FRANCE WP3


Mons
Bonvilliers
Vallangoujard
Saint Hilaire en Woevre
L'Épine
Boigneville
St Martin des Champs
Nancy
Crenay
Lapan
Plaimpied-Givaudins
Rians
Vomay
Gémeaux
Bergerac

WP3 – EXPERIMENTAL TRIALS ON ANNUALLY DRILLED CROPS IN NARROW ROWS

Several WP3 themes were studied during the 2018-2019 season within the IWMPRAISE project:

- delaying the sowing date;
- integration of agronomic levers (soil tillage);
- mechanical weeding.

DELAYED SOWING OF WHEAT

Trials combining herbicide and insecticide programmes have been implemented in winter wheat and winter barley to answer the following questions:
- Does a sowing-date delay of about 20 days limit the density of emerged weeds and/or aphid infestations?
- Which control methods are the most appropriate and for which yield differential?
- Does weed-control quality have an impact on the epidemiology of Barley Yellow Dwarf Virus (BYDV)?
- What is the variability of these responses?

In the five wheat trials implemented, no incidence appeared between BYDV and weeds, as pest populations were very low or not present. This report will therefore only include herbicide treatments comparable with the same insecticide programmes to control aphids, vectors of the BYVD. Only the impact on weed management will be studied in these trials. Thus, 0.075 litres of Karate Zéon was applied in all of the treatments studied in the five trials.
The trials, as well as the processes put in place, are described in Table 2 below. Two trials have been set up in Gemeaux (21 – Bourgogne-Franche Comté) on the same plot: the Minimum Tillage (MT) trial was set up on a strip worked under intercultural shallow tillage; while the Direct Seeding (DS) trial was mirrored from this trial on the direct seeding plot.

These trials were implemented on wheat, peas and oilseed rape, according to the following table:

Topic	Partner	Location
Delayed sowing in wheat	Arvalis	Gémeaux (21) L'épine (51) Crenay (52) St Hilaire en Woëvre (55)
Integration of an IWM tool before sowing of wheat	Arvalis	St Hilaire en Woëvre (55)
Comparison of early mechanical weed control strategies (tine harrowing) in wheat	Arvalis	Bergerac (24) Lapan (18) Plaimpied-Givaudins (18)
	CA IdF	Bonvilliers (91) St Martin des Champs (78) Vallangoujard (95)
Mechanical weed control (hoeing) in triticale	Arvalis	Boigneville (91)
Soil tillage strategies, without glyphosate, before sowing spring peas	Terres Inovia	Rians (18)
Mechanical weed control, with or without herbicides, in oilseed rape	Terres Inovia	Mons (80) Nancy (54)
Associated crops in organic farming to prevent weed infestation	Terres Inovia	Rians (18)
Long-term experiment on IWM-based weed control compared to a reference cropping system (OSR/WW/WB)	Fdgeda 18	Vomay (18)

Table 1 - WP3 trials managed by the National French Cluster (number of geographical Department in brackets)

Trials	Gemeaux MT (21)	Gemeaux DS (21)	L'Epine (51)	Crenay (52)	Saint-Hilaire-en-Woëvre (55)
Weeds	Blackgrass	Blackgrass	Blackgrass	Blackgrass	Matricaria, volunteer OSR, and field pansy
Resistance status	/	/	Beginning of resistance in the field	Beginning of resistance in the field	/
Soil	Sandy clayey loam	Sandy clayey loam	Chalk	Clay and limestone superficial on hard limestone	Hydromorphic loam
Variety		Unik	Fructidor	Boregar	Chevignon
Sowing date 1	01/10/2018	01/10/2018	02/10/2018	05/09/2018	21/09/2018
Sowing date 2	24/10/2018	24/10/2018	18/10/2018	27/09/2018	11/10/2018
Sowing date 3	/	/	09/11/2018	16/10/2018	/

Table 2 - Trials on delayed sowing of wheat in France
Herbicides were adopted in each trial, as described in Tables 3, 4 and 5 below.
Fosburi = diflufenicanil + flufenacet
Tolurgan = chlortoluron
Atlantis Pro = mesosulfuron-me + iodosulfuron-me-na
Actirob B = esterified rapeseed oil
Actimum = ammonium sulphate
Défi = prosulfocarb
Flight = picolinafen + pendimethalin
Daiko = prosulfocarb + clodinafop-propargyl + cloquintocet-mexyl

Early post-emergence 1-2L	End of winter (tillering)	Price (in €/ha)
Fosburi 0.5L + Tolurgan 50SC 3L	/	77.9
Fosburi 0.5L + Tolurgan 50SC 3L	Atlantis Pro 0.9L + Actirob B 1L + Actimum 1L	124

Table 3 - Herbicides trial set up in Gémeaux

Pre-emergence	Early post-emergence 1-2L	End of winter (tillering)	Price (in €/ha)
/	/	Atlantis Pro 0.9L + Actirob B 1L + Actimum 0.5L	43.6
Défi 2L + Flight 3L	Fosburi 0.5L + Tolurgan 50SC 3L	/	146.7
/	Fosburi 0.5L + Tolurgan 50SC 3L	Atlantis Pro 0.9L + Actirob B 1L + Actimum 0.5L	121.5

Table 4 - Herbicide trials set up in Crenay & L'Epine

Early post-emergence 1-2L	End of winter (tillering)	Price (in €/ha)
Fosburi 0.5L + Daiko 2.25L + Actirob B 1L 50SC 3L	/	80.3
Fosburi 0.5L + Daiko 2.25L + Actirob B 1L 50SC 3L	Atlantis Pro 0.9L + Actirob B 1L + Actimum 1L	126.4

Table 5 - Herbicide trial set up in Saint-Hilaire

As occurred in previous campaigns, the 2018-2019 trials highlighted the importance of delaying the sowing date in wheat when grass-weeds are present. The shortest delay was about 20 days between early and mid-October; the delays were mostly equivalent to a sum of nearly 200 degree days (base 0°C). A shift of 200 degree days allowed a reduction in the populations of blackgrass and ryegrass. Efficiencies were variable and ranged from 18% to 87%. For a shift of 200 degree days, the average reduction observed was close to 60%. As the sum of the degree days increased between the two trial seeding dates, the reduction in the weed populations of untreated controls also increased. Thus, with delays of 250 to 300 degree days, efficiencies are between 60% and 82%, with a 70% average. Both trials saw reductions close to 85% between 350 and 400 degree days. Within the five trials of this campaign, the effects of a 50%-plus reduction were visible on blackgrass in three out of the five trials. One of the trials had a low impact, but had a very low infestation, while the fifth trial included three broadleaved weeds which were partially impacted.

Effects on yields and economic margin were visible in three trials, confirming the value of this method. However, the idea is not to switch to the general recommendation of postponing the sowing date. These practices are effective when conditions are so ready, so they must be implemented on heavily infested fields, i.e. where weed control has failed and/or resistance is a problem, or on reduced populations in order to limit the amount of herbicide. In small populations (Gemeaux No Till trial), loss of potential can compensate for loss via less competitive weeds, so it would not be wise to postpone the sowing date on clean fields.

On difficult fields, the economic risk of a 20-day delay in wheat is limited, even in a rainy autumn.

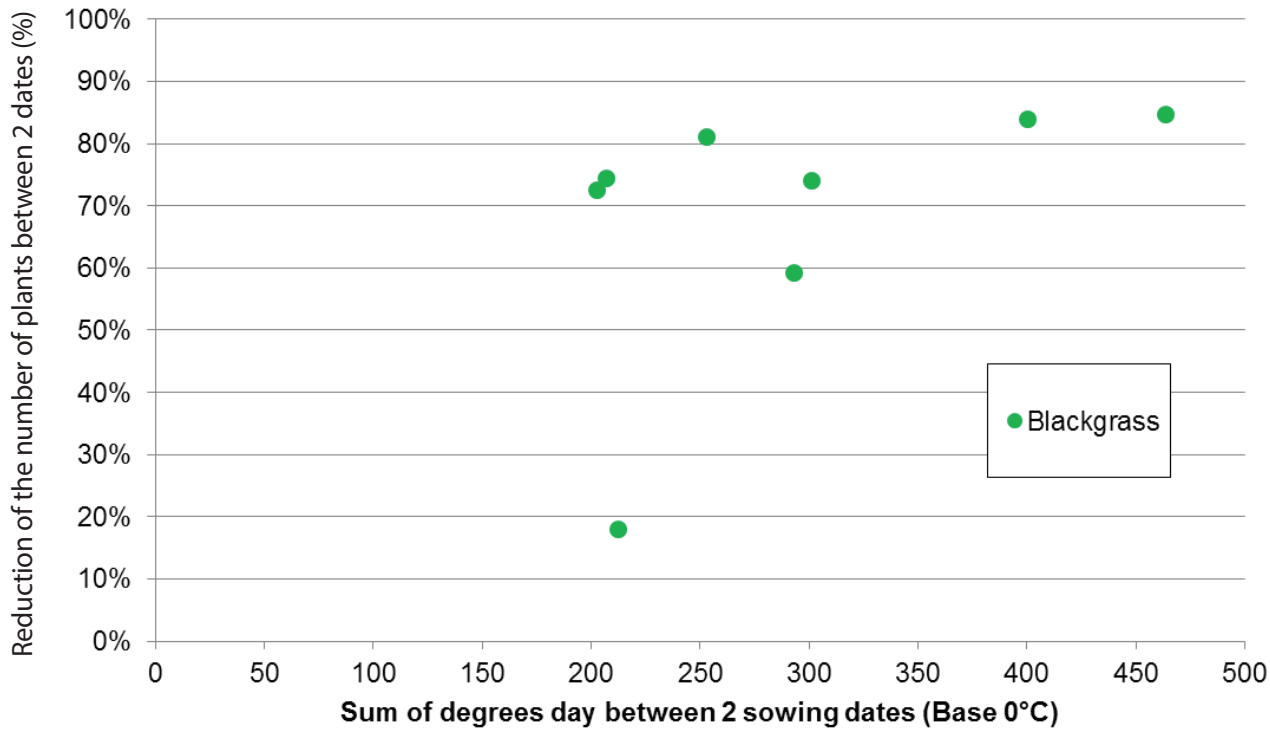


Figure 1 - Effect of delayed sowing on grass populations in wheat (%)

INTEGRATION OF AN IWM TOOL BEFORE SOWING OF WHEAT

A trial was implemented in Saint Hilaire-en-Woëvre (55) with a comparison of soil tillage before wheat was drilled, crossed with herbicide programmes in cultivation. The table below summarizes the treatments put in place.
The plot compares a "Ploughed" and a "No Till" situation infested with blackgrass. The technical itinerary included a passage with an Optimer stubble cultivator (by Kuhn) on the entire plot on 7 July 2018. The ploughing was performed on 20 August 2018, with subsoil being added to the "No Till" (NT) part on the same day. After this, the itinerary was the same on both parts: two passages with a rotary harrow to refine the seedbed (21 August and 27 August), then the sowing on 3 October 2018 (combined rotary harrow + disc sowing machine).

Figure 2 - Field visit during the Gémeaux trials on 27/05/2019

Blackgrass counts were carried out after sowing on 25 October 2018. Overall, 400 blackgrass plants/m² were found in the "No Till" part and only 2 blackgrass plants/m² in the "Ploughed" part.

Soil tillage	Sowing date & Variety		Herbicides	Stage & Dates
Ploughing (20/08/2018)	2 passes with rotative harrowing (21/08/2018 + 27/08/2018)	KWS Extase, 3/10/2018 (320 seeds/m²)	DÉFI+CODIX 2L+2L	Pre-emergence (05/10/2018)
			FOSBURI 0.5L DAIKO+FOSBURI+H 2.25L+0.5L+1L	1-2 leaves (17/10/2018)
			DÉFI+CODIX 2L+2L then DAIKO+FOSBURI+H 2.25L+0.5L+1L	Pre-em fb 3 leaves (5/10/2018 then 5/11/2018)
No till (Sub soiling on 20/08/2018)			DÉFI+CODIX 2L+2L ATLANTIS PRO+H+ACTIMUM 0.9L+1L+1L	Pre-em fb tillering (5/10/2018 then 20/02/2019)
			DAIKO+FOSBURI+H 2.25L+0.5L+1L 1-2F then ATLANTIS PRO+H+ACTIMUM 0.9L+1L+1L	1-2 leaves fb tillering (17/10/2018 then 20/02/2019)
			ATLANTIS PRO+H+ACTIMUM 0.9L+1L+1L TallFinTall	tillering (20/02/2019)

Table 6 - Experimental plan of trial on integration of an IWM tool before sowing of wheat in Saint Hilaire-en-Woëvre.
Défi = prosulfocarb
Codix = diflufenicanil + pendimethalin
Fosburi = diflufenicanil + flufenacet
Daiko = prosulfocarb + clodinafop-propargyl + cloquintocet-mexyl
H = Actirob B = esterified rapeseed oil
Atlantis Pro = mesosulfuron-me + iodosulfuron-me-na
Actimum = ammonium sulphate

This trial illustrates the complementarity between agronomic levers and weed control in cultivation. In very infested situations (in this case, no-till with 400 blackgrass plants/m²), even the best herbicide programme will not be able to control weed populations. This will result in an economic loss (unprofitable investment) and re-infestation of the field. However, weed control in cultivation on only a few blackgrass plants/m² allows better control of the population in the ploughed part, even when it is not perfect. A limited herbicide programme in the ploughed part can achieve a very good result when compared to the NT part. Doubling the programme in the NT part failed to achieve the efficiency of the "light" programme in the ploughed part.

COMPARISON OF EARLY MECHANICAL WEED CONTROL STRATEGIES (TINE HARROWING) IN WHEAT

Six trials were set up. The main objective of four was to study the early passages of a weed harrow (sometimes pre-emergence) and their frequency, crossed with the herbicide programmes. Only three trials were usable, and one trial had to be abandoned due to a lack of weeds.
In the three usable ARVALIS-led trials, the results were very variable, with tine harrowing showing limited efficiency. The herbicides used ensured a good performance, even when doses were limited.

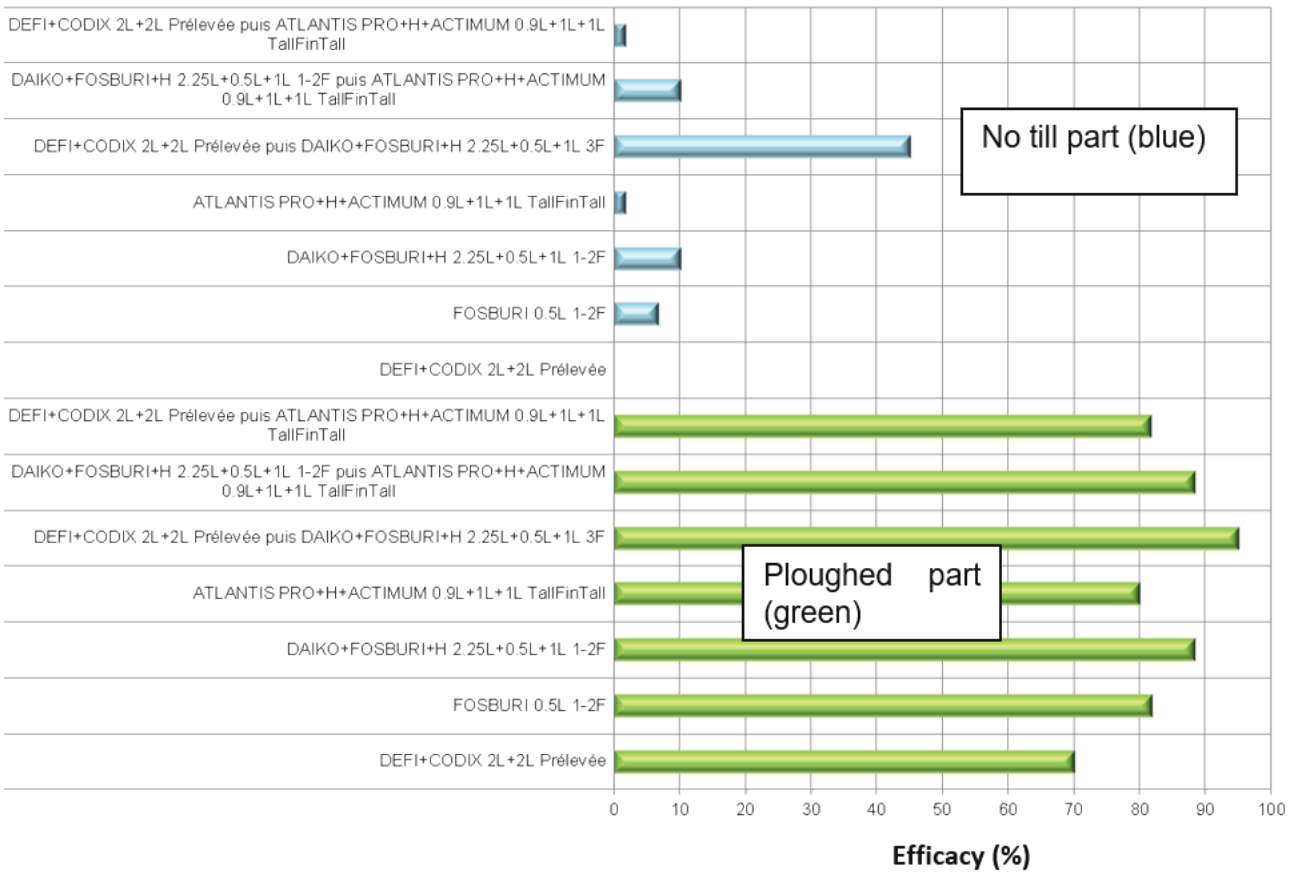


Figure 3 - Effect of ploughing of wheat/herbicide programmes on foxtail populations in wheat (%)

TRIAL IN BERGERAC

Itinerary	Dates of pass	Herbicides	Weeds
Sowing	30/10/2018	TROOPER 2.5L 1-2F FOSBURI 0.6L 1-2F NESSIE 1L 1-2F PICOSOLO 0.08KG 1-2F PICOTOP 1.3L Tall/FinTall PIXXARO EC 0.5L Tall/FinTall FOSBURI 0.6L 1-2F then PICOTOP 1.3L Tall/FinTall	*Papaver rhoeas* (≈50 pl/m²) *Senecio vulgare* (25 pl/m²) *Juncus bufonius* (12 pl/m²)
Herbicide 1-2 leaves	20/11/2018		
Tine harrowing no. 1 – 3 leaves	28/11/2018		
Tine harrowing no. 2	19/02/2019		
Herbicide (tillering)	22/02/2019		

Table 7 - Mechanical weed control strategy in wheat in the Bergerac trial
Trooper = flufenacet + pendimethalin
Fosburi = diflufenicanil + flufenacet
Nessie = bromoxynil + diflufenicani
Picosolo = picolinafen
Picotop = picolinafen + dichlorprop-p
Pixxaro EC = haloxyfen-me +fluroxypir + cloquintocet-mexyl

