONE FARMER'S EXPERIENCE (DEPARTMENT OF OISE)

François Mellon, farmer

"For the last two years, I have been undersowing white clover in winter grains on my farm. The goal is to produce nitrogen for spring grains, maize, or barley, which follow the fallow period in the rotation. The results have been especially amazing with my grain maize—even though I did not use manure, it grew extremely well, as did the weeds! In 2010, we had a particularly hot, dry spring. We noticed that when we planted small-seeded legumes—we broadcast them with a Delimbe seeder—seedling growth was more heterogeneous than when we used a grain drill. For the last two years, I have successfully established a lucerne cover crop by undersowing in spring barley. I chose the method that is the most time intensive but that also seems to be the most effective: sowing with a disc grain drill. In the spring of 2011, conditions were good in March, and I decided to seed the white clover earlier than I had in 2010. The soil surface was still moist, and thus the clover seedlings emerged evenly, although I think I lost some later in the spring. When the harvest came around, the clover was still there. My fellow organic farmers seem to be having a different experience because they complain about the lack of legumes at harvest time.

TERMINATING COVER CROPS

When cover crops end up harming the following cash crop and soil structure, it is usually the result of poorly executed farming practices, such as terminating and turning under cover crops too late in the season or deeply turning under fresh organic matter.

These examples underscore the importance of proper cover crop termination.
It can be difficult to decide upon a termination date because the tendency is to let cover crops develop for as long as possible to maximise their agricultural benefits (e.g., soil protection, nitrogen fixation, nitrate capture, bolstering of beneficial soil microorganisms). However, the later the termination date, the greater the chance that the following cash crop will have a harder time getting established or that nitrogen and water availability will be limited. Farmers must also take into account their farm's equipment, their objectives/limitations (e.g., budget, work hours, tillage system), and the constraints imposed by the nitrates directive.

Shredded mustard plants

WHEN TO TERMINATE

It is important to carefully time cover crop termination so that high levels of nutrient mineralisation coincide with the following cash crop's period of uptake.

A SPECIES-DEPENDENT PROCESS

The termination date will depend on whether the cover crop is composed of legumes, grasses, or brassicas. It is important to know how fast the species goes to seed. Certain species, like forage radish, bolt quickly after becoming established and must therefore be terminated in the autumn. In contrast, if the cover is composed of legumes, which have a lower C/N ratio and a slower rate of development, then termination can occur later because the mineralisation process will occur more quickly.

MANAGEMENT OBJECTIVES

To increase soil organic matter, it is possible to let the cover crop become woody to attain the right C/N ratio.
If legumes have been planted with the objective of providing nitrogen to the following cash crop, then it is important to wait until the plants have flowered (which is when most legumes fix atmospheric nitrogen).
Finally, if the goal is to capture nutrients and limit nitrogen leaching (e.g., for agricultural, environmental, and regulatory reasons), termination should occur when the cover crop exhibits signs of nitrogen deficiency (which means soil nitrogen has been depleted). To limit nitrate leaching, the cover crop should remain in place during the months of October and November, which is when drainage occurs. It can then be terminated because the efficacy of nitrate capture diminishes over time.
To avoid issues related to cover crop termination, decomposition, and nitrogen release, it is necessary to consider the following cash crop's nitrogen requirements. For instance, if nitrogen needs to be available early on, termination should occur early (e.g., mid-November). For cash crops that do not need nitrogen until later, termination can occur later. In most departments, these recommendations are in line with nitrates-directive-related regulations.

IDENTITY OF THE FOLLOWING CASH CROP

- *Spring cash crops*: the cover crop must be terminated around two months before the following cash crop is sown, so that the residues can properly decompose and negative effects are avoided.
- *Autumn cash crops*: the cover crop can be terminated just before the following cash crop is sown without any negative repercussions—grains require less nitrogen in the autumn. Over the autumn and winter, before grains begin to grow, nitrogen from the cover crop will mineralise and groundwater resources will be recharged.

