Meeting on sustainable weed management in arable cropping systems

How to improve weed management in new production environments?

Tuesday, December 15th 2015

FIAP – 30 rue Cabanis – 75014 PARIS

Table of contents

I. Two organizers: GIS GC HP2E & RMT Florad

PRESENTATION OF GIS GC HP2E:

The GIS is a national multidisciplinary cooperation between the different links of the agricultural research and development system to ensure the sustainability of arable crop production systems. In order to reach this aim, the consortium works to provide stakeholders with the scientific elements that are missing and to generate the necessary collaborative dynamics.

GIS GC HP2E is an R&D consortium on arable crops gathering twenty-five partners involved in research, development extension services, education and professional organizations.

Technique A qualitative leap in technical expertise of farmers and of their advisers	**Performances** A joint dynamic for the improvement of economic, social and environmental performances
Environment A reflection on the environmental finality in decisions and technical acts of production but also in compensation arrangements for farmers and supply chain stakeholders	**Design** A capacity to design and spread innovations at territory level

There are prioritized actions to establish a common and renovated framework of methods, tools and data collecting devices.

Integrated pest management **Agricultural equipment** **Economic performance**	
Varietal innovations Ideotypes Interaction genotype/environment Characterization of environments	**Analysis of performances for arable crop systems** Multicriteria evaluation Indicators Observatory of practices
Weed management Effect of cropping systems Resistance management	**Sustainable management of soils** Characterization of soils for decision support systems

Actions of the consortium are implemented thanks to:

- reflection groups on specific topics
- seminars of co-construction
- feasibility studies
- coordination to elaborate devices for the acquisition, sharing or management of data but also the development and transfer of methods
- thematic audits
- building of collaborative projects

President
André Pouzet, Terres Inovia
Scientific coordinators
Antoine Messéan, INRA
Frédérique Angevin, INRA
Etienne Pilorgé, Terres Inovia
General secretariat
Stéphanie Potok, INRA Transfert

PRESENTATION OF RMT FLORAD: (Multidisciplinary Technological Network of weed management)

Farming practices implemented since the « Green Revolution » (use of pesticides and fertilizers, mechanization, intensive monocultures...) have greatly contributed to soil degradation, loss of biodiversity and the pollution of groundwater and surface water (Millenium Ecosystem Assessment, 2005 ; Tilman et al., 2002). However, herbicides are still very useful due to their simplicity of use, their regularity and their broad-spectrum effectiveness which almost completely covers weeds present on farmland. Today, the development of herbicide resistant weed populations and the awareness of the environmental effects (water pollution, loss of biodiversity in agroecosystems) require the design of new methods to control and manage weed flora. It is essential to conceive new innovative practices combining both integrated management and mechanical and/or chemical weed control. Similarly, viticulture is concerned by this objective of reducing pesticides: while it represents only 4% of French UAA (Agreste, 2007), it consumes 20% (in mass) of pesticides (Aubertot et al., 2005). Even if the practice of chemical weeding is tending to regress (5% of the surface of the Gironde region vineyard), herbicides are still used on the majority of the vineyard (over 80% in the Gironde region). They are most commonly used to control weeds under the vine row, but sometimes also in the inter-row as a complement to temporary cover or mechanical weeding (Agreste survey, 2006).

Searching alternative practices of chemical weed control is today a priority issue for many winegrowers facing new challenges: a regulatory context evolving towards a drastic reduction of authorized active molecules (glyphosate, amitrol…), new environmental concerns (water pollution, environmental certification approach…), technical issues (onset of weed resistance), conversion to organic production...These stakes mean that researchers and actors involved in development, collection of data and education have to work closer together and in a more systematic and intensive way to go beyond individual approaches and offer real innovative solutions.

WHO ARE WE ?

RMT Florad (Réseau Mixte Technologique Gestion de la Flore adventice) was created in 2007. It brings people together to work on global projects (INRA UMR Agroecology, AgroSup Dijon), public research, technical institutes (ACTA, ARVALIS Institut du Végétal, Terres Inovia, IFV, ITAB and ITB), agriculture boards (CA33), agricultural schools (EPLEFPA Toulouse Auzeville, EPLEPA Bordeaux Gironde, AgroSup Dijon) and farming cooperatives (IN VIVO). RMT is managed by ACTA (A. RODRIGUEZ), INRA (Sabrina GABA) and the Gironde agriculture board (Pascal GUILBAULT).

OVER-ALL AIM AND OBJECTIVES

- Explore new issues and build new projects to bring out and identify priority themes in order to offer clear and useful solutions,
- Provide expertise and solid links with national and regional working groups
- Promote and diffuse results and knowledge: training, management, transfer and dissemination.