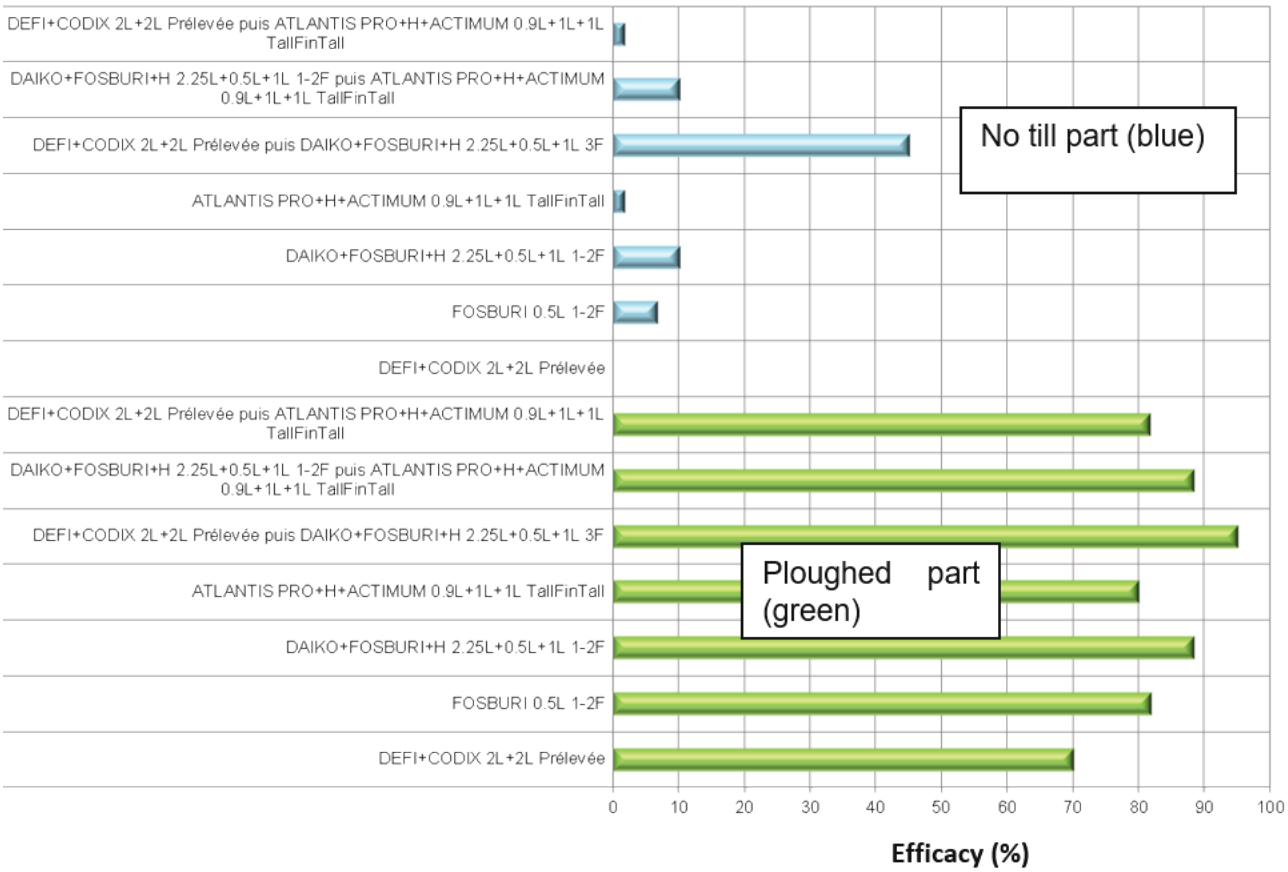


Figure 4 - Efficacy of mechanical weed strategy in the Bergerac trial

TRIAL IN LAPAN

Itinerary	Dates of pass	Herbicides	Weeds
Sowing	19/10/2018	DÉFI+CODIX 3L+1.5L pre-emergence DÉFI+FOSBURI 2.5L+0.5L 1-2F DÉFI+CODIX 3L+1.5L pre-emergence then FOSBURI 0.6L 1-2F DÉFI 2.5L + FOSBURI 0.5L then ARCHIPEL DUO 1L + ACTIROB_B 1L + ACTIMUM 1L ARCHIPEL DUO 1L + ACTIROB_B 1L + ACTIMUM 1L	Rye-grass (400 pl/m²)
Herbicide pre-emergence	23/10/2018		
Tine harrowing no. 1 – pre emergence	23/10/2018		
Herbicide 1-2 leaves	16/11/2018		
Herbicide tillering	05/02/2019		
Tine harrowing no. 2	25/02/2019		
Tine harrowing no. 3	22/03/2019		

Table 8 - Mechanical weed control strategy in wheat in the Lapan trial
Défi = prosulfocarb
Codix = diflufenicanil + pendimethalin
Fosburi = diflufenicanil + flufenacet
Archipel Duo = mesosulfuron-me + iodosulfuron-me-na
Actirob B = esterified rapeseed oil
Actimum = ammonium sulphate

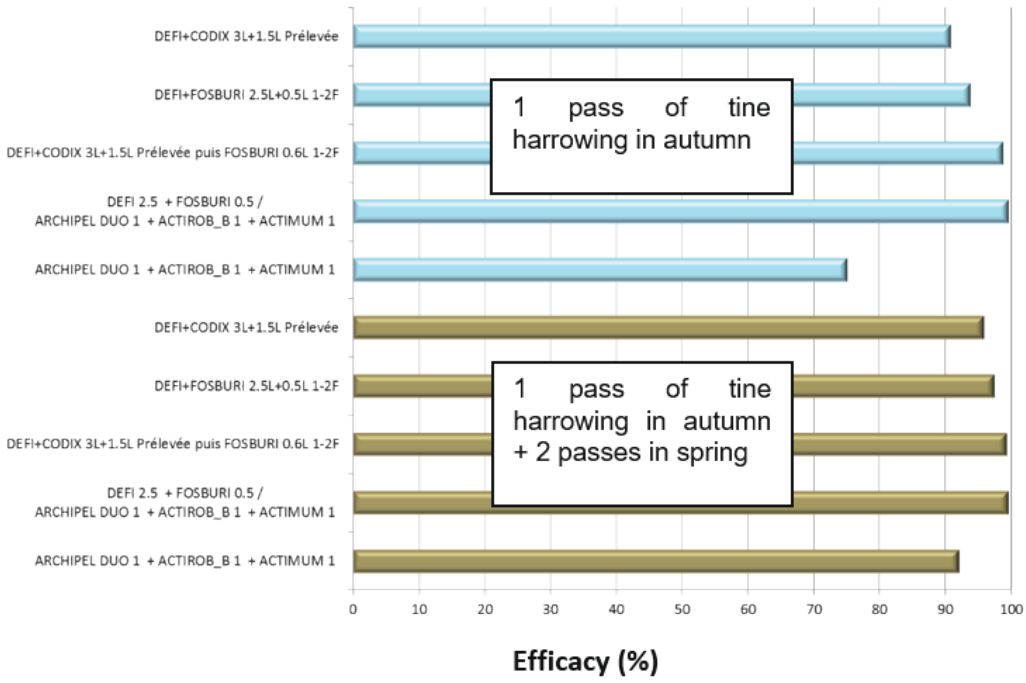


Figure 5 - Efficacy of mechanical weed strategy in the Lapan trial

TRIAL IN PLAIMPIED-GIVAUDINS

Itinerary	Dates of pass	Herbicides	Weeds
Sowing	12/10/2018	DÉFI+FLIGHT 2L+3L pre-emergence DAIKO+FOSBURI+H 2.25L+0.6L+1L 1-2F DÉFI+FLIGHT 2L+3L pre-emergence then DAIKO+FOSBURI+H 2.25L+0.6L+1L 1-2F DAIKO+FOSBURI+H 2.25L+0.6L+1L 1-2F then ATLANTIS PRO+H+ACTIMUM 1.5L+1L+1L TallFinTall ATLANTIS PRO+H+ACTIMUM 1.5L+1L+1L TallFinTall	Blackgrass (5 pl/m²)
Tine harrowing no. 1 – pre emergence	16/10/2018		
Herbicide – pre-emergence	18/10/2018		
Herbicide 1-2 leaves	10/11/2018		
Herbicide Tillering	05/02/2019		
Tine harrowing no. 2	22/02/2019		

Table 9 - Mechanical weed control strategy in wheat in the Plaimpied-Givaudins trial
Défi = prosulfocarb
Flight = picolinafen + pendimethalin
Daiko = prosulfocarb + clodinafop-propargyl + cloquintocet-mexyl
Fosburi = diflufenicanil + flufenacet
H = Actirob B = esterified rapeseed oil
Atlantis Pro = mesosulfuron-me + iodosulfuron-me-na
Actimum = ammonium sulphate

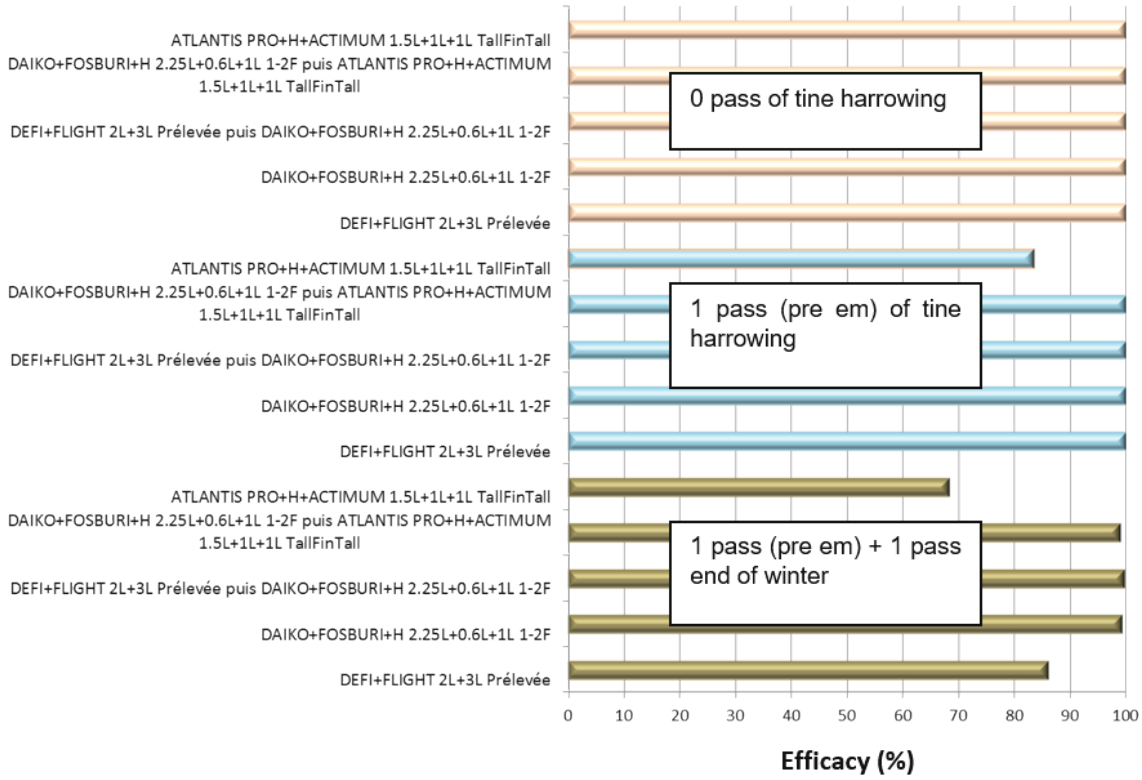


Figure 6 - Efficacy of mechanical weed strategy in the Plaimpied-Givaudins trial

In conclusion, these three trials did not show a strong trend towards effective integration of mechanical weeding. In Lapan trial, we observed that when combined with herbicides harrowing shows little interest in situations of heavy infestations. The conclusions were more mixed for the two other trials, with mechanical weeding proving to be very low efficiency, or even counterproductive.
Nevertheless, these trials will be implemented again in 2019-2020.

"ILE DE FRANCE" CHAMBER OF AGRICULTURE TRIALS

Three trials were set up by the partner "Ile de France" Chamber of Agriculture.
One trial was located in Saint-Martin-des Champs (78) in a field moderately infested by blackgrass. The goal of this trial was to find ways to complement chemical treatment. Over the last few years, weed infestation has not been sufficiently eradicated. The field was last ploughed in August 2017.

Wheat was sown at a minimum depth of 3-4 cm in order to protect seedlings from harrowing. Sowing density was increased by 15-20% in order to prevent wheat losses due to mechanical intervention.
In this trial, delaying the sowing date was the most effective way to prevent weed infestation.
For the first sowing date (5 October), all mechanical treatments were found to improve the efficiency of the chemical programme by 31% to 74%. We found that the more the plots were harrowed, the better the efficiency. These results confirmed those from last year's experiments, and they also confirmed that a combination of mechanical and chemical treatments is of interest.
For the second sowing date (25 October), late sowing was sufficient to achieve good weeding results.
The use of a harrow did not improve the results, but rather degraded them because it boosted the emergence of black-grass seeds.
To conclude, when the soil was clean, it should not be tilled in order to prevent weed emergence.
Figure 8 below shows the density of black-grass observed in June 2019 before harvest.

One trial was conducted in Bonvilliers (91) in a plot highly infested by ryegrass (80 to 650 plants/m²).
Chemical weeding was no longer satisfactory and needed to be supplemented with other control methods.
The goal of this trial was to compare 100% mechanical weed control, 100% chemical weed

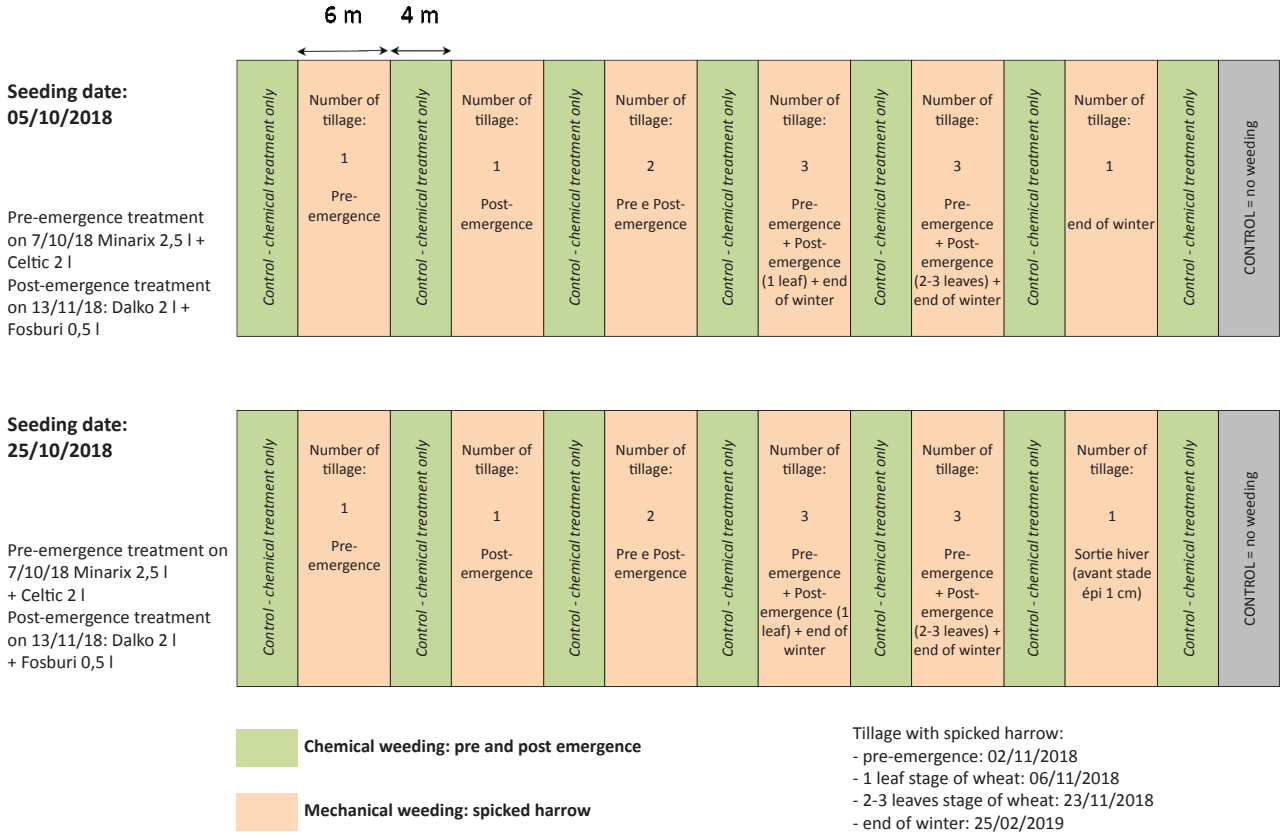


Figure 7 - Test protocol in Saint Martin des Champs (south of Paris)

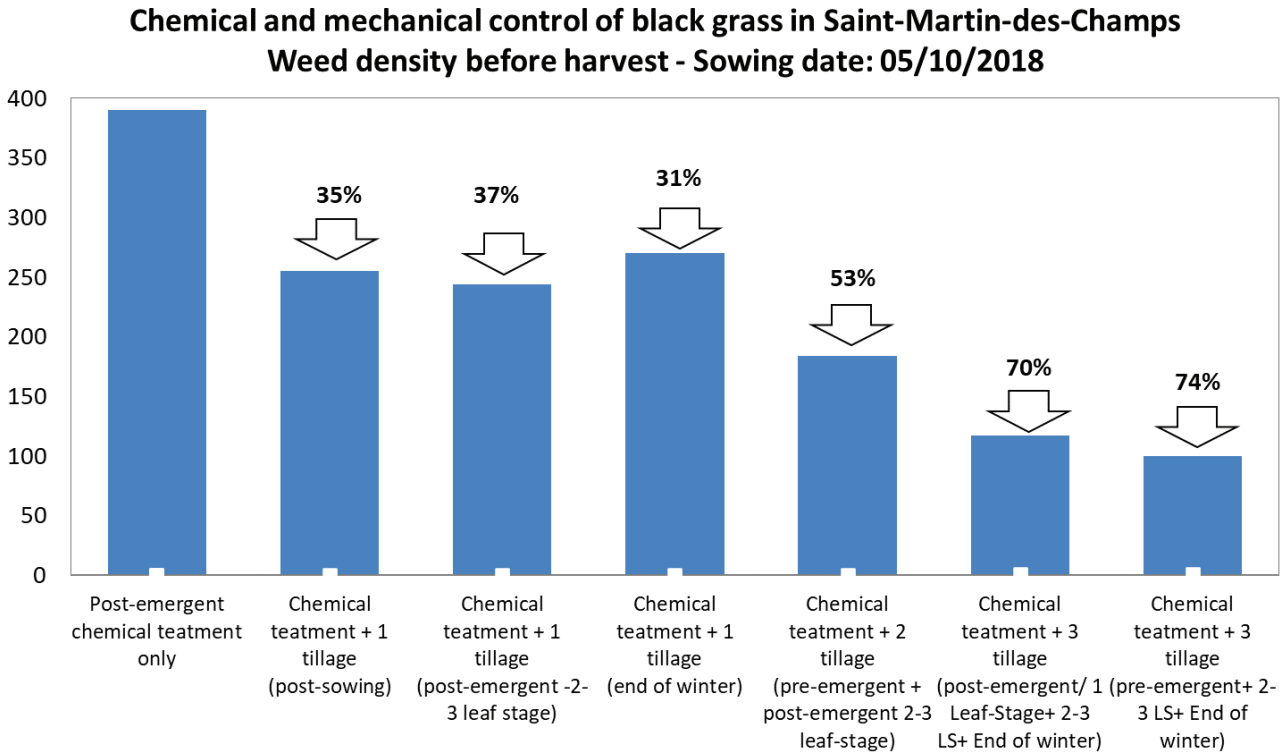


Figure 8 - Effect of chemical and mechanical control on weed density (black-grass) in the St Martin des Champs trial

Figures 9, 10 and 11 - Guided visit of the Test Platform on 4 June 2019 (85 visitors)

control and chemical weed control supplemented with spring soil tillage.

Two types of weeding methods were tested, as was a pre- and post-sowing chemical treatment:
- Delayed sowing (early = 5 October or late = 25 October sowing)
- Mechanical weeding = tine harrow, 1 to 3 passes.

Harrowing dates were:
- in pre-emergence phase: 2 November
- 1-leaf stage of wheat: 6 November
- 2-3-leaf stage of wheat; 23 November
- after winter: 25 February

Wheat seeds were sown at a minimum depth of 3-4 cm in order to protect seedlings from harrowing. Sowing density was increased by 15-20% in order to offset wheat losses due to mechanical intervention. The chemical treatment, applied on 2 November on some of the plots, was carried out on moist soil without ryegrass. Poor weather conditions in autumn made it impossible to implement mechanical weed control. Chemical weeding had 85% efficiency, but due to the very high weed infestation, there were still 100 ryegrass plants/m^2 by the end of winter. Harrow operations were performed on 25 February on dry surface soil. In the following days, weeds that were pulled out died quickly thanks to dry weather conditions. The rotating harrow, however, was rarely

Date of seeding : 23/10/2018
Seeding depth : 3-4 cm
Seeding density increased by + 15-20 %

Dates of passes
1- February 25th and 28th, 2019
2- March 28th, 2019

		1	2	3	4	5	6		7	8	9	10	11	12	
Fall herbicide	CONTROL	H-Φ	Φ-H	H-H	R-Φ	Φ-R	R-R	CONTROL	HR-Φ	Φ-HR	HR-HR	HH-Φ	Φ-HH	HH-HH	CONTROL
No herbicide		H-Φ	Φ-H	H-H	R-Φ	Φ-R	R-R		HR-Φ	Φ-HR	HR-HR	HH-Φ	Φ-HH	HH-HH	

6m 3m

LEGEND
R = Rotary harrow H = tine harrow Φ= no tillage

Figure 12 - Experimental protocol in the Bonviliers trial (south of Paris)

	1	2	3	4	5	6	7
Soil tillage 2017-2018	Pseudo ploughing	False seed bed	Direct sowing without vegetative cover	Direct sowing with vegetative cover	False seed bed	Pseudo ploughing & False seed bed	Ploughing & False seed bed
Type of seeder 2018	Disc harrow	Disc harrow	Disc harrow	Disc harrow	Rotary harrow	Rotary harrow	Rotary harrow
Soil tillage 2018-2019	**Pseudo ploughing (15-20 cm depth)**	**False seed bed (3 cm) with rotary harrow**	**Direct sowing without vegetative cover**	**Direct sowing with vegetative cover**	**False seed bed (3 cm)**	**Pseudo ploughing & False seed bed**	**Ploughing & False seed bed**
Type of seeder 2019	Disc harrow	Disc harrow	Disc harrow	Disc harrow	Rotary harrow	Rotary harrow	Rotary harrow

Table 10 - Protocol of Vallangoujard trial

more aggressive towards the crop than towards weeds.
The second mechanical treatment took place on 28 March. The soil was dry, and the teeth of the harrow had difficulty digging into the ground. The harrow had to be used another time in order to remove ryegrass.
In this trial, mechanical weeding with normal and rotative harrowing was very disappointing. Only three plots were slightly better than the control, but they failed to provide a satisfactory level for farmers.