INFLUENCE OF SOIL TYPE

The speed of cover crop decomposition depends on soil type. For example, coming out of the winter, grasses and grains decompose very slowly in calcareous clay soils.
Soil type will also affect the degree of tillage. Cover crops may need to be terminated earlier on heavier soils because the latter dry more slowly. In contrast, termination can take place later on lighter soils that are compacted and well drained. Table B gives some recommendations for cover crop termination dates based on soil type, the following cash crop, and tillage system (till vs. no till).

Table B: Cover crop termination dates based on soil type, the following cash crop, and tillage system (source: ARVALIS)

Soil type	Following cash crop		
	Winter crop	**Spring crop**	**Maize, sunflower**
Well-drained silt, chalk, sand	Just before sowing	From mid-November to mid-December	From November to February (early March at the latest)
Silty clay, calcareous clay			- Till: starting on Nov. 15 - No-till: between Nov. 15 and early Feb
Clay	- No-till: just before sowing - Till: plan ahead for termination and tilling dates	- No-till: Nov. 15 - Till: plan ahead for termination and tilling dates	- No-till: from mid- November to mid- December - Till: plan ahead for termination and tilling dates

TERMINATION METHODS

Crushing, shredding, ploughing, tilling, and winter killing—there are many termination methods. Several factors must be considered when choosing a termination strategy.

AVAILABLE EQUIPMENT

The equipment that a farmer has available will affect the choice of cover crop species.

NO-TILL SYSTEMS

Farmers using no-till systems must employ cover crops that can be terminated in alternative ways, such as winter killing.

SOIL COMPACTION

If fields cannot be accessed during the winter because of the risk of compaction, farmers need to use winter-kill cover crops or cover crops that can be terminated mechanically in the spring. However, it is always crucial to monitor cover crops and intervene if necessary. For example, in the case of winter-kill species, if a freeze has not occurred by December 31, then a mechanical termination strategy will need to be used. The same is true if a species is observed to be in flower around mid- November—it must be prevented from bolting.

OBTAINING BENEFITS FROM COVER CROPS REQUIRES PROPERLY TERMINATING THEM

Each termination method has advantages and disadvantages. To preserve soil structure, cover crop termination should always take place under optimal conditions, regardless of the method used. Table C below summarises the advantages and disadvantages of different termination strategies.

Termination method	Advantages	Disadvantages	Mean cost (€/ha/use)
Ploughing	- Can be used on little-developed or frozen cover crops - Plants decompose quickly - Soil is prepared for planting of the following cash crop	- Expensive - Time intensive - Risk of deeply ploughing under large quantities of plant residues (i.e., refuges for insect pests, diseases, and weed seeds) - If the cover crop is well developed, it is better to shred the plants first to limit residue clumps	65–70 €
Shredding	- Recommended if biomass production >2 t DM/ha - Homogeneous distribution of cover crop residues - Small residues decompose quickly - If ploughing or stubble ploughing is carried out 1–4 days after shredding or crushing, plant residues and soils will have time to dry out	- Not effective on grasses or brassicas (except if preceded by ploughing) - Additional costs - Native fauna may be killed (better to shred from centre of field outwards) - Requires special equipment	50–55 €
Tilling (stubble ploughing)	- Soil is ready for the establishment of the following cash crop - No special equipment required - Plant biomass is well incorporated - Can be used on little-developed cover crops	- Expensive and time intensive - Much less effective on well-developed cover crops (shredding required)	20–25 €
Winter killing	- Free - Plant residues remain at the surface - No risk to compaction-sensitive soils - Preserves improvements to soil structure	- Limited to regions that experience freezes (-6°C) - Small selection of species - May require early mechanical termination (if no freeze)	0 €
Winter killing + crushing	- Plants break down quickly - Soil structure preserved if soil is frozen - Low cost - Low time investment	- Limited to regions that experience freezes; for use on well-developed cover crops (equivalent effect to stem pinching method) - Damage can occur to silty waterlogged soils—because the cover crop layer is flattened against the ground, it can slow or interfere with soil drainage in the spring - Requires special equipment (roller-crimper)	20–25 €