The last trial was set up in Vallangoujard, to the north west of Paris.
The objective was to test a range of mechanical weed-management strategies on ryegrass.

The lowest ryegrass infestation was observed in plots that were ploughed deeply in autumn 2017 (Strategies 7 and 6). The worst result was obtained in the direct-seeded plot with cover. In this plot,

Figure 13 - Field trial visit in Bonvilliers (2019)

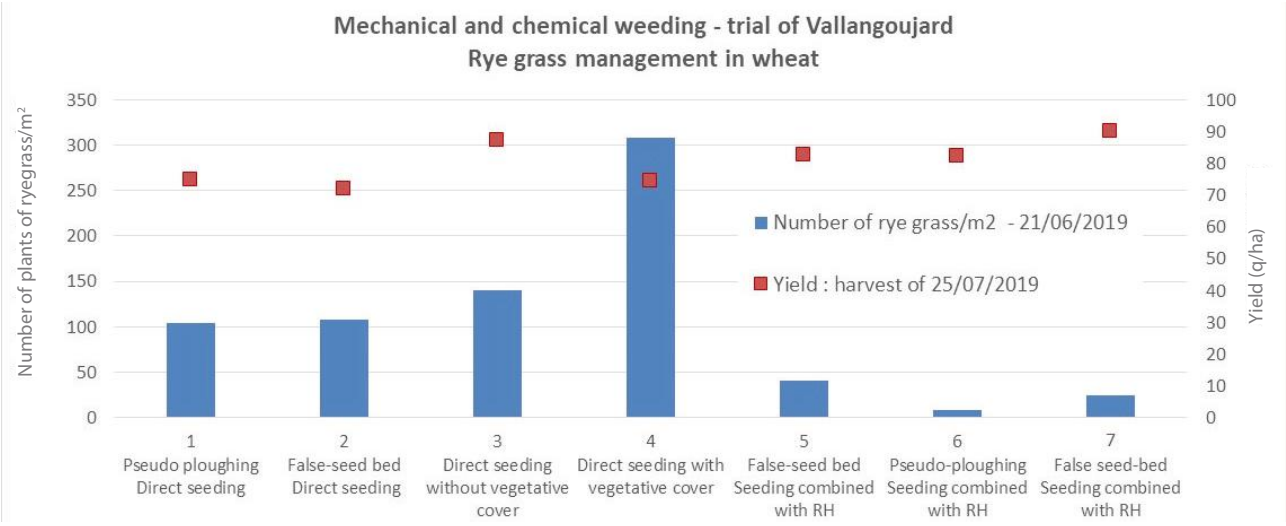


Figure 14 - Effect of mechanical and chemical weeding on ryegrass

1 Pseudo ploughing Direct seeding	2 False-seed bed Direct seeding	3 Direct seeding without vegetative cover	4 Direct seeding with vegetative cover	5 False-seed bed Seeding combined with rotary harrow	6 Pseudo-ploughing Seeding combined with rotary harrow	7 False seed-bed Seeding combined with rotary harrow
4	4	3	1	5	7	6

Acceptability score
Scale: 0 = control to 10 = no ryegrass

Table 11 - Acceptability score for the various ryegrass-control strategies

chemical treatment in autumn did not reach the growing ryegrass plants that were protected by the cover.
Before harvest, the visual appearance of the plots was rated by consultants from the Ile-de-France Chamber of Agriculture. The purpose of the rating was to reflect acceptability of grass infestation by farmers. As we can see in Figure 14, the number of ryegrass plants was well-correlated to the rating. However, yield data did not illustrate these observations. This discrepancy was due to the heterogeneity of plot infestation in the band test.

MECHANICAL WEED CONTROL (HOEING) IN TRITICALE

Hoeing seems to be the most effective mechanical tool on developed weeds, but this control method deserves further investigation to evaluate expected efficiency and feasibility. Currently, where resistance to herbicides (ACCase and ALS inhibitors [HRAC A and B groups]) continues to increase, hoeing could be used to complement autumn applications of herbicides (the only herbicide applications still effective on such ryegrass resistant populations). Two new trials were set up in Boigneville (91) in 2019 in order to determine whether hoeing would be of interest for catching up on autumn herbicide strategies. The two trials were set up on a triticale plot historically under direct seeding. In 2018, part of the plot was ploughed, while the rest was kept under direct seeding. Each area hosted a trial (same

Mechanical weed control	Products & Doses Pre-emergence	Early post-emergence 1-2 leaves
	Control	
-	/	Défi 2.5 l
	Trooper 2 l	Défi 2.5 l
Hoeing in spring followed by tine harrowing	/	Défi 2.5 l
	Trooper 2 l	Défi 2.5 l
2 passes of hoeing in spring followed by tine harrowing	/	Défi 2.5 l
	Trooper 2 l	Défi 2.5 l
Full mechanical weed control = tine harrowing in autumn followed by 3 passes of hoeing in spring	/	

Table 12 - Mechanical weed control (hoeing) in triticale at the Boigneville trial
Défi = prosulfocarb
Trooper = flufenacet + pendimethalin

protocol as below, but with historical differences). The two trials in triticale have the same protocol. The only difference is the soil tillage history: one part was ploughed in 2017, the other part is still conducted under conservation tillage.
All plots were sown at a row spacing of 15 cm to allow the hoeing machine (Garford model self-guided by camera) to pass between the rows. Hoeing was performed on 21 February, 28 March and 12 April 2019. Only the first two passes were followed by a harrow, as the triticale had reached stage 1 node during the third pass on 12 April. A harrowing operation after hoeing enabled small clods to be 'broken' and transplanting to be limited. Climatic conditions before and after each pass of mechanical weeding were optimal.

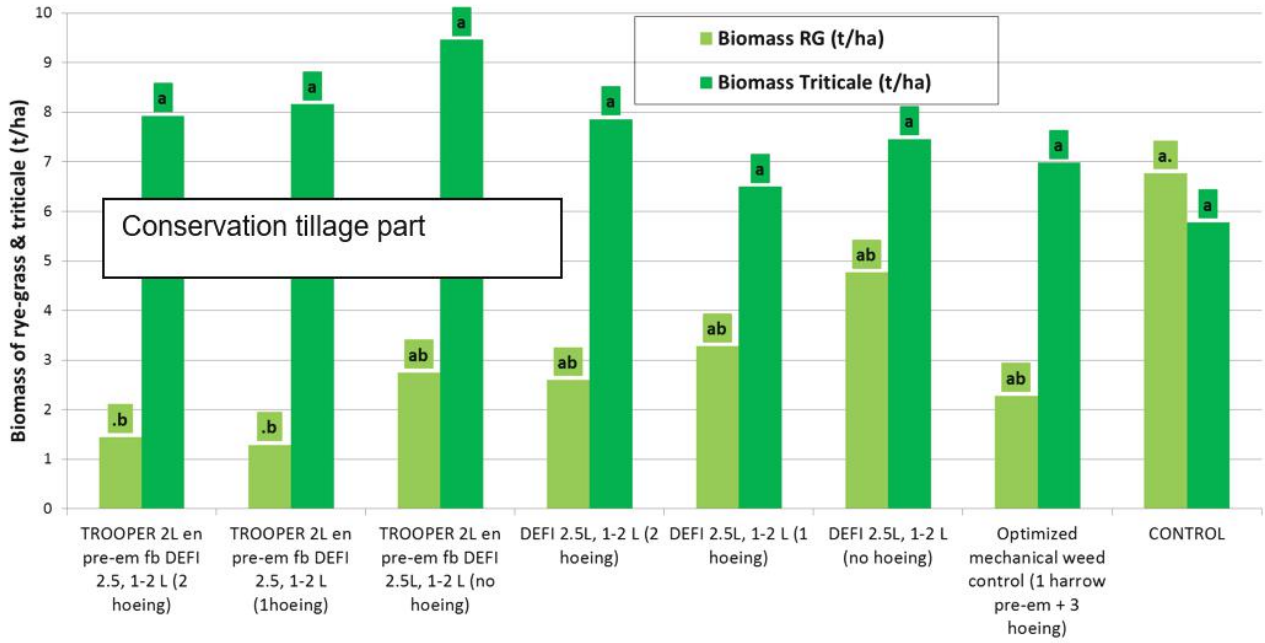


Figure 15 - Biomass of ryegrass and triticale according to various mixed weeding programmes with conservation tillage (. = significantly different)

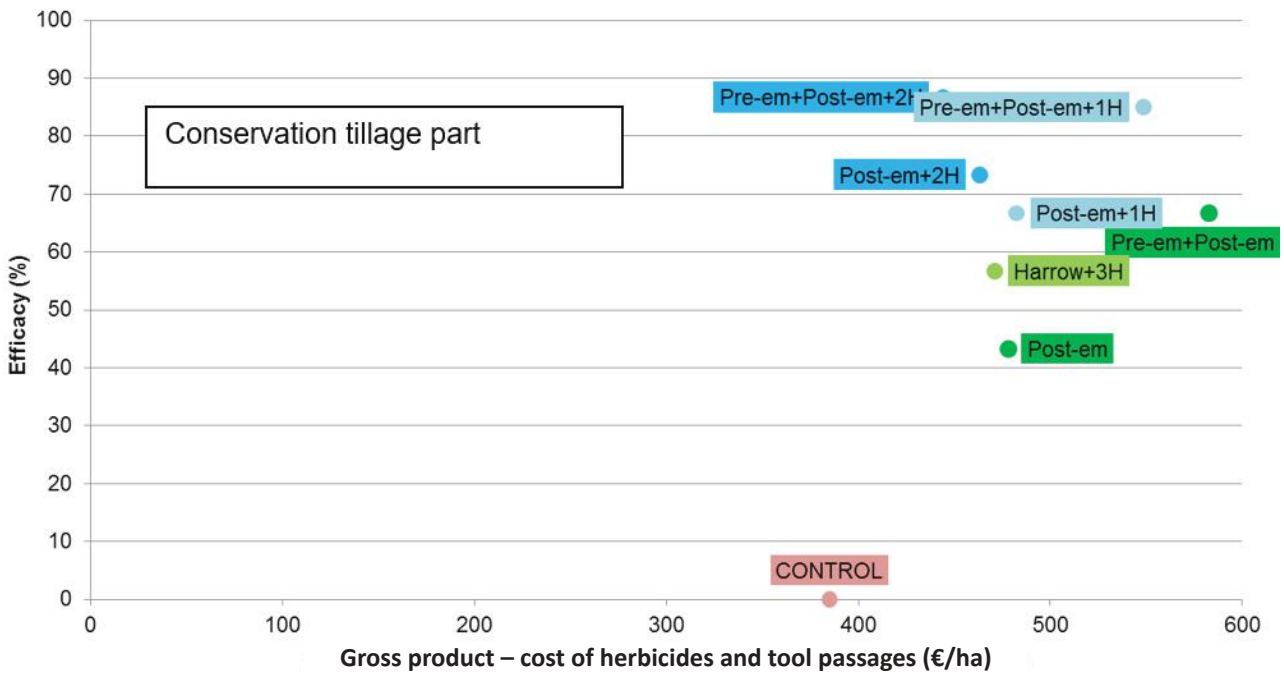


Figure 16 - Gross product and efficacy following mixed weeding programmes with conservation tillage

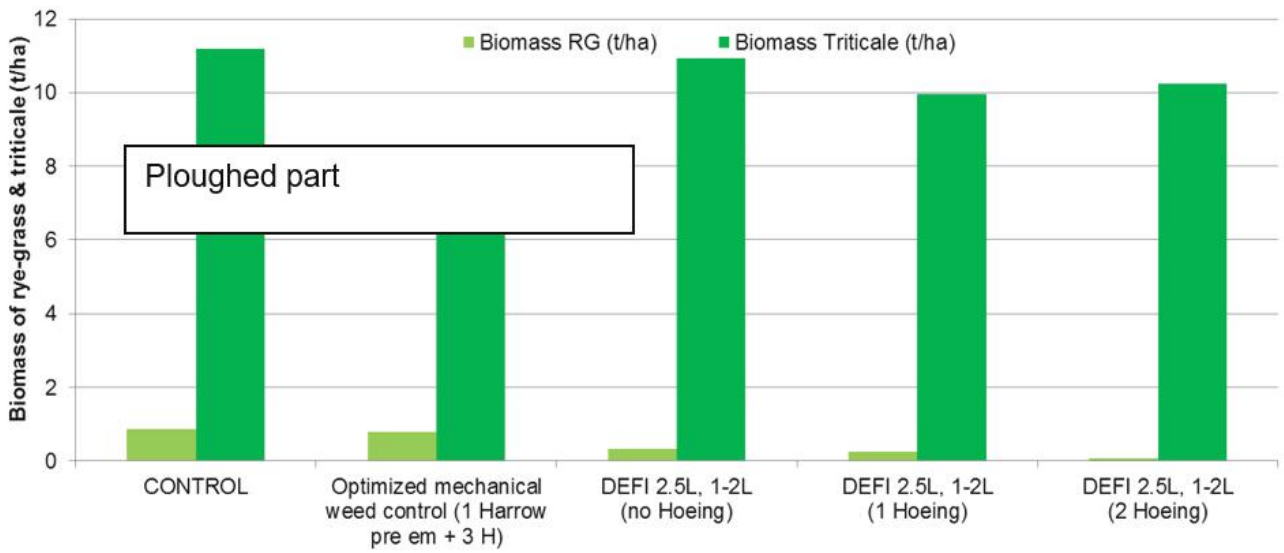


Figure 17 - Biomass of ryegrass and triticale following mixed weeding programmes with conservation tillage

There were around 1000 ryegrass plants/m² in control plots in the conservation tillage part and only 70 ryegrass plants/m² in the ploughed part.

These trials did not enable us to answer all the questions on hoeing in cereals, as the conditions of the year and the trials caused great variability in hoeing response. It should be noted that this variability will also be found in the efficiency of applications in large plots, since mechanical weeding is very dependent on soil and climatic conditions, which can produce very different results. However, these tests make it possible to highlight a few elements:

- Seed spacing of more than 20 cm penalizes yield.
- Hoe passages equipped with 15 to 17 cm spacings are possible without deteriorating the yield a priori, when the hoe passages are carried out under conditions that are not stressful for the crop (particular care is needed in the cereal's stage over 1

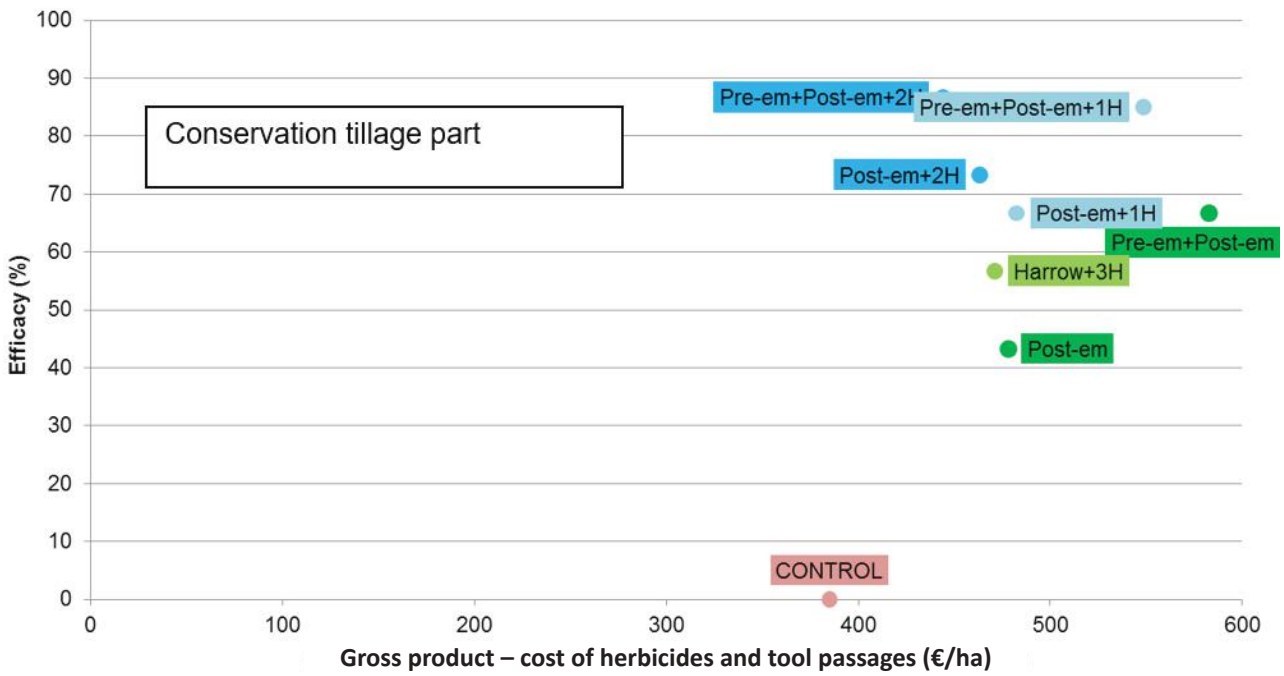


Figure 18 - Gross product and efficacy following mixed weeding programmes with ploughing

node). Weed-free testing would ideally be required to measure the potentially negative effect on tool passage performance.
- Gains on developed floras (grasses) are moderate but do exist, with them depending on the populations as well as on the soil and climatic conditions surrounding the weeder passage(s).
- Weeding only mechanically in cultivation has advantages in terms of efficiency and yield, but does not make it possible to manage large grass populations completely.

SOIL TILLAGE STRATEGIES, WITHOUT GLYPHOSATE, BEFORE SOWING SPRING PEAS

This trial was performed by Terres Innovia in Rians (18). In order to sow on clean soil, it was important to test tools and tillage depths before sowing spring peas in order to:
1) verify that weeds present before peas were destroyed;
2) ensure that the quality of crop establishment was not affected;
3) verify that this did not cause too many new weeds to emerge in subsequent crops.
These questions are important, and it is necessary to find the optimal tillage type (tool, depth, passage conditions) both to destroy weeds and to ensure crop growth. The experimental plan was a “strip” trial, the protocol of which is summarized in the following table. Before the flora was destroyed, major types were found to be present, especially brome (*Bromus* spp.), but also *Veronica*, cleaver (*Galium aparine*), and poppy (*Papaver rhoeas*). There is perhaps a fragmented heterogeneity even before any intervention, because Treatment 3 seemed less infested than the other two, by bromes in particular, even before any intervention.
After flora had been destroyed (mechanical on Treatment 1, chemical on Treatment 3), peas sown and herbicide applied (Challenge then Nirvana) on the 3 treatments, flora was more reasonable in Treatments 1 and 3 (i.e. where flora had been destroyed before sowing), with about 10 plants/m². However, there were about 75 plants/m² on Treatment 2, where flora had not been destroyed before sowing, in particular brome and field pansy, which is not satisfactory. Thus, chemical weeding alone in the pea is not enough to control flora. In the pea-flower bud stage, bromes are in their full tillering stage. Thus, the destruction of the flora before sowing is important.
Although Treatment 3 (glyphosate) appears to be the cleanest under the conditions of this test (the least infested with brome on 24 May), it was noted that Treatment 1 (vibrocultivator) had similar infestation rates in peas to Treatment 3. In this trial, the vibrocultivator seemed to control flora in peas as well as glyphosate.

Code	Treatment	Effective treatment
1	Soil tillage – with tool available on the farm (rotative harrow or stubble cultivator with a roller, etc.)	20/02: vibrocultivator (10-12 cm depth) followed by a flat harrow for ground levelling
2	-	-
3	Glyphosate before sowing	16/02: 1.2 L/ha glyphosate (good conditions)

Table 13 - Weed control protocols in the Rians trial

Figure 19 - Flat harrow

Figure 20 - Cultivator

MECHANICAL WEED CONTROL, WITH OR WITHOUT HERBICIDES, IN OILSEED RAPE

Two trials were set up by Terres Inovia in Nancy (54) and Mons (80). The main objectives were to
1) acquire references on mixed strategies of OSR (context of reduction in plant protection products) with a new post-emergence weed control product (MOZZAR – halauxifen + picloram) and mechanical weed control;
2) evaluate the technical and economic performance of these strategies, which partially or totally replace herbicides with mechanical or mixed alternatives with a weed harrow.
Trials were set up with three replicates. Weeds in Mons were volunteer cereals and *Matricaria*, whereas in Nancy weeds were *Capsella bursa-pastoris*. The protocol is described in the table below.

TRIAL IN NANCY

This trial had a low *Capsella* infestation that was heterogeneously distributed over the test. This was due to the weather conditions in late summer and autumn 2018, which were very dry both for weeds and rapeseed emergence. Consequently, not all the treatments were noted on the three blocks.

	Peas/m²
Treatment 1 – soil tillage	78
Treatment 2 – no soil tillage and no herbicide	85
Treatment 3 – glyphosate	78.6

Table 14 - Number of plants/m²

Overall, the treatments with MOZZAR applied in October at six rapeseed leaves (Chemical treatments 2, 3 and 4) had high efficacy (above 90%) and were better than the Alabama reference (Chemical 1: 80%). Late MOZZAR application alone (Chemical 5) had average efficacy (70%), but this improved when supplemented with weeding beforehand (Mixed 1: 90%). Mixed mode 1 with two passes of a weed harrow at pre-emergence and then at six leaves plus MOZZAR on 1 November was better (90%) than the same programme with IELO (Mixed 3: 80%).
The methods with mechanical weeding alone (pre-

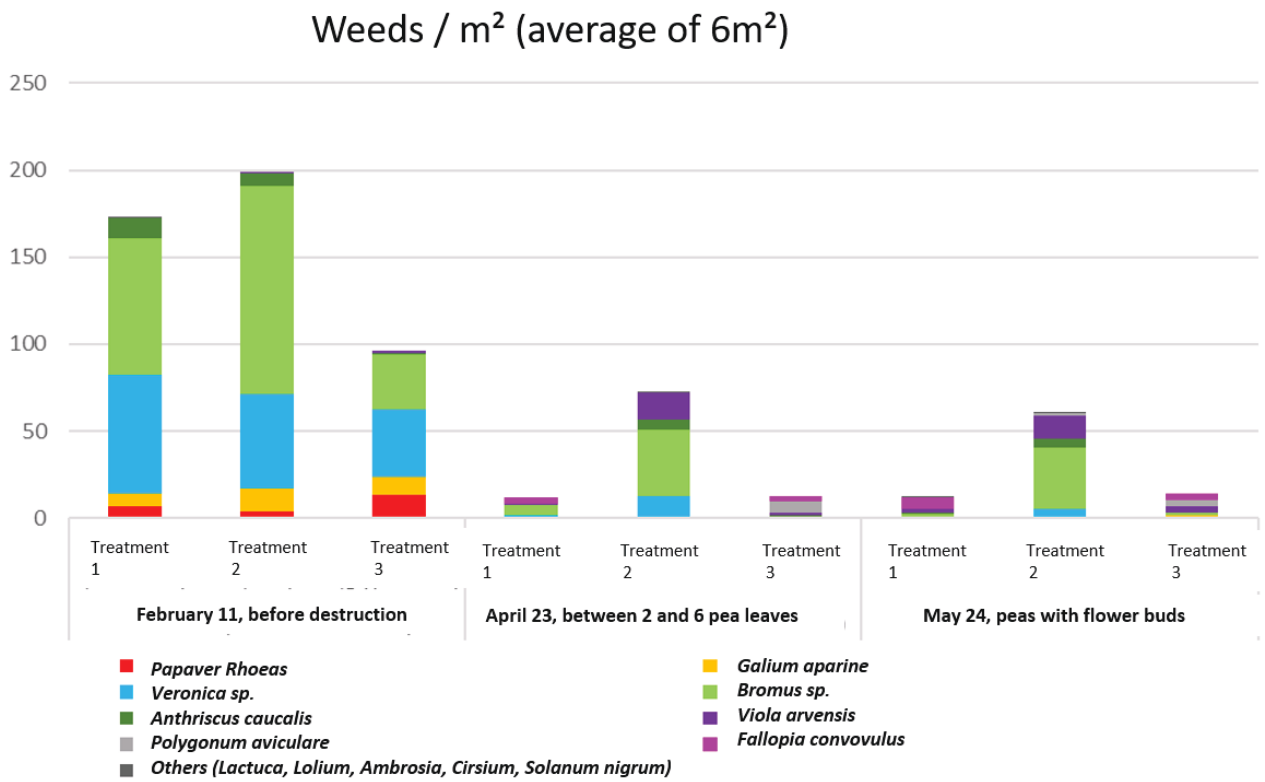


Figure 21 - Number of weeds/m² following various weeding programmes at three dates (11 Feb, 23 Apr 23 and 24 May)

	Treatment code	Treatments			Cost (€)	tfi
		Pre-emergence	4-6 leaves	Around 1 November		
1	Chemical 1	Alabama 2.5 L/ha	-	-	100	1
2	Chemical 2	-	MOZZAR 0.25 L/ha	-	45	0.5
3	Chemical 3	-	MOZZAR 0.25 L/ha	Kerb Flo 1.8 L/ha	75	1.5
4	Chemical 4	Alabama 1.8 L/ha	MOZZAR 0.25 L/ha	Kerb Flo 1.8 L/ha	150	2.25
5	Mixed 1	Tine harrowing (TE)	TE	MOZZAR 0.25 L/ha + Kerb Flo 1.8 L/ha	75	1.5
6	Mixed 2	TE	TE	Kerb flo 1.8 L/ha	30	1
7	Mixed 3	TE	TE	IELO 1.5 L/ha	55	1
8	Mechanical 1	TE	TE	-	0	0
9	Mechanical 2	TE	TE	TE	0	0
10	Chemical 5	-	-	MOZZAR 0.25 L/ha + Kerb Flo 1.8 L/ha	75	1.5

Table 15 - Mechanical weed control treatments in oilseed rape in the Nancy and Mons trials
Alabama = metazachlor + dmta-p + quinmerac
Mozzar = picloram + haloxifen-me
Kerb Flo = propyzamid
Ielo = aminopyralid + propyzamid

emergence weeding and then 6-leaf stage weeding: Mixed 2, Mechanical 1 and Mechanical 2) had unsatisfactory efficacy (60%).
Thus, even when the *Capsella* infestation was low and heterogeneous, this trial still answers the initial question, i.e. that blind harrow and early post-emergence weeding at six rapeseed leaves allow the application of MOZZAR to be postponed to 1 November at half-dose (0.25 L/ha). The efficacy obtained with this system is satisfactory (90%), i.e. better than both the Alabama reference (80%) and the same programme with IELO (80%), and almost as good as the modalities with MOZZAR carried out in October with 6 leaves of rapeseed (95%).

	Treatment code	Treatments			Efficacy (%) 20 February	Number of repetitions with enough *Capsella* to score
		Pre-emergence	4-6 leaves	Around 1 November		
1	Chemical 1	Alabama 2,5 L/ha	-	-	80	2
2	Chemical 2	-	MOZZAR 0.25 L/ha	-	95	1
3	Chemical 3	-	MOZZAR 0.25 L/ha	Not sprayed ~~Kerb 1.8 L/ha~~	95	2
4	Chemical 4	Alabama 1.8 L/ha	MOZZAR 0.25 L/ha	Not sprayed ~~Kerb* 1.8 L/ha~~	95	3
5	Mixed 1	Tine harrowing (TE)	TE	MOZZAR 0.25 L/ha ~~+ Kerb* 1.8 L/ha~~ (Not sprayed)	70	1
6	Mixed 2	TE	TE	Not sprayed ~~Kerb* 1.8 L/ha~~	90	2
7	Mixed 3	TE	TE	IELO 1.5 L/ha	60	1
8	Mechanical 1	TE	TE	-	80	2
9	Mechanical 2	TE	TE	Not applied ~~TE~~	60	1
10	Chemical 5	-	-	MOZZAR 0.25 L/ha ~~+ Kerb* 1.8 L/ha~~ (Not sprayed)	60	2

Table 16 - Weed control treatments in oilseed rape in the Nancy trial
* The plot was grass-free so Kerb was not applied.
Tine harrowing was not carried out a third time due to weather conditions.
Since Kerb application and third tine harrowing were not carried out, Mixed 2, Mechanical 1 and Mechanical 2 are the same.
Satisfaction level: green = good; yellow = average - insufficient; red = completely unsatisfactory

Figure 22 - *Capsella* infestation (2019/03/18) - control plot

Figure 23 - Tine harrowing pass

	Treatment code	Treatments			Matricaria (4 leaves) 18 December	Volunteers wheat (3 leaves) 18 December
		Pre-emergence	4-6 leaves	Around 1 November	Efficacy (%)	Efficacy (%)
1	Chemical 1	Alabama 2,5 L/ha	-	-	100	80
2	Chemical 2	-	MOZZAR 0.25 L/ha	-	68.3	30
3	Chemical 3	-	MOZZAR 0.25 L/ha	Kerb Flo 1.8 L/ha	73.3	65
4	Chemical 4	Alabama 1.8 L/ha	MOZZAR 0.25 L/ha	Kerb Flo 1.8 L/ha	100	81.7
5	Mixed 1	Tine harrowing (TE)	TE	MOZZAR 0.25 L/ha + Kerb Flo 1.8 L/ha	90	70
6	Mixed 2	TE	TE	Kerb Flo 1.8 L/ha	55	68.3
7	Mixed 3	TE	TE	IELO 1.5 L/ha	71.7	70
8	Mechanical 1	TE	TE	-	65	50
9	Mechanical 2	TE	TE	TE	33.3	66.7
10	Chemical 5	-	-	MOZZAR 0.25 L/ha + Kerb Flo 1.8 L/ha	40	43.3

Table 17 - Weed control treatments in oilseed rape in the Mons trial
Level of satisfaction: green = good; yellow = insufficient; red = completely unsatisfactory

TRIAL IN MONS

Concerning the selectivity of the passages, no differences in vigour, discolouration or deformation were observed on the test after each intervention, whether mechanical or chemical.
The use of pre-emergence weed harrows, however, was highly detrimental to rapeseed with a 50%-or-so loss of feet being observed (Figure 23). This can be explained by the harrowing being a little too late compared to sowing, with it probably being carried out when the seed had already germinated. This mechanical pre-emergence passage is quite a delicate operation because rapeseed is so small, making it sensitive to any intervention; the narrow intervention window and sowing depth, which must be increased for mechanical passage, were also issues.
The following mechanical passages caused only a few foot losses, around 3% to 5%. Indeed, despite more aggressive harrowing, there was almost no foot loss because the rapeseed was well established.
The final observation was made a little too early, as the herbicides did not have time to take full effect; observation should have been made during the winter season. In addition, there were late lifts of weeds. Thus, on chamomile (*Matricaria* sp.), MOZZAR was not completely effective (around 70% in Chemical treatments 1 and 2; 40% for late MOZZAR in Chemical 5). Similarly, the IELO in the Mixed treatment 3 was not completely effective. Nevertheless, this test shows that Mixed 1 had good efficacy (90%), which means that the two passages of the weed-harrow were a good complement to late-application of MOZZAR (which had only 40% efficacy at the beginning of winter). As MOZZAR is designed to continue working during the winter, we can imagine that the overall efficacy of the mixed treatment will potentially be very good (> 90%). Thus, mechanical treatments (here, weed-harrow) seem to be a good complement to chemical weeding. Mechanical treatments alone, however, do not provide satisfactory efficiency (65% and 33% respectively for Mechanical treatments 1 and 2 on *Matricaria*). It can be assumed that Mechanical 2 is less satisfactory because the last weeding in November caused new chamomile (*Matricaria sp.*) lifts. Indeed, November is traditionally a month when there is little drying time. The third pass of the weed harrow (Mechanical 2) eliminated more cereal volunteers than the two passes of the weed harrow together (Mechanical 1), although weed harrowing alone remains unsatisfactory for good overall weed control.

ASSOCIATED CROPS IN ORGANIC FARMING TO PREVENT WEED INFESTATION

The management of weed (and also parasitic pressure) poses many problems in organic farming systems. The main objective of this trial was to measure the impact of the association of crops, crossed with sowing densities, on a single crop (wheat or oat or faba bean). This trial was located in Rians (18), central France. The table below summarizes the various treatments.

1	Winter wheat + faba bean	Normal density: 200 + 20 gr/m²
2		High density: 300 + 30 gr/m²
3	Triticale + faba bean + forage pea	Normal density: 100 + 14 + 13
4		High density: 150 + 21 + 19
5	Triticale + forage pea	Normal density: 150 + 20
6		High density: 200 + 30
7	Oat + faba bean	Normal density: 150 + 20
8		High density: 200 + 30
9	Oat	Normal density: 300
10	Triticale	Normal density: 350
11	Faba bean	Normal density: 40
12	Winter wheat	Normal density: 400

Table 18 - Crop association in the Rians trial

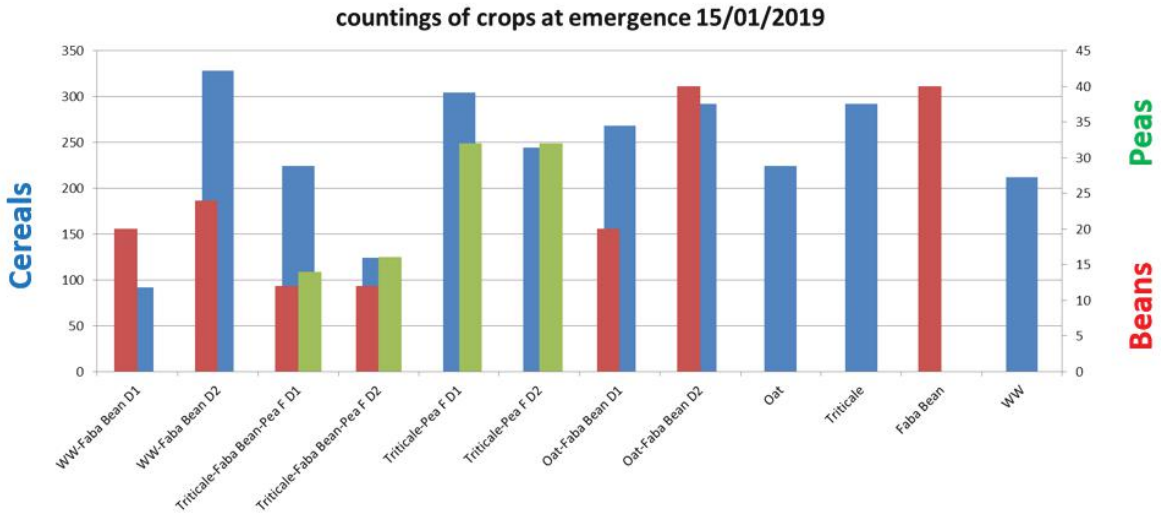


Figure 24 - Countings of crops at emergence (15 January 2019) in the Rians trial

LONG-TERM EXPERIMENT ON IWM-BASED WEED CONTROL COMPARED TO A REFERENCE CROPPING SYSTEM (OSR/WW/WB)

This trial, led by FDGEDA 18, is located in Vomay (18). The traditional cropping system in this region is based on autumn cash crops (oilseed rape, winter wheat & winter barley). Due to shallow soils (clay and superficial limestone), no till or direct seeding are common, and weed control is quite difficult (black-grass, including resistant population). The objective was to compare two situations: the reference (no till, OSR/WW/WB crop rotation) and a new one with IWM (change in crop rotation => introduction of winter pea and a spring crop, e.g. sunflower). The weeds present in the wheat part are only broadleaved weeds: mainly cleavers (*Galium aparine*), cornflowers (*Centaurea cyanus*), Anthrisque (*Anthriscus*), and Geraniums.

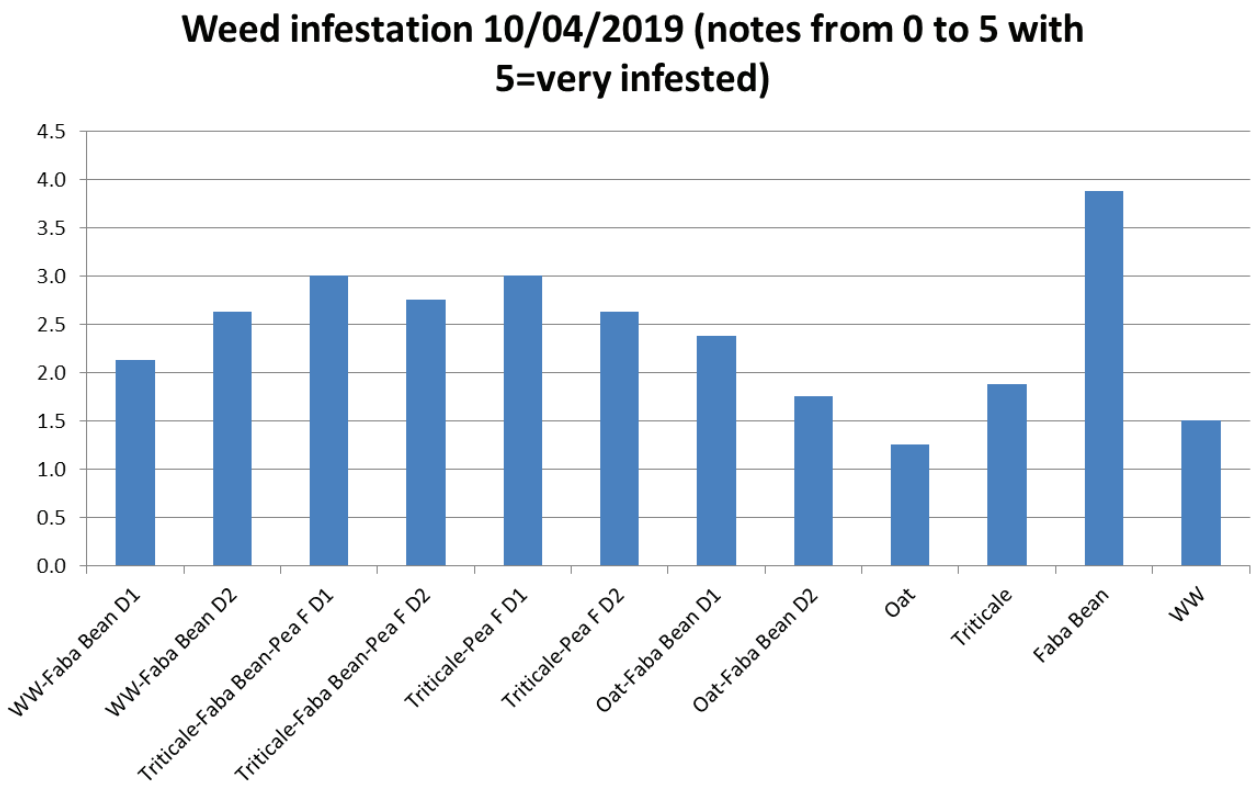


Figure 25 - Weed infestation (10/04/2019) in the Rians trial

Cropping systems	
Year 2017-2018	Reference: winter barley IWM: winter pea
Year 2018-2019	Reference: Oilseed rape (but due to drought in autumn, a sunflower was seeded in 2019) IWM: winter wheat

Table 19 - Cropping systems set up in the Vomay trial

	Emergence (pl/m²)	Weed infestation 14/12/2018 (0 to 5)	Weed infestation 17/01/19	Weed infestation 19/03/19	Weed infestation 12/04/19
Wheat	290	2/5	3/5	3.5/5	3.5/5
Sunflower		2/5	1/5	0/5	0.5/5

Table 20 - Weed infestation in the Vomay trial

FRANCE WP4


Mèry les Bois
Subdray
Arçay
St Priest la Feuille
Dijon
Agen
Seignalens
En crambade

Several WP4 themes were studied during the 2018-2019 season within the IWMPRAISE project:

Topic	Partner	Location
Comparison of full mechanical and mixed programmes in maize	Arvalis	St Priest la Feuille (23) Méry les Bois (18)
Soil preparation before sowing without glyphosate in sunflower	Terres Inovia	Agen (47) Subdray (36) Arçay (18) [2 trials] Seignalens (11)
Soil preparation before sowing without glyphosate in soybean	Terres Inovia	Agen (47) Dijon (21)

Table 1 - WP4 trials managed by the National French Cluster (number of geographical Department in brackets)

Treatment			
1. Full mechanical		Hoeing pass	Hoeing pass
2. Mixed with herbicides on the row	Adengo XTRA 0.44l/ha + Isard 1.2 l/ha (only on the row)	Hoeing pass	Hoeing pass
3. Full chemical	Adengo XTRA 0.44l/ha		Elumis 0.05 L/ha + Peak 0.006 L/ha
4. Mixed with herbicides	Adengo XTRA 0.44l/ha	Hoeing pass	Elumis 0.05 L/ha + Peak 0.006 L/ha

Table 2 - Protocol of the trials in Méry-les-Bois and St Priest la Feuille

COMPARISON OF FULL MECHANICAL AND MIXED PROGRAMMES IN MAIZE

During the 2018-2019 season, we were able to consolidate the results obtained in the three maize trials on alternative methods, which aimed to compare strategies and limit herbicide use. It should be noted that out of the three trials, one had to be abandoned due to farmer error (detected late) and one treatment was not traceable.