Table C: Advantages and disadvantages of different termination methods (source: Poitou-Charente Chamber of Agriculture)

MAIN COVER CROP SPECIES

(NON-EXHAUSTIVE LIST)

Plant family	Species	Winter-kill temperature	Root system
Legumes (Fabaceae)	Fenugreek	-7 °C	intermediate
	Spring faba bean	-5 °C	fibrous
	Winter faba bean	-10 °C	fibrous
	Grass pea	-10 °C	taproot
	Forage lentil	-7 °C	intermediate
	Bird's-foot trefoil	-10 °C	intermediate
	Lupin	DU	intermediate
	Lucerne	DU	fibrous
	Sweet clover	DU	taproot
	Black medic	DU	taproot
	Spring field pea	DU	fibrous
	Winter field pea	DU	fibrous
	Spring forage pea	-2 °C	fibrous
	Winter forage pea	-10 °C	fibrous
	Sweetvetch	-10 °C	fibrous
	Soybean	DU	intermediate
	White clover	DU	intermediate
	Berseem clover	-5 °C	intermediate
	Crimson clover	-10 °C	fibrous
	Red clover	DU	taproot
	Persian clover	-10 °C	intermediate
	Spring vetch	0 °C	taproot
	Winter vetch	-7 °C	taproot
	Legume regrowth	DU	intermediate
Grasses (Poaceae)	Spring oat	0 °C	taproot
	Winter oat	-13 °C	taproot
	Black oat (Brazilian cultivar)	-4 °C	taproot
	Foxtail millet	-1 °C	taproot
	Proso millet	DU	taproot
	Italian ryegrass	DU	taproot
	Rye	DU	taproot
	Sudan grass	-1 °C	intermediate
	Grain regrowth	DU	intermediate
Brassicas (Brassicaceae)	Camelina	-10 °C	fibrous
	Winter forage rapeseed	DU	fibrous
	Winter rapeseed	DU	intermediate
	Rapeseed regrowth	DU	fibrous
	Brown mustard	DU	fibrous
	White/yellow mustard (normal cultivar)	DU	intermediate
	White/yellow mustard (anti-nematode cultivar)	DU	intermediate
	Winter turnip rape	-13 °C	fibrous
	Forage radish	-13 °C	fibrous
Composites (Asteraceae)	Nyger	-1 °C	fibrous
	Sunflower	-3 °C	fibrous
Waterleafs (Hydrophyllaceae)	Blue tansy	-6 °C	intermediate
Knotweeds (Polygonaceae)	Buckwheat	-2 °C	intermediate
Linseeds (Linaceae)	Spring linseed	-10 °C	intermediate
	Winter linseed	-13 °C	intermediate

DU: data unavailable

METHOD FOR CHOOSING COVER CROPS

As we have seen, choosing a cover crop species (or species mixture) can be complicated. There are several factors to consider, and some are not easily characterised (e.g., precipitation in particular). Also, farmers must carefully consider how they will establish and terminate the cover crop; both are crucial steps. Choosing a cover crop for a given situation requires ranking the different relevant factors (see the approach described in the sidebar below).

This guide describes a method that helps facilitate the process. Circumstances vary—cover crop choice will depend on the farm and year. Consequently, this document seeks to provide farmers with tools for determining the cover crop that is right for them.

The schematic on the next page highlights the major issues to consider. It describes the different steps involved in choosing a cover crop species (or species mixture) and major concerns related to cover establishment and termination.

Oat and vetch

STEP 1: DEFINING CONSTRAINTS

Based on existing constraints, farmers can eliminate certain species and thus narrow down their list of possibilities. They can also filter out species based on crop rotation type, fallow-period duration, sowing date, and soil type.