Weeds:
In Méry-les-Bois: grasses
In Saint Priest la Feuille: broadleaves

The updated results are presented in the graph below, with results in-row and inter-row.

The inter-row results of the “full-mechanical” strategy were, on average, fairly similar to those for the herbicide-based strategies. Its efficacy on the row, however, was nil and unacceptable for the growers.

The most-promising strategies, both in terms of effectiveness and herbicide savings, were those that implemented localised application (Strategies 2 and 4). They reached the reference level (Strategy 3) for weed control on the row. They remained below this level for inter-row efficiency, while being acceptable, scoring 7.
Note that the averages here included a range of weed species (grasses in Mery les Bois and broadleaved weeds in Saint Priest la Feuille). Strictly speaking, these results should be analysed separately. We have grouped them together here because they point in the same direction.
Protocols for the 2020 season are still under discussion; although they will probably be renewed in a similar form (localised application + hoeing); they will also integrate yield in order to have a techno-economic analysis.

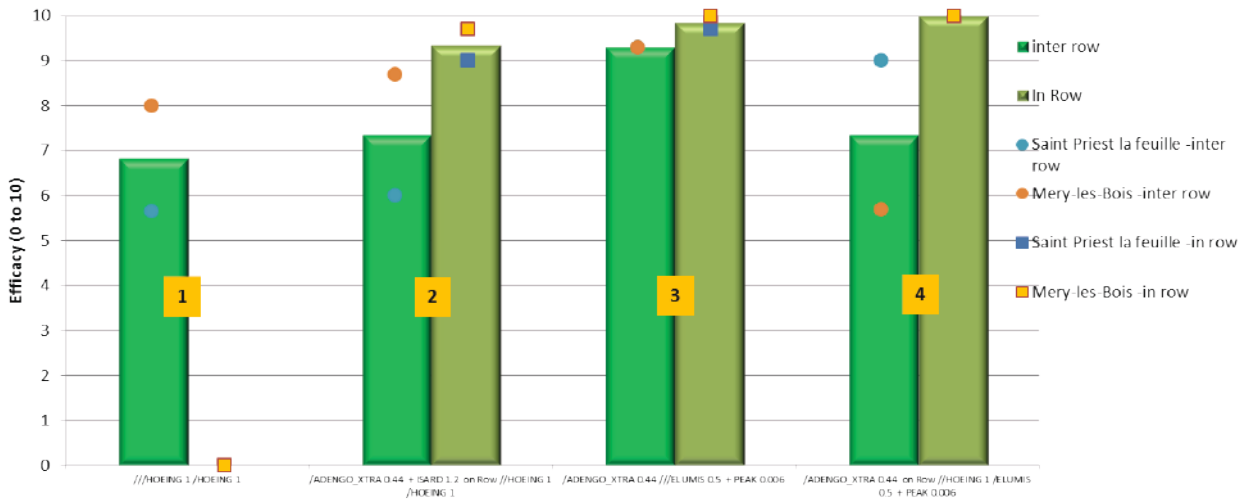


Figure 1 - Efficacy of mechanical and mixed strategies on maize (two trials)
Adengo XTra= isoxaflutol + thiencarbazone-me
Isard = dmta-p
Elumis = mesotrione + nicosulfuron
Peak = prosulfuron

SOIL PREPARATION BEFORE SOWING WITHOUT GLYPHOSATE IN SUNFLOWER

During the 2018-2019 season, seven trials were set up, with five trials being on sunflower. As the aim was to seed on clean soil, it was important to study tillage tools and depths before sunflower seeding in order to ensure that:
1) the weeds present before crop sowing were destroyed;
2) crop establishment quality was not affected;
3) soil tillage did not cause too many new weed emergences in the crop.

These issues are important and optimal tillage type (tool, depth, conditions) needed to be found both to destroy weeds and to ensure crop establishment. The test principle was to use a soil tillage tool during the month in order to do without applying glyphosate pre-sowing, according to the treatments below.

AGEN TRIAL

Sunflower sowing was performed with a single seed drill with 66 cm spacing on 1 April 2019 on fresh soil. The sowing density was 73,500 seeds/ha; the seed was the Carrera CLP variety. The day after sowing, pre-emergence herbicide, Mercantor gold (s-metolachlor) 1.05 L/ha + Proman (metobromuron) 2 L/ha, was sprayed on the entire trial. The final stage saw PULSAR 40 (imazamox) applied at 1.25 L/ha at the B6 stage of the sunflower on 16 May 2019.
In sunflower, Treatment 3 had by far the lowest density of weeds. After the two Roundup Innov (glyphosate - potassium salt) treatments (12 March and 9 April) and the pre-emergence treatment, no wild oats and only 0.67 ryegrass plants/m² remained, although the 12 March treatment was found to be ineffective due to the low dose.
Treatment 1 + pre-emergence treatment had average effectiveness on ryegrass (32.67 plants/m²), but was highly effective on wild oats (1.33 pl/m²).
Treatment 2 + the pre-emergence treatment had the highest ryegrass density (38.67 plants/m²), with all weeds ranging from the seedling to the adult plant stages.

Treatment 2 was the most weed-infested, followed by Treatment 1. Although Treatment 3 was the least infested, its first 1.5 L/ha rate of glyphosate was not effective enough to control weeds properly. Pre-emergence retreatment with 2 L/ha of Roundup Innov (glyphosate - potassium salt) was required. This treatment used a total of 3.5 L/ha of Roundup Innov (glyphosate - potassium salt).
Although it was thought that the fairly dry conditions during tool passes would allow considerable weed control, some weeds were present from the young seedling to the flowering stages in this treatment. This meant that the tools did not totally destroy the weeds, leading to new weed emergences. Only young plants, however, were observed in Treatment 3.
Visual observation confirmed the trends. The vibrocultivator treatment was the most infested, with this being the case from the first tool run (1 April). After the second application, the glyphosate

Code	Name	Treatment
1*	Destruction with soil tillage tool	Tool available on trial site
2*	Destruction with another soil tillage tool	Another soil tillage tool available on trial site
3	Farmer's treatment with glyphosate	To understand the consequences of tillage on weed emergence and seedbed quality

Table 3 - Treatments for trials on sunflower
** for Treatments 1 and 2, two tools were chosen from among these four types:*
- rotary harrow
- vibrocultivator
- straight-toothed tool
- stubble cultivator or vibrocultivator equipped with a roller

Location	Flora	Soil type	Sunflower sowing date
Agen (47)	Ryegrass (+ wild oat)	Clay and limestone	1 April 2019
Subdray (36)	*Mercurialis annua + Polygonum convolvulus*	Superficial clay and limestone	21 April 2019
Arçay (18)	Ambrosia *artemisiifolia* and all flora	Candy loam	19 April 2019
Arçay (18)	Ambrosia *artemisiifolia*	-	19 April 2019
Seignalens (11)	Ambrosia *artemisiifolia*	Clay and limestone	23 May 2019

Table 4 - Description of the five trials on sunflower

Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Rotary harrow + roller packer: 12 March Rotary harrow + roller packer: 1 April
2	Destruction with another soil tillage tool	Vibrocultivator + roller: 12 March Rotary harrow + roller packer: 1 April
3	Farmer's treatment with glyphosate	Roundup Innov 1.5 L/ha: 12 March Roundup Innov 1.5 L/ha: 9 April

Table 5 - Scheme of the Agen trial. The main weed in this trial was ryegrass

Figures 2 and 3 - Destruction on 12 March 2019 with rotary harrow (left) and the visual effect (right)

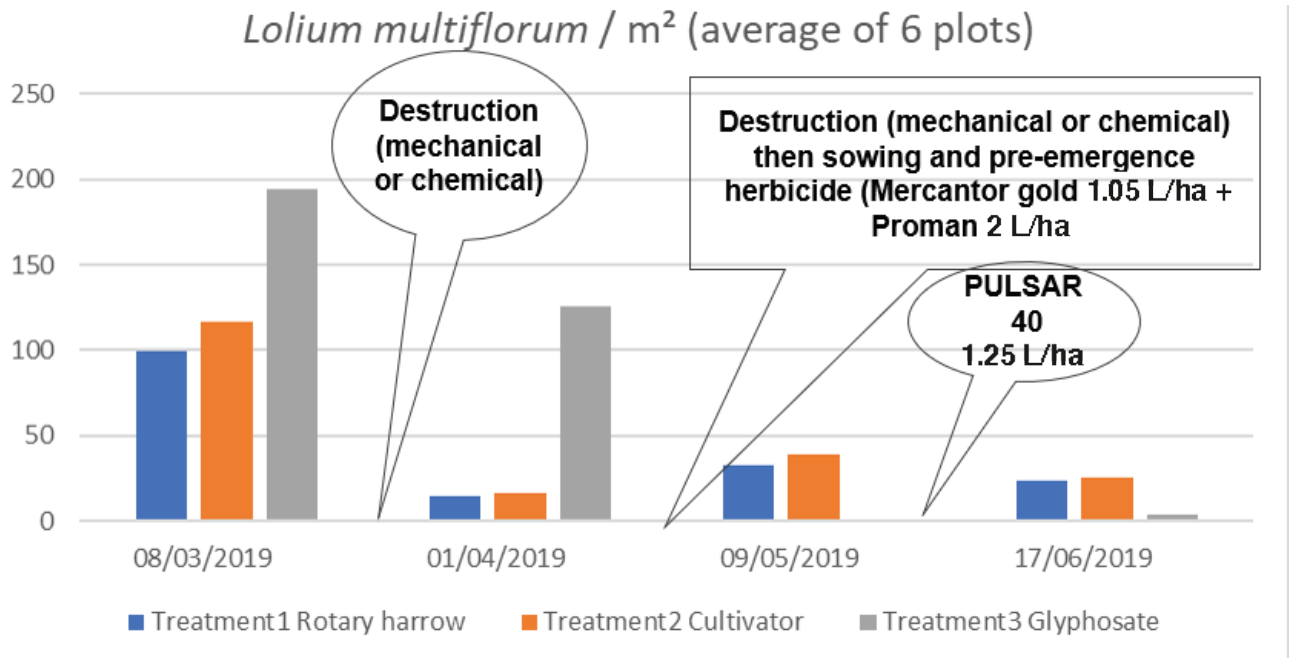


Figure 4 - Efficacy of mechanical and glyphosate strategies on ryegrass

Figures 5, 6 and 7 - Sunflower in Treatment 1 (left), Treatment 2 (middle) and Treatment 3 (right)

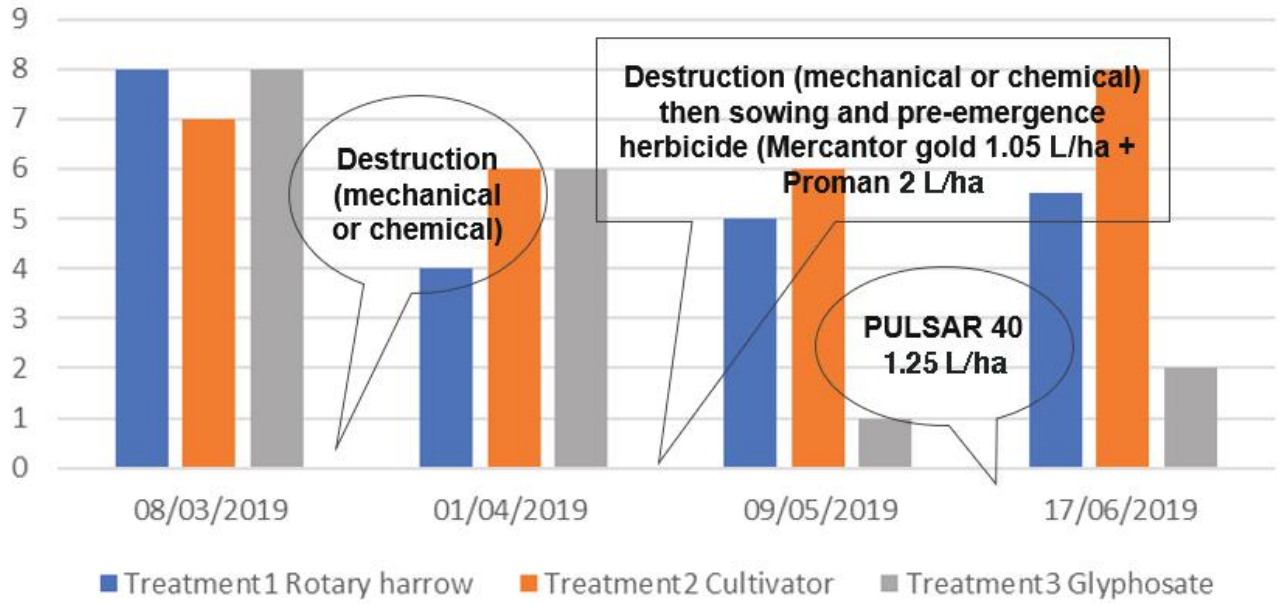


Figure 8 - Visual observation in the Agen sunflower trial (0 = very clean, 9 = full of weeds)

	Tillage depth	Soil moisture	Soil structure	Contact soil-grain
Treatment 1 (rotary harrow)	5 cm	Fresh	Clods from 5 to 8 cm	Medium
Treatment 2 (vibrocultivator)	Between 4 and 6 cm	Fresh	Clods from 5 to 7 cm	Medium
Treatment 3 (glyphosate)	4 cm	Fresh	Compact soil	Very good

Table 6 - Trial specifications

treatment proved to be the cleanest (observations on 9 May and 17 June). The visual observation was global (all weed types, so it also took into account the new emergence that took place in sunflower (mainly broadleaf weeds), and not only ryegrass.
Sunflower establishment quality (crop stand + taproot shape):
emergence appeared in good condition and homogeneous. Heterogeneity in population, to the disadvantage of glyphosate, was minimal and negligible.
At the E2 sunflower stage, an observation on taproot shape was carried out on two plots of 25 plants per treatment to check the quality of crop establishment. The percentage of straight taproots was higher in the rotary-harrow and vibrocultivator treatments (88%) than in the glyphosate treatment (68%).
This situation can be explained on the glyphosate-treated plot, as the soil was wet when the last tillage was done in November (rotary harrow) and no additional tillage was carried out after that date, creating a “plough sole”.
Tillage arrangements had a better percentage of straight taproots because past tools had broken up this “plough sole”, allowing the taproots to develop properly and a little deeper.

SUBDRAY TRIAL

The main weeds in this trial were *Mercurialis annua* (mercury) and *Fallopia convolvulus* (wild buckwheat).
The rotary harrow treatment was the most weed-infested (mainly mercury) and the vibrocultivator treatment was the “cleanest”, but density was still

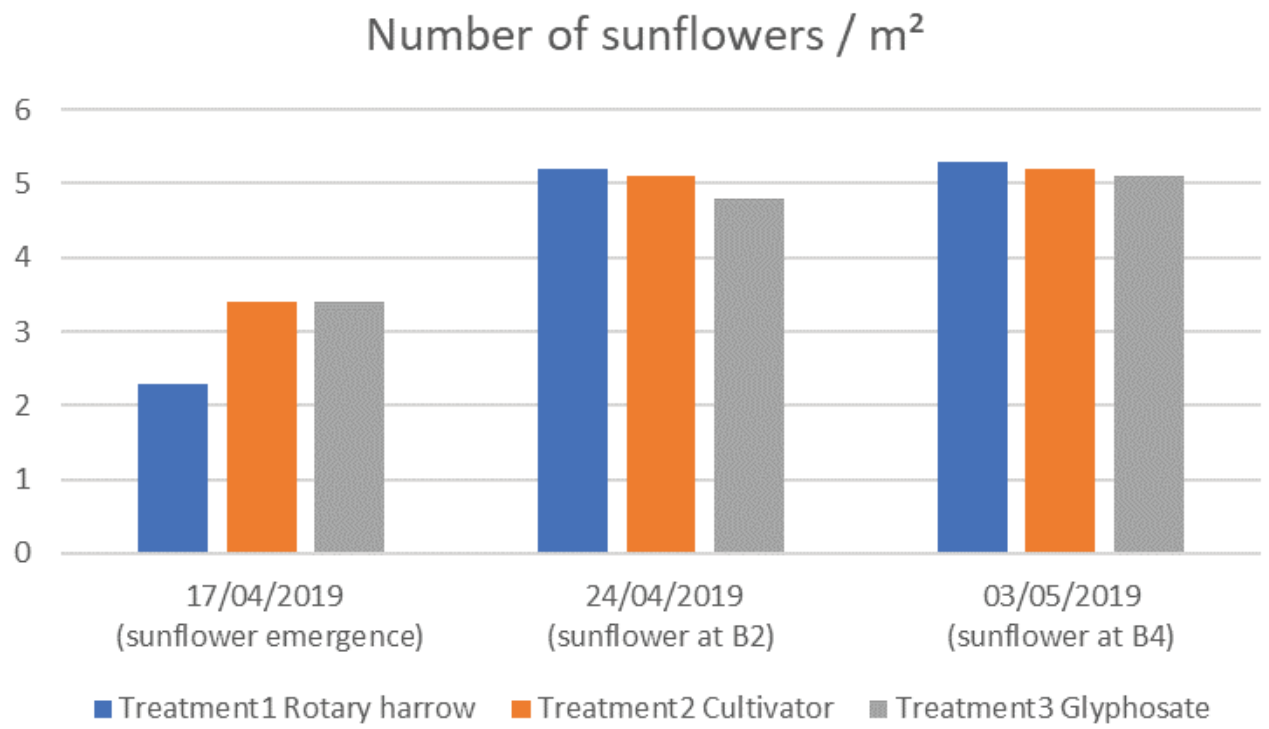
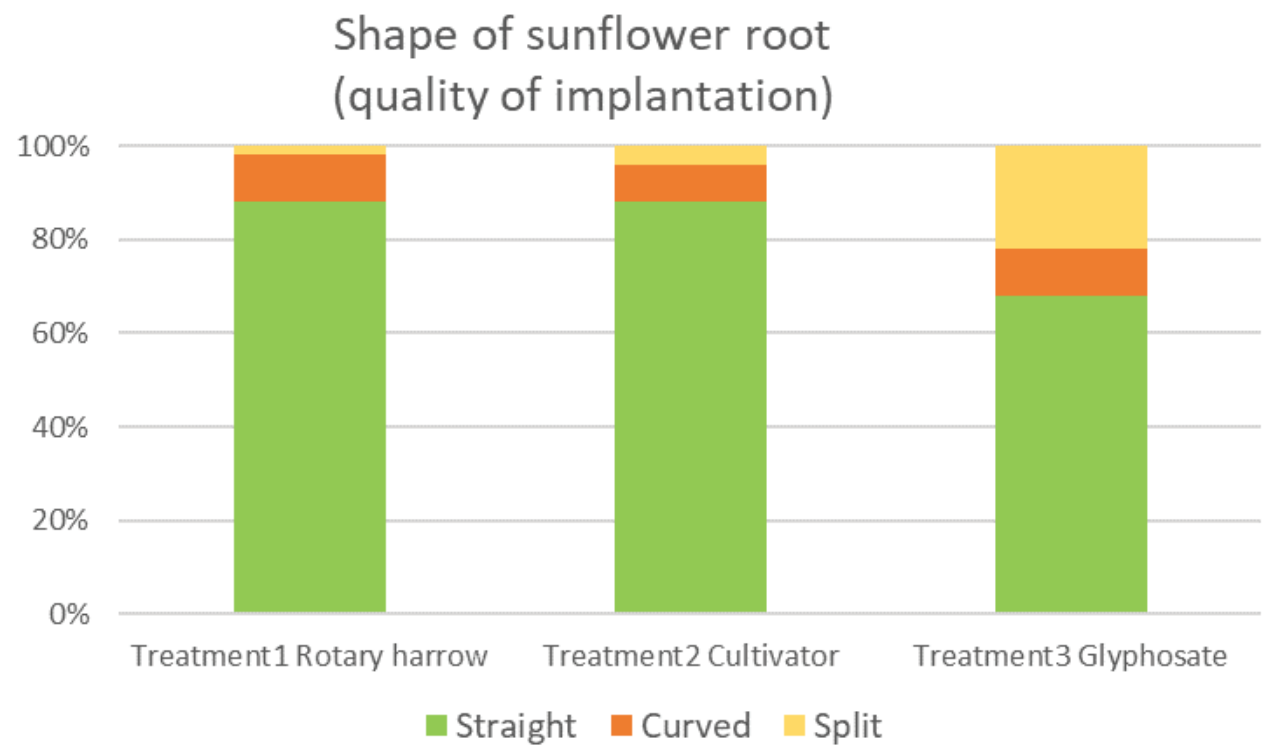


Figure 9 - Effect of different strategies on sunflower density



Figures 10 - Effect of different strategies on sunflower implantation

50 mercury plants/m².
Weather conditions in the first ten days of April were not favourable for weed emergence, as temperatures were quite low and rainfall was relatively low. In the end, sunflowers were sown on 21 April, when emergence conditions were more favourable. These results may be explained by glyphosate being applied too early on dry soil, low rainfall and non-emerging flora.
The weeds observed in sunflowers (mercury and wild buckwheat) were only new emergences.

Visual estimation:
As of 26 June, the rotary harrow and glyphosate treatments scored 7/9 (9 being the most-infested situation possible), while the vibrocultivator treatment scored 5/9 (0 being a totally clean plot).

Quality of sunflower establishment (crop stand + shape of taproots):

	Sunflowers/m²
Treatment 1 (rotary harrow)	5
Treatment 2 (vibrocultivator)	6
Treatment 3 (glyphosate)	8

Table 8 - Number of plants/m²

Although the rotary harrow treatment was the most weed-infested, it was the one with the straightest taproots. The vibrocultivator treatment had the most bent taproots. In all three treatments, the quality of sunflower establishment seemed poor.

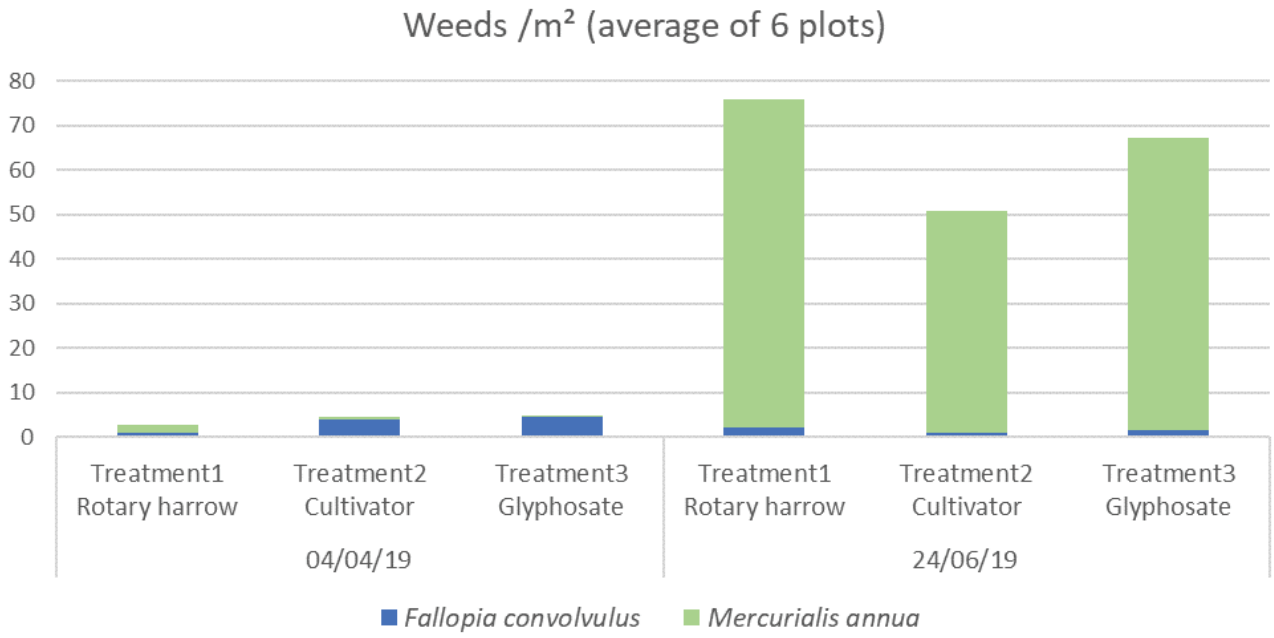
ARÇAY TRIAL 1

The main weeds in this trial were *Ambrosia artemisiifolia* and different broadleaves (*Solanum nigrum, Erodium cicutarium, Viola arvensis*).
Sowing was carried out with a single seed drill at

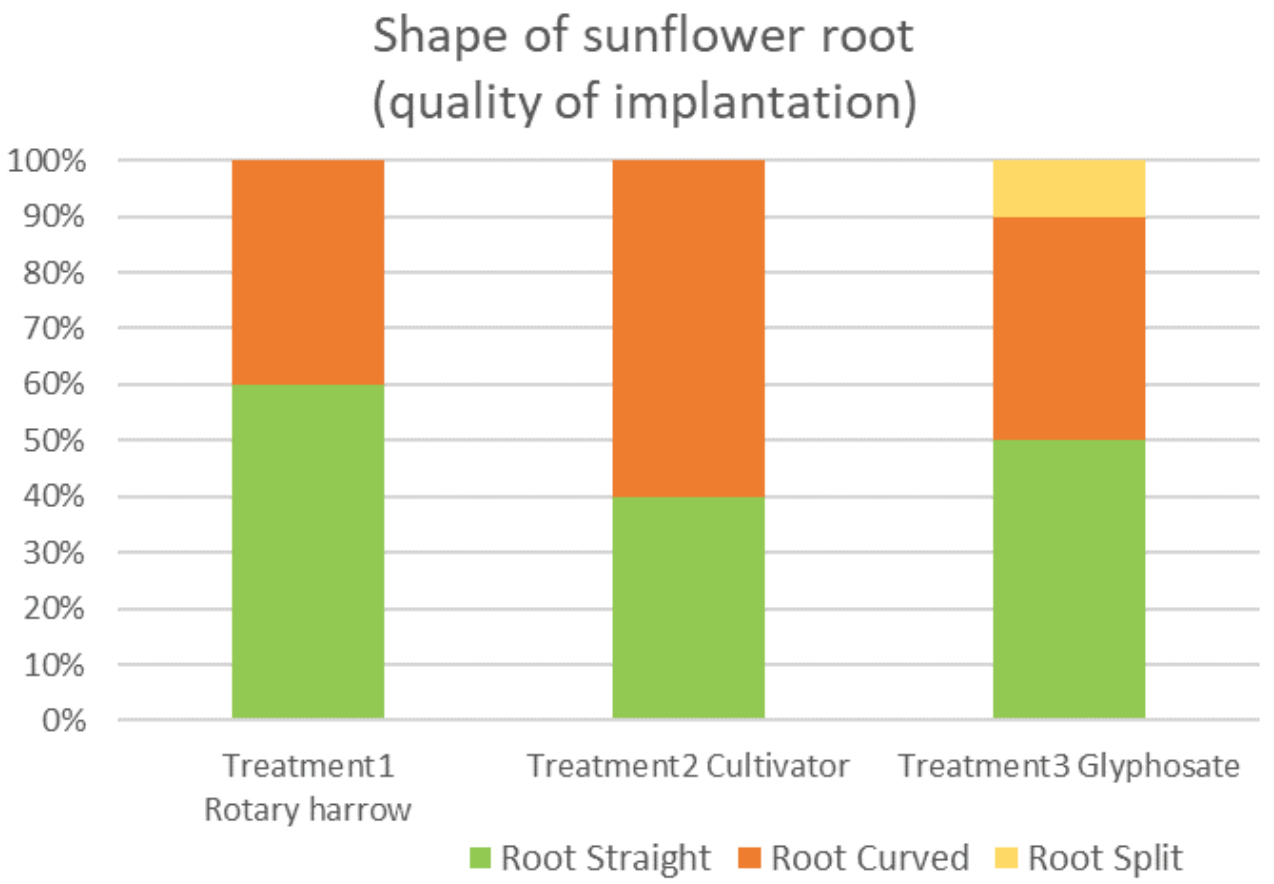
Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Rotary harrow + roller packer: 5 April
2	Destruction with other soil tillage tool	Vibrocultivator + roller: 5 April
3	Farmer's treatment with glyphosate	Glyphosate 2.5 L/ha: 8 April

Table 7 - Scheme of the Subdray trial

Figures 11 and 12 - Tools used on the Subdray trial: rotary harrow (left) and vibrocultivator (right)
Sowing was carried out with a single seed drill with 60 cm spacing on 21 April 2019 under optimal conditions. Sowing density was approximately 71,000 seeds/ha. The variety sown was Buffalo. Pre-emergence weeding was carried out on 24 April 2019 on the whole trial with Soléto (metobromuron) at 2.5 L/ha.



Figures 13 - Effects of weeding strategies on two weeds



Figures 14 - Effect of different strategies on sunflower implantation

Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Rotary harrow+ roller: 15 April
2	Destruction with other soil tillage tool	Vibrocultivator + levelling rod: 15 April
3	Farmer's treatment with glyphosate	Glyphosate 2.5 L/ha: 18 April

Table 9 - Scheme of Arçay Trial 1

Figures 15 and 16 - Vibrocultivator (left) and soil structure after pass (right)

60 cm spacing on 19 April 2019 under optimum conditions. Sowing rate was approximately 75,000 seeds/ha. The variety sown was ES Balistic CL. Pre-emergence weeding of the sunflower was carried out on 20 April 2019 with Pentium flo (pendimethalin) at 1.5 L/ha. The farmer then applied Pulsar (imazamox) in two passes at 0.625 L/ha (split) on 24 and 29 May 2019.

During the first count before destruction, which was carried out to sow on clean soil, mainly ragweed and pansy were found, but other weeds were also present in small numbers. Resurfacing therefore acted well as a stale seedbed.

On the second tillage count on 23 May 2019, about a month after seeding, ragweed and nightshade emerged well on both tillage systems, with their numbers remaining quite low in the glyphosate treatment. Thus, the second pass after ploughing was resumed favoured weed emergence. The counts showed that the rotary-harrow treatment had the highest infestation in this trial. The rotary harrow perfectly levelled the soil for sowing, removing all the weeds present. However, the harrow's packer roller compacted the soil, which can allow weeds to be "transplanted" to the surface and seed germination to be promoted. The vibrocultivator treatment had a lesser impact, as nothing was re-compacted after the pass. The glyphosate treatment was still relatively clean at the time of observation.

The Pulsar run was carried out on 24 and 29 May 2019 (half dose each), and the last observation was carried out on 17 June 2019 when the sunflower was at the star bud stage. The tillage treatment was more infested than the glyphosate treatment.

Despite a decrease in the number of weeds (nightshade disappeared), the rotary-harrow treatment remained the most infested, mainly with ragweed. The cleanest treatment on this date, and under the conditions of our trial, was glyphosate.

The visual observation scores confirmed the trends in the frameworks. Nevertheless, the glyphosate treatment did not appear to be weed-free, although it remained the most effective.

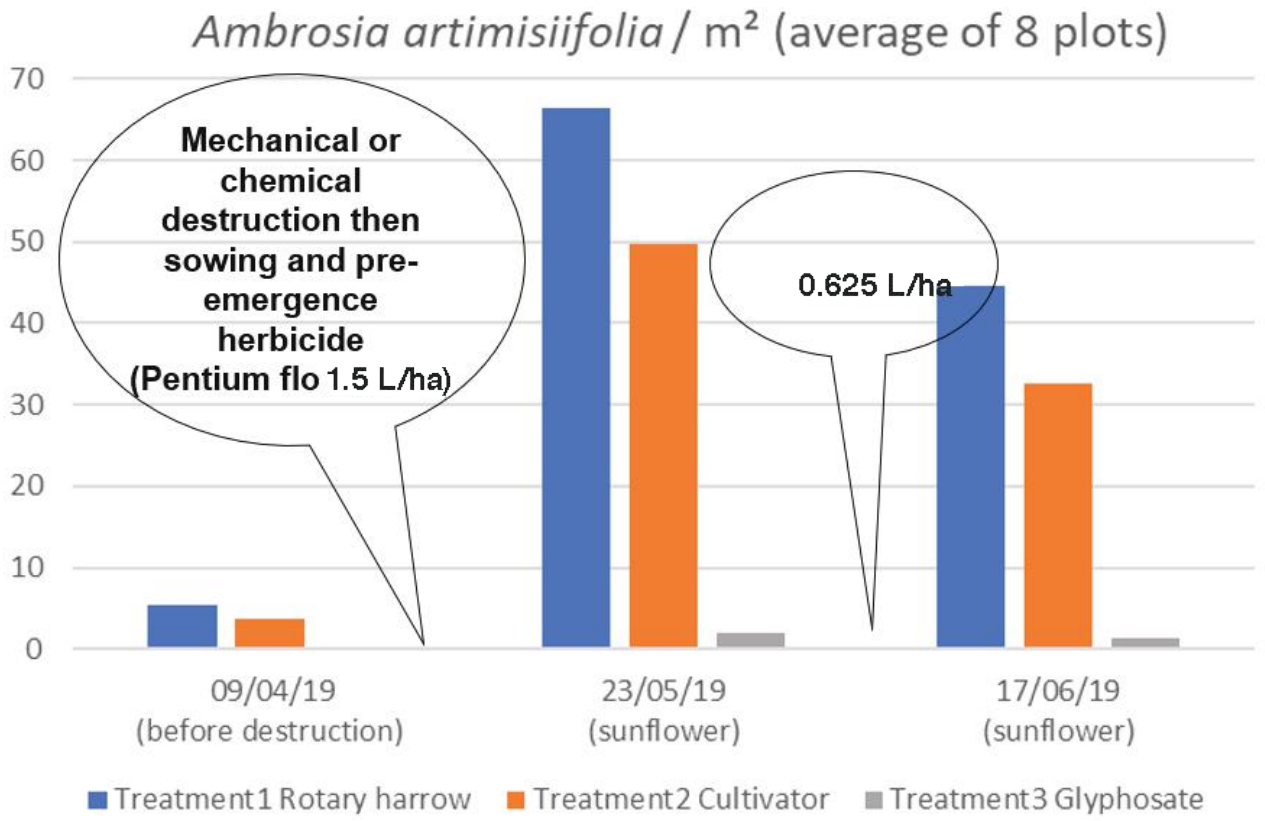


Figure 17 - Effects of weeding strategies on Ambrosia

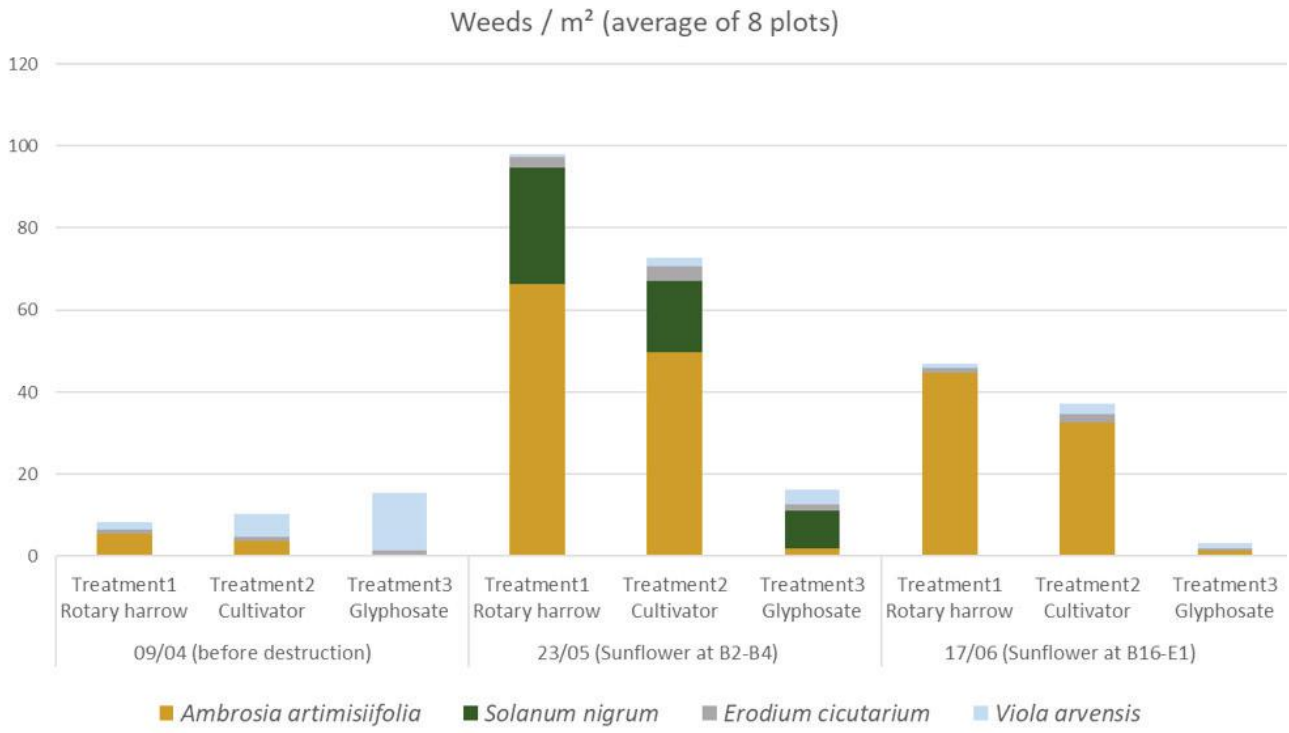


Figure 18 - Effects of weeding strategies on four weeds at three dates

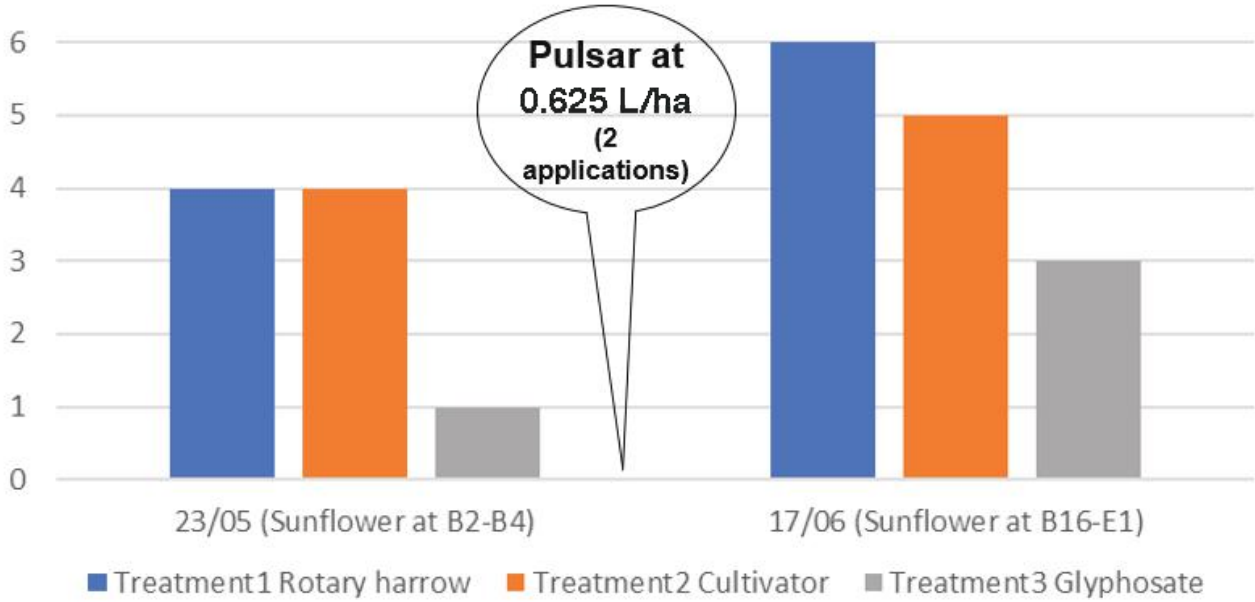


Figure 19 - Visual observation on Arçay sunflower Trial 1 (1 = very clean, 9 = full of weeds)

Figures 20 and 21 - Rotary harrow (left) & glyphosate (right)

The sunflower population appeared to be homogeneous throughout the trial. In addition, 100% of the taproots were straight in all three treatments. The soil type was less problematic than in the previous trials (sandy loam and clayey limestone).