STEP 2: RANKING OBJECTIVES

Farmers must choose one, two, or multiple cover crop management goals among those listed in this guide. Different species have different features that vary in how well they correspond to different goals.

→ Once these two steps have been carried out, the species best suited to a farmer's situation can be identified.

STEP 3: DEFINING SOWING/TERMINATION DATES AND METHODS

In this step, farmers must consider the sowing and termination dates and methods associated with the species on their initial list.

Sometimes farmers will not have the equipment required for the best-suited species; they will need to go through the species list again and filter accordingly.

→ Refine the initial species list (see Steps 1 and 2) based on the farm's equipment and both sowing and termination dates.

FINAL CHOICE

This entire process will lead to a selection of species that are best adapted to a particular situation. The farmer can then choose whether to utilise a single cover crop species or a species mixture. When making the final choice, other factors to consider include seed cost and seed availability (on the commercial market or as farm-saved seeds).

Nota bene: A farmer may wish to use other plant species for economic reasons (lower cost) or because they are already available on the farm. It is possible to use such species, which will be less well suited to the situation, if they are used in small quantities and in association with other species.

Recommendations for creating a good species mixture (see page 4).

Choosing the right species

1/ Define constraints

→ Use field-based constraints to filter species

I. Crop rotation/sequence

Exclude species presenting too many health risks

II. Sowing period

- **Undersowing** — *Exclude unsuitable species*

(Plan on overseeding into the grain depending on the technique used and whether the spring is wet)

- Late-summer sowing
  - Sowing before July 15 — *No particular constraints*
  - Sowing after Aug 15 — *Exclude unsuitable species*
  - Sowing after Aug 15 — *Exclude unsuitable species*
  - Sowing after Sept 1 — *Exclude unsuitable species*

III. Fallow-period duration

- **Long** — *No particular constraints*
- **Short** — *Exclude species with slow development (if seeding in late summer)*

IV. Soil type

Exclude unsuitable species

2/ Rank objectives

→ Choosing the right species based on management objectives

- **Nitrogen capture** (+ following regulations)
- **Maintenance of soil organic matter**
- **Nitrogen release to following crop**
- **Weed control**
- **Forage production**
- **Soil structure**
- **Pest control**

3/ Adapt dates and methods

→ Adapt species choice based on seeding date, termination date, and available equipment

Cover crop

- **Sowing date:**

  Post-harvest soil preparation? *(Late-summer sowing)*
  - Yes: *Sowing is delayed. Exclude unsuitable species.*
  - No: *Modify sowing date. Choose suitable species.*

- **Sowing method**

  Necessary equipment available?
  - Yes: *No constraints*
  - No: *Exclude unsuitable species*

- **Farm-saved seed available:**

  Are the seeds suited to the situation?
  - Yes: *Single-species or mixed cover crop*
  - No: *Exclude usage or include as part of mixture* *(If farmer really wishes to use them)*

Cover crop termination

- **Termination date:**

  Modify termination date based on key considerations (pg. 8)
  (Account for cover species [single or multiple], the following cash crop, soil type, management objectives, and local regulations)

- **Termination method**

  Required equipment available?
  - Yes: *No particular constraints* *(Note of caution: If it freezes, pay attention to exact temperature)*
  - No: *Exclude unsuitable species*

  No-till system?
  - Yes: *Exclude unsuitable species* *(Better to use winter-kill or non-taproot species)*

  Can soils withstand compression?
  - Yes: *Modify termination technique*
  - No: *Exclude unsuitable species* *(Better to use winter-kill species or terminate early)*

THE METHOD IN ACTION

THIS EXAMPLE INVOLVES A FARMER IN NORTHERN FRANCE

ANALYSIS OF THE SITUATION:

Located in the Nord Department, the farm grows cash crops.
It uses the following rotation: potato—wheat—faba bean—chicory—spring barley.
The farmer wishes to use cover crops in the fallow period between the spring barley and the potato. Once the barley has been harvested, the straw is collected and traded for manure, which is then spread on the fallow field by a contractor.