Sunflower establishment quality (crop stand + taproot shape):

	Sunflowers/m²
Treatment 1 (rotary harrow)	8
Treatment 2 (vibrocultivator)	7
Treatment 3 (glyphosate)	8

Table 10 - Sunflower plants per m² in Arçay Trial 1

Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Rotary harrow + roller: 15 April
2	Destruction with other soil tillage tool	Vibrocultivator + levelling rod: 15 April
3	Farmer's treatment with glyphosate	Glyphosate 2.5 L/ha: 18 April

Table 11 - Scheme of Arçay Trial 2

Figures 22 and 23 - Rotary harrowing (left) was performed at 10 cm depth. All weeds were destroyed (right)

ARÇAY TRIAL 2

The main weed in this trial was ragweed *Ambrosia artemisiifolia*.

The trial was set up in a plot where ragweed had been present for a few years and was a problem for sunflowers.

Sowing was carried out with a single seed drill at 60 cm spacing on 19 April 2019 under optimum conditions. Sowing rate was approximately 75,000 seeds/ha. The variety sown was ES Balistic CL. Pre-emergence weeding was carried out on 20 April 2019 on the whole plot with pentium flo at 1.5 L/ha. The farmer then applied Pulsar in two passes at 0.625L/ha (split) on 24 and 29 May 2019.

The count on 9 April before mechanical or chemical destruction of flora showed that early ploughing, carried out in March, created a false seedbed which caused a great deal of ragweed emergence (between 200 and 380/m²), and thus destocking.

Despite this high density, tillage in Treatments 1 and 2, which was carried out under optimal conditions, destroyed the existing ragweed.

The count on 23 May showed that the rotary-harrow treatment saw an increase in the number of ragweeds between the first count (before intervention) and the second (a month later). We can therefore assume that the packer roller of the rotary harrow reconsolidated the soil and allowed ragweed to transplant. Even though the ragweed count in the vibrocultivator treatment on 23 May was lower than the initial count on 9 April, we can assume that the tillage also raised ragweed (even more than in the rotary-harrow treatment), since the 15 April tillage had destroyed most of the ragweed present. Glyphosate induced the least amount of ragweed to emerge since the soil was not disturbed.

Figure 24 - A vibrocultivator was used at 12 to 15 cm depth. Soil structure appeared more cloddy

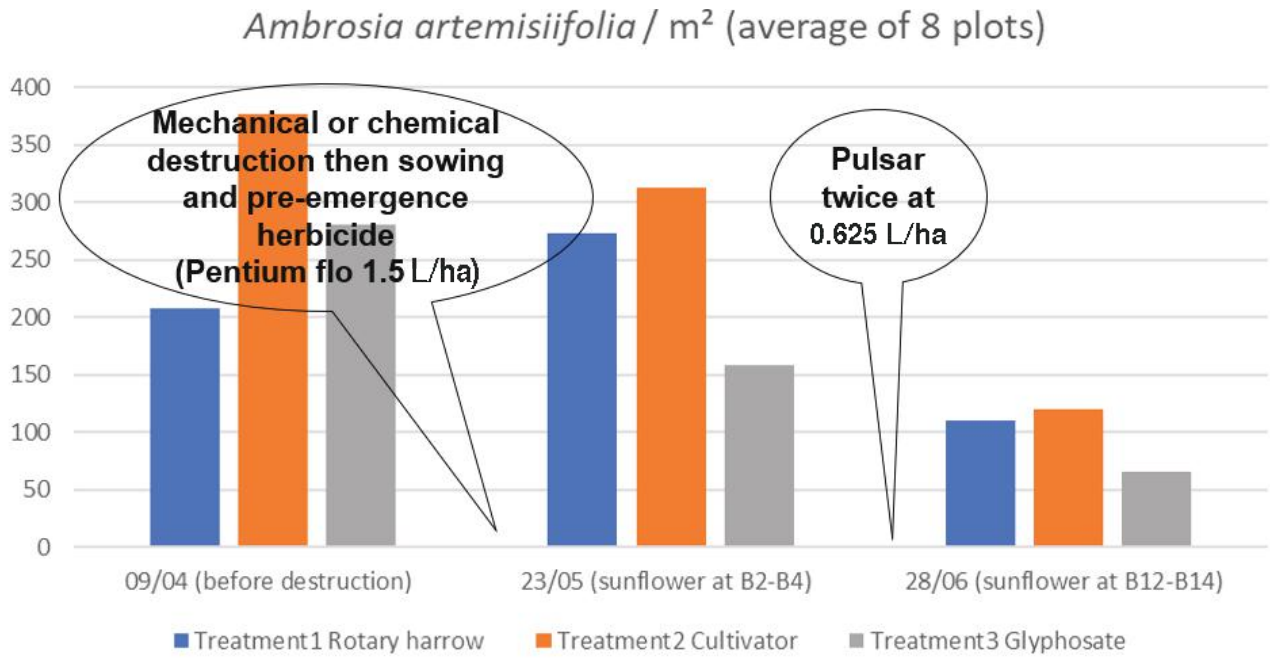


Figure 25 - Effects of weeding strategies on Ambrosia

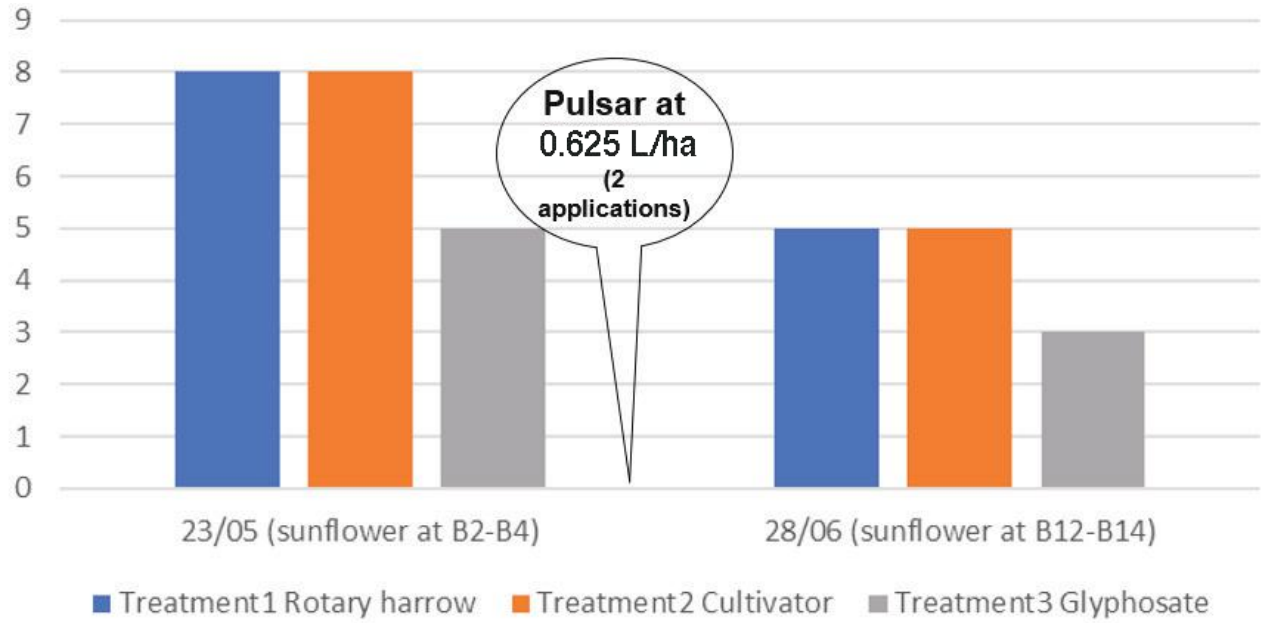


Figure 26 - Visual observation on Arçay sunflower Trial 2 (0 = very clean, 9 = full of weeds)

Nevertheless, there were still 150 ragweed plants/m² in this treatment. Indeed, the light but regular rains in April and May, as well as the above average temperatures of the season, caused significant emergence of ragweed on the whole plot.
Observations confirmed the trends seen in the samples. Nevertheless, the glyphosate treatment did not appear to be weed-free, although it remained the best treatment.
For example, during a heavy ragweed infestation, glyphosate combined with Pulsar can greatly reduce the ragweed population, but not eradicate it.
Tillage (rotary harrow or vibrocultivator) was not sufficient to ensure total destruction of ragweeds (even when coupled with Pulsar).
The quality of implantation seemed poor for the

three treatments because the vibrocultivator treatment, even though it was the one with the best implantation quality, had only 60% straight taproots. The no-tillage treatment (glyphosate) did not have satisfactory implantation, but it was no worse, or even better, than the rotary-harrow treatment. The least well-established treatment (only 20% straight taproots) was the rotary harrow.

SEIGNALENS TRIAL

The main weed in this trial was *Ambrosia artemisiifolia*.
Sowing was carried out on 23 May in good conditions, just after the rotary harrow and vibrocultivator passes. The farmer then carried out pre-emergence post-seeding weeding with Mercantor (s-metolachlor) and Racer (flurochloridon).
Large thistle rings were present on the trial before the sunflower was sown. The regularity of the ragweed stand was far from optimal at the time of sowing, as very few plants were present.
Ragweeds began to emerge in significant numbers between 20 June and mid-July, following the rainy spell that occurred during this period.
The results show that, overall, Treatment 3

Quality of sunflower establishment (crop stand + taproot shape):

	Sunflowers/m²
Treatment 1 (rotary harrow)	5
Treatment 2 (vibrocultivator)	4
Treatment 3 (glyphosate)	4

Table 12 - Sunflower plants per m² in Arçay Trial 2

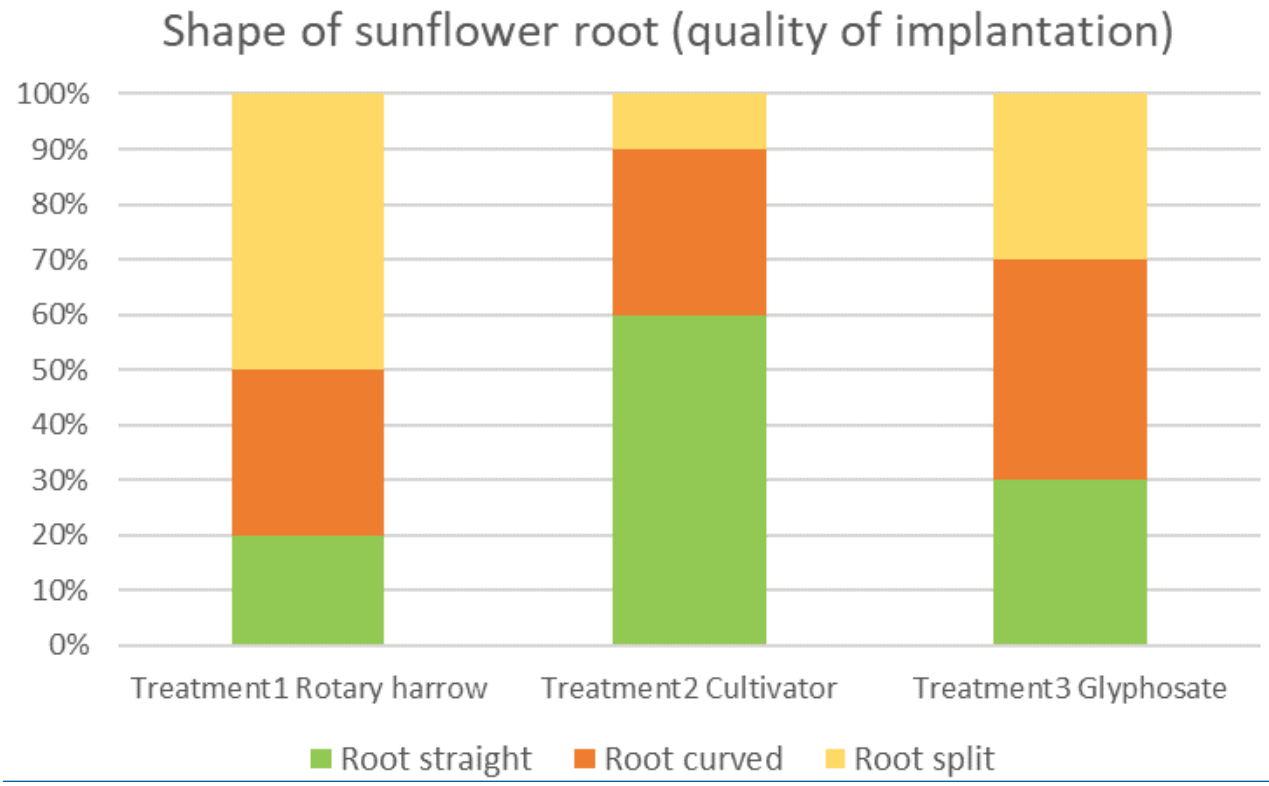


Figure 27 - Effect of different strategies on sunflower implantation

Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Rotary harrow 10 cm depth: 23 May
2	Destruction with another soil tillage tool	Vibrocultivator 15 cm depth: 23 May
3	Farmer's treatment with glyphosate	Glyphosate 3 L/ha: 23 May

Table 13 - Scheme of the Seignalens trial

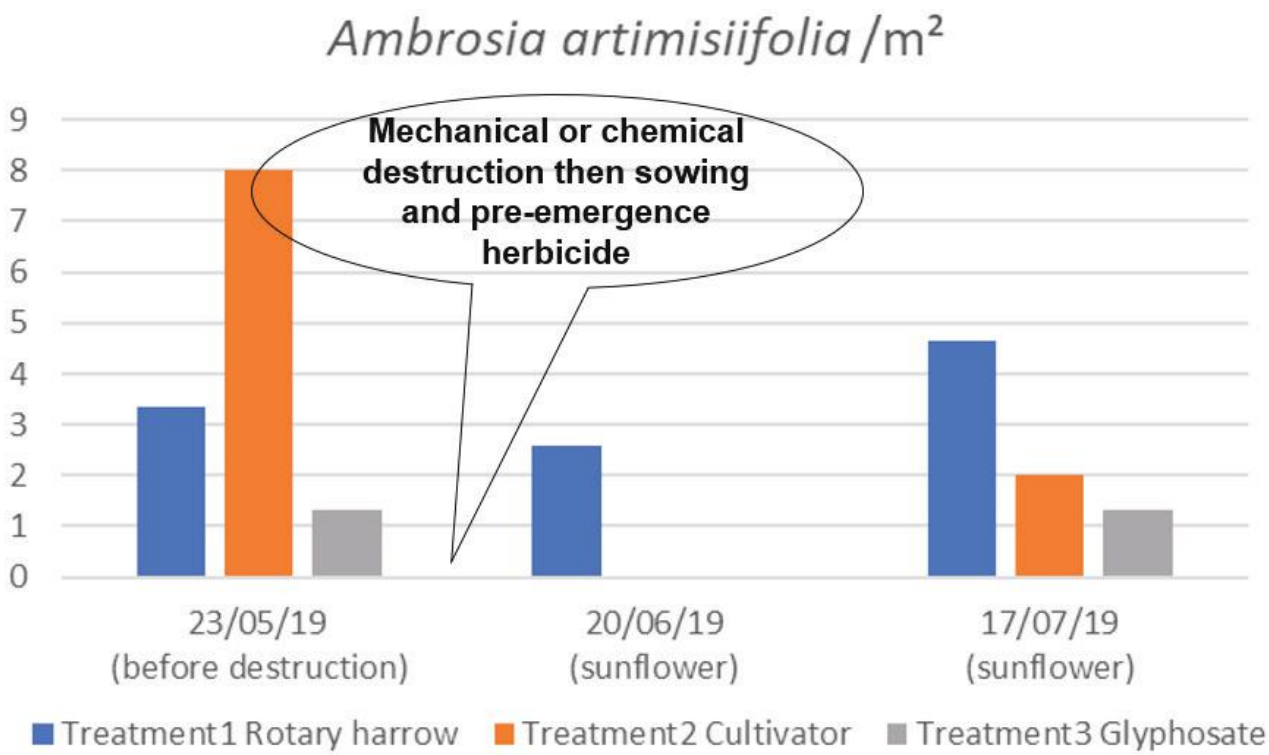


Figure 28 - Effects of weeding strategies on Ambrosia

(glyphosate) had much less ragweed in sunflower than Treatment 1 (rotary harrow), and less than Treatment 2 (vibrocultivator).
The rotary-harrow treatment seemed to be more infested with ambrosia than the vibrocultivator and glyphosate treatments. The hypothesis was that since the rotary-harrow tillage (10 cm) was shallower than the vibrocultivator tillage (15 cm), it would probably have unburied fewer seeds. This means that there would have been a slightly higher number of emergences. The rotary harrow treatment may have been more infested than the glyphosate treatment because tillage with a rotary harrow can cause new ragweed emergence, or there may have been a gradient in the plot, or at least heterogeneity in the ragweed infestation.
Sunflower emergence was between 5.5 and 6.6 plants/m². The population was relatively homogeneous.
Concerning sunflower rooting, it would appear that on Treatments 1 and 2 (tillage), there were more bent or forked taproots than on the glyphosate treatment. The rotary harrow treatment had the majority. In any case, the quality of implantation was not excellent for any of the treatments. The glyphosate treatment gave the best quality of implantation, with 75% straight taproots.

SOIL PREPARATION BEFORE SOWING WITHOUT GLYPHOSATE ON SOYBEAN

During the 2019 season, two trials on soybean were set up. The objectives were the same as in the sunflower trials.
As the aim was to seed on clean soil, it was important to study tillage tools and depths before soybean seeding in order to ensure that:
1) the weeds present before crop sowing were destroyed;
2) crop establishment quality was not affected;
3) tillage did not cause too many new weed emergences in the crop.
These issues are important and the optimal tillage type (tool, depth, conditions) needed to be found both to destroy weeds and to ensure crop

Sunflower planting quality (crop stand + tap root shape):

	Sunflowers/m²
Treatment 1 (rotary harrow)	5.6
Treatment 2 (vibrocultivator)	6.6
Treatment 3 (glyphosate)	5.5

Table 14 - Sunflower plants per m² in Arçay Trial 2

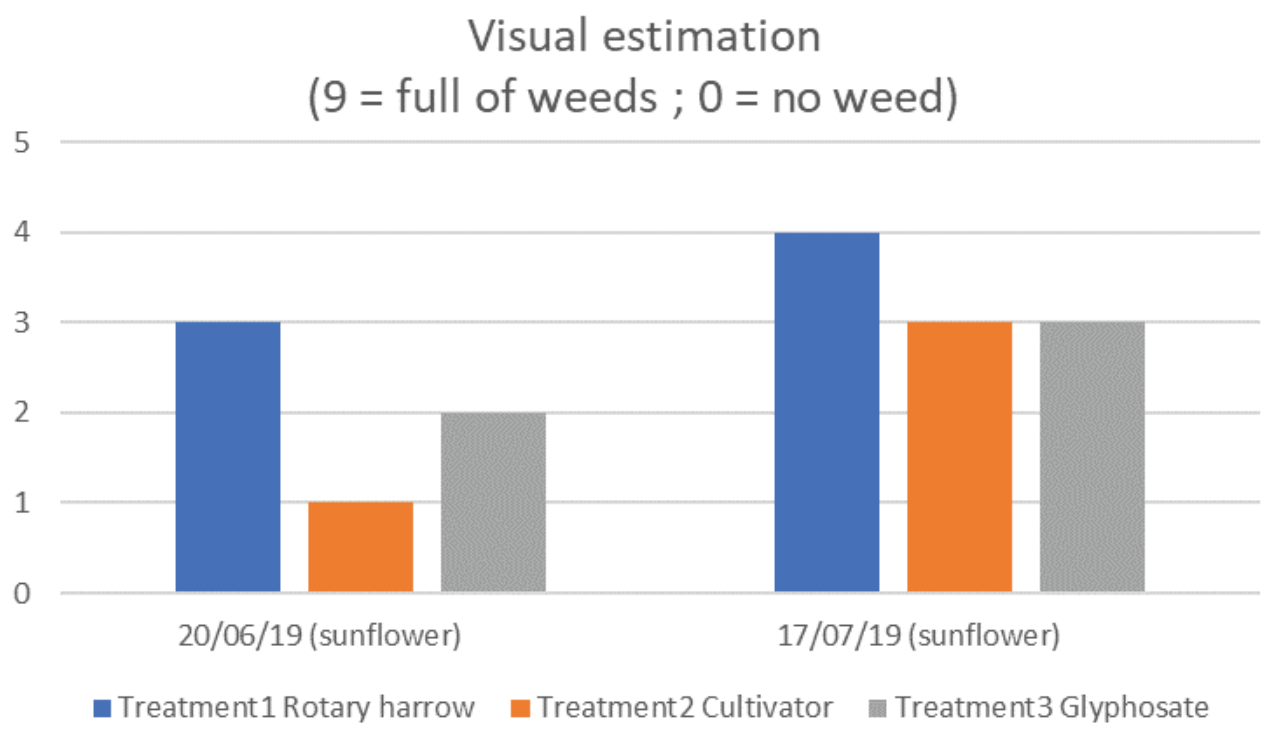


Figure 29 - Visual observation on Seignalens sunflower (0 = very clean, 9 = full of weeds)

Trials	Flora	Soil type	Sowing date
Agen (47)	Ryegrass	silty-clay	06/05/2019
Dijon (21)	All flora	silty-clay	15/05/2019

Table 15 - Scheme of the soybean trials

establishment.
The test principle was to use a soil tillage tool during the month in order to avoid applying glyphosate pre-sowing, according to the treatments below.
As in sunflower, two trials were implemented, with practically the same protocol, with the main objective being to control weeds during the intercropping period without glyphosate and to ensure good crop implantation.

AGEN TRIAL

The main weed in this trial was ryegrass.
Rotary harrowing combined with a roller packer (12 April 2019) was carried out on fresh soil up to a depth of 7 cm. Weed control appeared to be effective. Indeed, a subsequent count showed that more than 75% of ryegrass plants had been eliminated. Ryegrass was still present, but in clearly decreased numbers. Rotary harrowing was thus carried out again on 6 May a few hours before sowing in order to sow on clean soil.
A vibrocultivator combined with a cage roller (12 April 2019) was run on fresh soil at a depth of 10 cm. Weed destruction appeared to be moderately effective. It was, however, impossible to sow in this soil structure due to the large clods made by the cultivator. A subsequent count showed that the first pass with the vibrocultivator eliminated 50% of the ryegrass. The ryegrass was still present, but in clearly decreased numbers. Rotary harrowing was carried out on 6 May a few hours before sowing in order to sow on clean soil.
Sowing was carried out with a single seed drill with 66 cm spacing on 6 May 2019 on fresh soil. Sowing density was 400,000 seeds/ha with the ISIDOR variety. On 8 May 2019, a pre-emergence herbicide, Mercantor Gold (s-metolachlor) 1.4 L/ha, was distributed on the whole trial. The farmer applied a PULSAR 40 (imazamox) at 0.8 L/ha at V3 stage on 17 June 2019.
Before destruction on 11 April, there was a very large population of ryegrass (about 260 to 400 plants/m²). The vibrocultivator treatment was the most infested from the start.

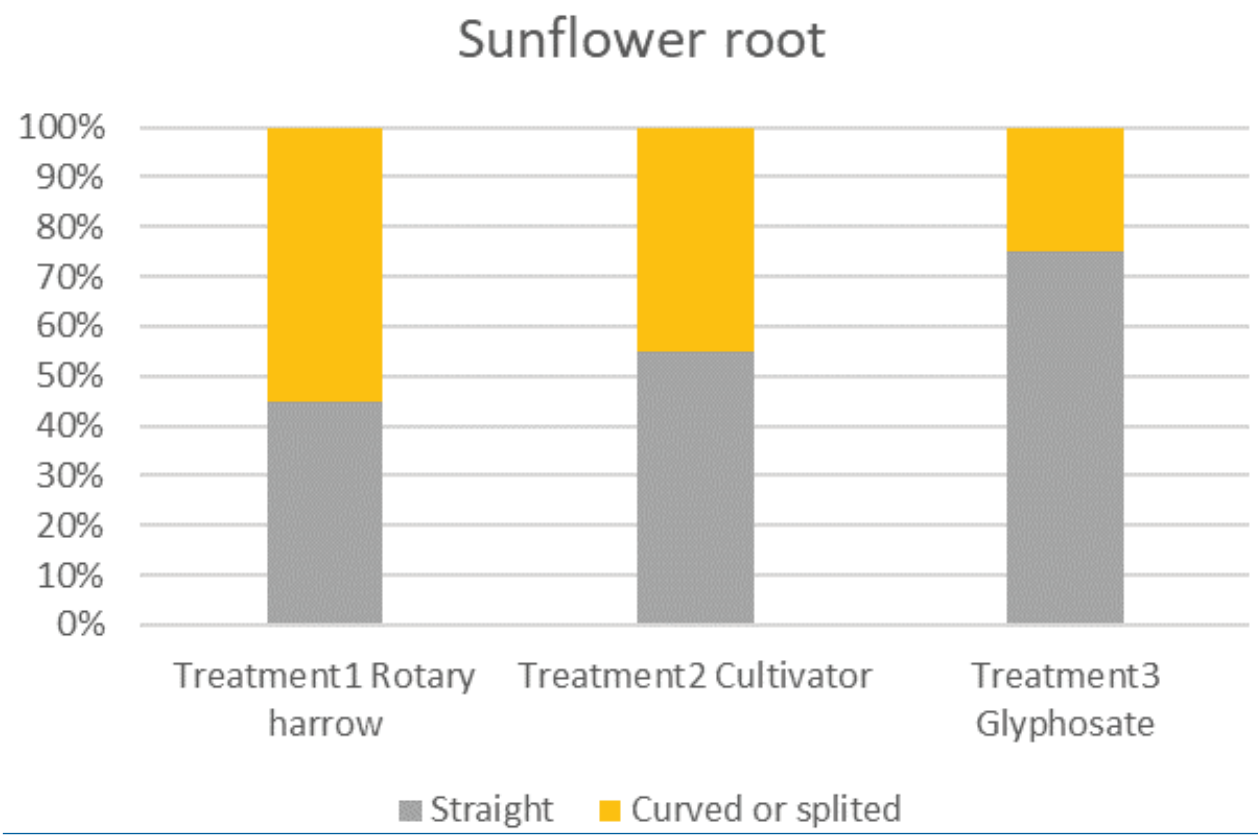


Figure 30 - Effect of different strategies on sunflower implantation

Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Rotary harrow + roller packer: 12 April Rotary harrow + roller packer: 6 May
2	Destruction with another soil tillage tool	Vibrocultivator + roller: 12 April Vibrocultivator + roller: 6 May
3	Farmer 's treatment (glyphosate)	Roundup Innov 2 L/ha: 10 April

Table 16 - Scheme of Arçay Trial 2

After destruction (mechanical or chemical) and before sowing on 3 May, we noted that glyphosate was very effective (0 ryegrass) and that the rotary harrow was quite effective because it considerably reduced the ryegrass population, but not enough to eradicate it (66 ryegrass plants/m²). This was either because mechanical destruction was not complete, or because tillage caused new emergences (ryegrass plants were at Stage C on 11 April and 3 May). The vibrocultivator was less efficient than the rotary harrow, as the ryegrass population had decreased, but there were still 196 plants per m², which was a large population. This was either because mechanical destruction was not complete, or because tillage caused new germinations (ryegrass plants were at Stage C on 11 April and 3 May).

On 3 June, the tillage method in soybean using vibrocultivator (4 April and 6 May) + pre-emergence treatment was the one with the most ryegrass plants/m² (48.67). The majority of this weed was in the flowering stage. The glyphosate treatment was by far the least infested. Indeed, after the Roundup Innov (glyphosate - potassium salt on 10 April) and pre-emergence treatment, only 0.67 ryegrass plants/m² remained, with there being just a few chickweeds and other broadleaf weeds. It seems that most of the weeds were late flushes, as they were mostly in the young-plant stage. Finally, rotary tillage (12 April and 6 May) + pre-emergence treatment had average efficacy on ryegrass (22.67 plants/m²), but these were

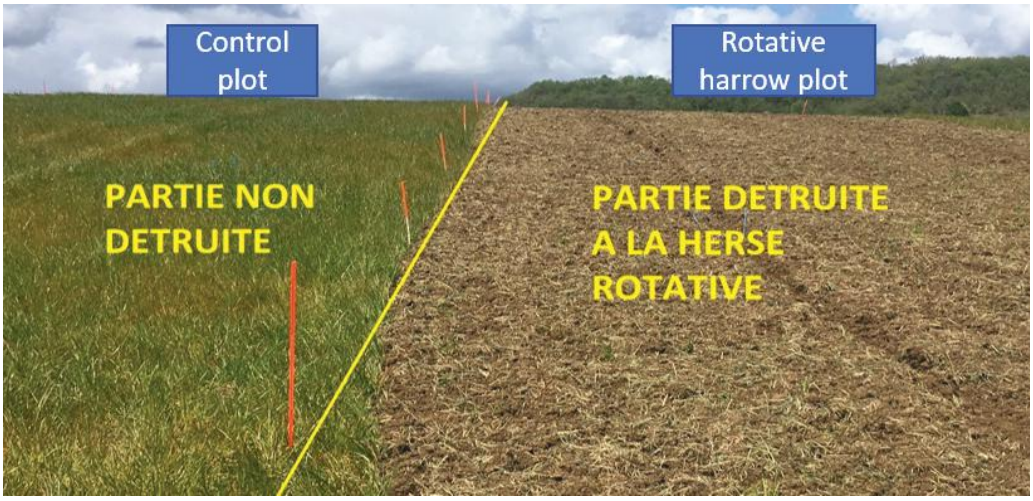


Figure 31 - Rotary harrow pass (two passes) on 12 April 2019 (right) and control plot (left)

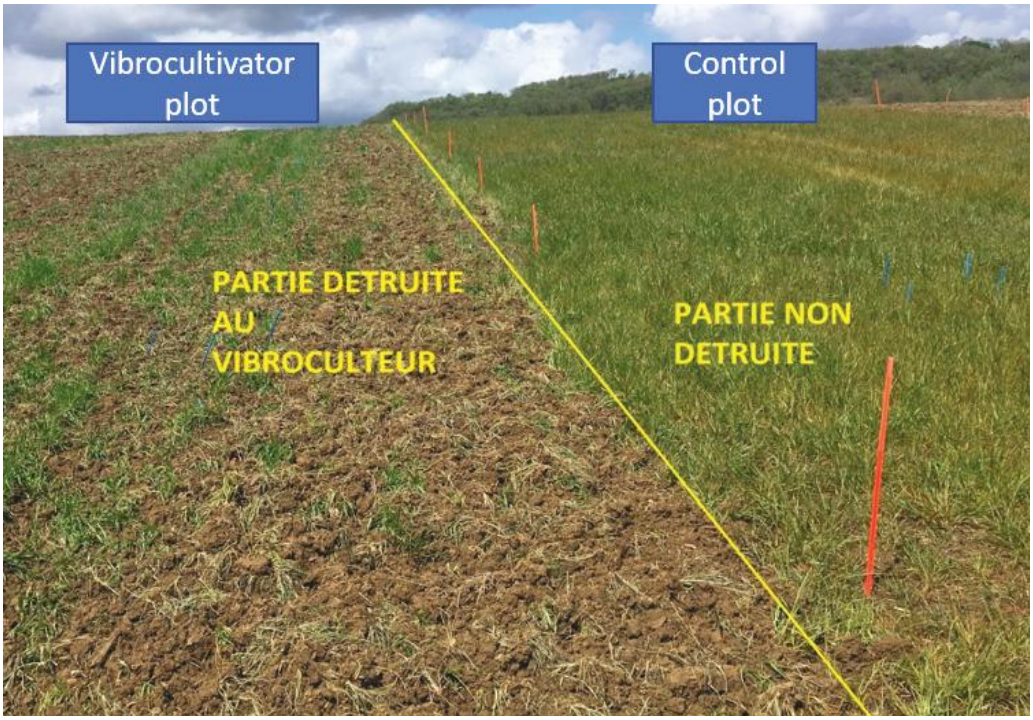


Figure 32 - Vibrocultivator treatment (two passes) 12 April 2019 (left) and control plot (right)

new plant emergences.
On 18 July, at the R2 stage of soybean, the vibrocultivator treatment had the most ryegrass plants per m² (35.33), the majority of them being at the shot-blasting stage, which meant poor destruction during tool pass. In the rotary-harrow treatment, only 2.67 ryegrass plants/m² remained. Most of them were at the shot-blasting stage. There were a few broadleaf weeds at a fairly young stage.
In the 2 L/ha Roundup Innov (glyphosate - potassium salt) treatment, no ryegrass plants were present on the counting plots, although some broadleaf weeds were present at different stages.
The visual ratings confirmed the trends observed in the samples; however, when there was very strong ryegrass pressure, we were unable to discriminate between the treatments.
In light of the observations, Treatment 2 (vibrocultivator + rotary pass) was more weed-infested than both the Treatment 1 (two rotary passes) and Treatment 3 (glyphosate).
Wet conditions after tillage did not allow for good

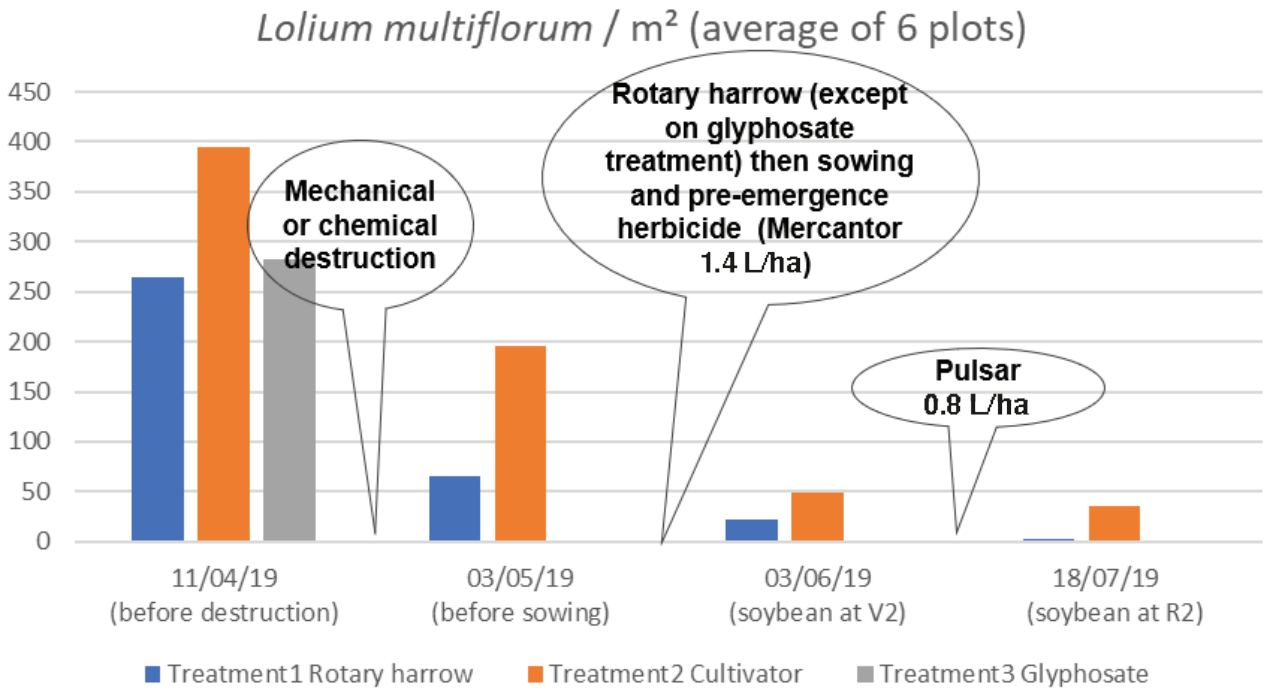


Figure 33 - Effects of weeding strategies on ryegrass

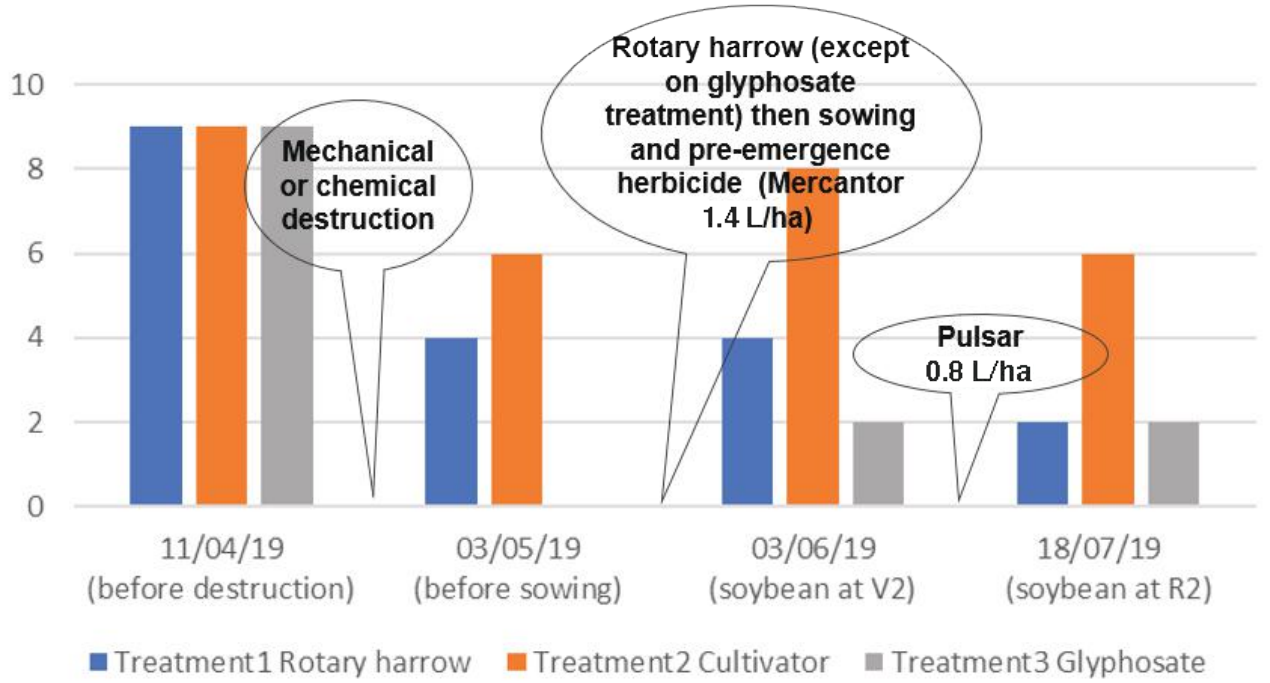


Figure 34 - Visual observation on the Agen soybean trial (1 = very clean, 9 = full of weeds)

weed control. However, since some weeds ranged from the young seedling to the flowering stages in the rotary-harrow treatment, this meant that the tools did not completely destroy the weeds, and therefore weed surveys were conducted. In Treatment 2, the weed stage was mostly at the shot-blossom or flowering stages, which meant that weed control was not very effective. In Treatment 3, only a few plants were in the shot-bloom and flowering stages, with most being in the young or adult stages. The efficacy of this treatment was thus good according to the broadleaf-weed surveys afterwards.

Soybean establishment quality (crop stand):

Soil preparation was carried out in good conditions

and was homogeneous. Heterogeneity in population was minimal and negligible.

DIJON TRIAL

The weed flora was very diverse. Sowing was carried out at a depth of 2-3 cm in all three treatments. The soil was dry at 2 cm and cool-to-wet underneath.
The herbicide treatments on the trial were as follows:
- 16 May 2019: Prowl 400 (pendimethalin) 1.2L/ha, Mercantor Gold (s-metolachlor) 1.4L/ha
- 13 June 2019: Pulsar (imazamox) at 0.6L/ha at the V2-V3 stage of soybean to begin control of well-developed weeds.
- 20 June 2019: Pulsar (imazamox) at 0.6L/ha at the V3-V4 stage of soybean + new emergence of cotyledon soybean, to finish destroying well-developed weeds and new emergence following the rains that fell between 9 and 15 June 2019.

Note that PULSAR 40 applications showed symptoms of phytotoxicity on soybean with leaf yellowing and soybean compaction.

Soybean establishment quality (seedbed characterization + crop stand):
Seedbed characterization: soil-seed contact was good in all treatments. However, surface clod size differed according to the treatment: the glyphosate and harrow treatments had identically sized clods (from 1 to 5 cm); and the vibrocultivator treatment had surface clod sizes ranging from 2 to 10 cm. Nevertheless, fine soil was observed at seed level for this treatment.
Emergence took place in two waves, the second of which was after a rainy spell between 9 and 15 June, resulting in different stages (from V1 to V4) at the time of counting.

Soybean stand:
This count was carried out on 24 June 2019 at stages V4 (first emergence date) and V1 (second emergence date).

Code	Name	Treatments & Dates
1	Destruction with soil tillage tool	Vibrocultivator: 7 May
2	Destruction with another soil tillage tool	Tine harrowing: 13 May
3	Farmer 's treatment (glyphosate)	Glyphosate 3 L/ha: 10 May

Table 17 - Scheme of the Dijon trial

Count at V1 to V4 stages	Soybeans/m²
Treatment 1 (vibrocultivator)	34.6
Treatment 2 (tine harrowing)	44.2
Treatment 3 (glyphosate)	37.5

Table 18 - Soybean plants per m² in the Dijon trial