STEP 1: DEFINING CONSTRAINTS

I. CROP ROTATION AND SEQUENCE

To avoid any health risks to the crops, the identity of the preceding and following cash crops must be considered. However, no particular concerns were identified for either the spring barley or the potato.

II. SOWING DATE

The farmer must take into account two types of constraints:
- Technical constraints:
  - The barley is harvested late, around August 10–15. Consequently, the cover crop of choice should be one that can emerge and grow under the pedoclimatic conditions (temperature and soil moisture) typical of late summer. Since there is a high risk of seedling failure, the farmer should use a small-seeded species.
  - After the barley harvest, the farmer must collect the straw and spread the manure. Departmental regulations arising from the nitrates directive dictate that the manure must be spread before August 31.
    For this reason, the two tasks mentioned above must be performed between August 15 and 31. Therefore, the cover crop cannot reasonably be sown before September 1.
- Regulatory constraints: According to the Nord Department's prefectoral order implementing the nitrates directive, cover crops must be in place by September 15. This means that the cover crop must be sown before September 15.

The farmer therefore has a narrow window of action: sowing can only happen during the first half of September.

III. FALLOW-PERIOD DURATION

The fallow period between the spring barley (harvested by August 15) and the potato (planted around April 15–20) is relatively long, which means that the cover crop will have ample time to develop. Consequently, development rate is not a selection criterion.

IV. SOIL TYPE

The farm has silty soil, which does not impose any particular constraints on the cover crops that can be used. Soil type is therefore not a selection criterion.

RESULT 1 **The first two steps defined the sowing period (September 1–15). Because this window of time is narrow and occurs relatively late, it would be impossible to successfully plant certain species, such as clover, lucerne, fenugreek, and ryegrass.**

STEP 2: RANKING OBJECTIVES

The farmer has two main cover crop management goals:

I. CAPTURE NITROGEN

The cover crop must take up soil nitrates and make use of the nitrogen provided by the manure. Large-seeded grasses can accomplish this objective.

II. SUPPLY NITROGEN TO THE FOLLOWING CROP

The cover crop must provide nitrogen to the following cash crop. Legumes can accomplish this objective.

RESULT 2 **These goals narrow down the range of possibilities, and two types of species emerge: large-seeded grasses (e.g., winter oat, black oat [Brazilian cultivar], rye) and large-seeded legumes (e.g., faba bean, grass pea, forage lentil, winter forage pea, winter field pea, winter vetch).**

STEP 3: DEFINING SOWING/TERMINATION DATES AND METHODS

I. SUCCESSFULLY ESTABLISHING COVER CROPS

- SOWING DATE

Given the constraints identified in Step 1, the cover crop must be sown between September 1 and 15. Consequently, the species chosen must be able to germinate and grow at the temperature and humidity found at that time of year. The lentil can therefore not be used.

- SOWING METHOD

Before sowing can occur, the farmer must prepare the land by harvesting the straw, spreading the manure, and stubble ploughing the field (to mix plant residues and manure into the soil). The analysis in Steps 1 and 2 has identified that a mixture of large-seeded species should be used. The farmer can broadcast sow because the farm has the proper equipment.

II. COVER CROP TERMINATION

- TERMINATION DATE

To allow enough time for cover crop residues to decompose, termination must take place at least two months before the following cash crop is planted in the spring. In this case, that crop is potato (sowing date: April 15–20).
According to departmental regulations arising from the nitrates directive, cover crops must remain in place between September 15 and November 30. Consequently, termination can occur between December and February.

- TERMINATION METHOD

The farmer has access to the necessary equipment, except for the roller-crimper. He prefers not to plough. He ploughs once every five years, after the chicory crop, to restructure the soil. Chicory is harvested in November, after the rainy season. The soil is more vulnerable to compaction, and thus ploughing is necessary.
Winter killing seems to be the most suitable termination method in this case. It fits with the termination period (December to February) and pedoclimatic conditions (e.g., soil vulnerability to compaction, temperature). It is also the least expensive of the termination methods.

RESULT 3 Later-season, large-seeded species that can be broadcasted are best suited to this particular situation. Because of issues related to cover crop termination, winter-kill species would be best. As a result, the most appropriate winter-kill legume species are field bean, winter forage pea, winter field pea, and vetch. The farmer has chosen oat as the winter-kill grass.

There are therefore two cover crop mixtures suited to this situation:

- ⇨ **A faba bean-oat cover**: This is the obvious choice since the farmer already grows faba bean and can use farm-saved seeds. Using this cover would allow him to save money. This legume-grass mixture is also well suited to the farmer's goals and constraints. The faba bean will generate nitrogen for the following cash crop, and the oat will take up nitrates from the soil and manure. Furthermore, faba bean creates large quantities of biomass, which will guarantee good-quality cover.
- ⇨ **A vetch-oat cover**: Since faba bean comes around every five years in the rotation, it could be a better idea to use vetch (another large-seeded species) as a substitute in the cover crop mixture. In this way, disease and pest risks are reduced.

A cover crop for the fallow period between spring barley and potato: a management timeline

Preceding cash crop harvested: **spring barley**	Straw collected	Manure spread by contractor	Soil preparation (stubble ploughing)	Broadcast sowing + pass with a roller	Cover crop development **field bean + oat** or **vetch + oat**	Winter killing	Incorporation of cover residues based on pedoclimatic conditions	Establishment of following cash crop: **potato**
Aug 10–15	**Aug 15–31**			**Sept 1–15**	**Oct to Nov**	**Dec to Feb**	**Feb to March**	**April 15–20**

KEY POINTS:

- CAREFUL CHOICES

The use of fallow-period cover crops is required by law. However, cover crops can provide farmers with real benefits if properly implemented. By considering field and logistical constraints as well as management objectives, farmers can identify the species, termination date, and termination method that are right for their system.

- GOOD-QUALITY COVER

A good-quality cover crop will produce a maximum amount of biomass and thus provide a variety of benefits. However, cover establishment must be successful, and the termination method needs to account for the identity of the following cash crop. If not, the latter could be harmed (e.g., because of issues related to water or nitrogen availability), and the cover crop would fail to serve its intended purpose.

- SPECIES MIXTURES

Species provide numerous agricultural, environmental, and economic benefits. Complementarity among species allows the production of good-quality cover and optimal levels of biomass.

- EFFECTS ON THE FOLLOWING CASH CROP

If the cover is managed properly, the following cash crop will benefit from additional nitrogen, nutrient availability, and enhanced soil structure.

- EFFECTS ON SOIL

Organic matter, soil fertility, biodiversity, soil structure, healthier populations of beneficial soil microorganisms, and erosion control—this is a short list of the positive effects of cover crops on soils.

VENTURING EVEN FURTHER…

ADDITIONAL POSSIBILITIES

- No-till farmers are already taking advantage of cover crop systems utilising mulch (dead or living): their proficient use on organic farms may represent the next natural step to planting fallow-period cover crops. These systems allow the soil to remain almost permanently under cover.

- In a living mulch system, the cover crop (e.g., lucerne) can remain in the field for several years. The cash crop is planted directly through the living cover crop. After the harvest, the cover crop is left alive (no need to resow it) and remains functional.

- Cover crop sowing can take place as the cash crop is being harvested (sowing apparatus attached to the combine harvester) or just before the harvest takes place. In general, small-seeded species are used. Although this technique is simple and inexpensive, it may produce unpredictable results in the absence of rainfall.

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