PROGRAM

Explore new issue and build research and development project

TACHE 1 .1 : Knowing weed	Life historic characteristics	Phenology monitoring to improve weeding practices
		Biomass and seed production relations
		Improve, update, expand INFLOWEB
	Risk Assessment	Infestation risk Assessment
	Epidemiological Stake out	Value and optimization of epidemiological surveillance systems in a sustainable strategy for crop protection
		Inventory of weed resistance
TACHE 1.2 : Methodology	Sampling	Sampling errors
	Standardisation process	Promoting standard protocols
TACHE 1.3 : Weed control	Optimization of chemical weeding	Database : "Herbicide sensitivity of weeds"
	Alternatives practices	Alternatives practices baseline
		Reducing herbicides by 50% in wheat - oilseeds cropping system
		Selecting varieties crops for their competitive power on weeds
	Intercrop management	Improving false seed-bed
		Crucifer species used as monospecific intermediate crop or associated with leguminous plants for complementarity ecosystem services
	Soil management in vineyard	Evaluating alternative practices to chemical weed control
		Inter-crop management for improving ecosystem services
	Technical innovations	UAV, board cameras, RTK…
TACHE 1.4 : Biodiversity	Cropping systems	Effect of cropping systems on performance and biodiversity
	Preservation	Harvest plants protection

Training courses

For teachers	Set-up lessons for teachers	Teaching tools and materials
For students	Soil variability and diversity of weeds awareness	Teaching tools and materials

SOMES RESULTS AVAIBLE ON THE WEB : http://www.florad.org

Digital and decision-aiding tools :

- INFLOWEB : http://www.infloweb.fr/
- R-SIM : http://www.r-sim.fr/
- ECOHERBI : à venir

Proceedings :

- ECOHERBI 18 juin 2015 "Reducing herbicides : policy end practice" http://www.florad.org/moodle/course/view.php?id=37#section-5
- DESHERB'ACTION 2010 : http://www.florad.org/moodle/course/view.php?id=36

Learning materials (http://www.florad.org/moodle/course/view.php?id=68)

- Technical sheet « Wheat chemical and mechanical weeding»
- Ragweed (*Ambrosia artemisiifolia and A.trifida*): criteria for recognition and practical weeding
- Rat's tail fescue (*Vulpia myuros*) : criteria for recognition and practical weeding
- False seed-bed
- Mechanical weeding
- …

II. Programme

09h00 – 09h30 *Welcoming coffee*

09h30 – 09h45 ***Introduction (A. Pouzet & Ph. Vissac)***

09h45 – 11h05 ***Session 1***

Disrupting weed species in order to get a better weed management: intercropping cover-crops or associates, implantation techniques, innovative cropping systems

09h45 – 10h10 Changing cropping system and crop establishment practices to reduce the use of herbicides (S. Cadoux, Terres Inovia)

10h10 – 10h35 Impact of cover crops on weeds and volunteers: observation during the intercropping and crop period (P. Métais, Arvalis Institut du végétal)

10h35 – 10h45 Presentation of the session's posters

10h45 – 11h05 General discussion

11h05 – 12h45 ***Session 2***

Which combinations of practices to allow weed management?

11h05 – 11h35 'Effect of reduced tillage on weed management: a SSP survey analysis (2011)' (N. Cavan, INRA/Arvalis Institut du végétal) & 'Which combinations of drivers for a low reliance on herbicides? Analysis of a national demonstration farms network' (M. Lechenet, INRA/InVivo AgroSolutions)

11h35 – 12h05 'Weed management through the combination of agronomic methods: technical and economical analysis of a long term trial (2006-2014) in Epieds (27-France)' (L. Bonin, Arvalis Institut du végétal) & 'Impact and evolution of residual weed flora in cropping systems alternative to conventional maize monoculture' (G. Adeux, INP Ecole d'ingénieurs de Purpan)

12h05 – 12h20 Weed species are critical to maintain agricultural production in low-input cropping systems (S. Gaba, INRA)

12h20 – 12h25 Presentation of the session's posters

12h25 – 12h45 General discussion

12h45 – 13h55 *Lunch*

13h55 – 14h30 ***Posters session***

14h30 – 15h35 Session 3

Which terms of implementation of these strategies for the farmers et which assistance?

14h30 – 14h55	Work in a group of farmers on weed management, from the object cropping system. For a bigger independence regarding pesticide use (B. Omon, CA of département Eure & Cyrille Savalle, a farmer from the group)
14h55 – 15h10	Account of a farmer on his practices to allow weed management – breaking a technical deadlock
15h10 – 15h20	Presentation of the session's posters
15h20 – 15h35	General discussion

15h35 – 17h10 Session 4 / Round table

Which new leads to explore in weed management?

15h35 – 16h00	Towards the conceptualization for an improved integrated management of the weed flora with extended targets of their life cycle (X. Reboud, INRA)
16h00 – 16h05	Presentation of the session's posters
16h05 – 17h05	Round table led by Th. Doré (AgroParisTech) with the main representatives of the arable cropping systems' actors: which priorities and collective actions must be launched around weed management?
17h05 – 17h10	Conclusion of the meeting

III. List of contributions

NAME	First Name	Organization	Session	Oral / Poster	Title of the contribution
CADOUX	Stéphane	Terres Inovia	1	Oral	Changing cropping system and crop establishment practices to reduce the use of herbicides
METAIS	Pascale	Arvalis Institut du végétal	1	Oral	Impact of cover crops on weeds and volunteers: observation during the intercropping and crop period
CARTON	Nicolas	ESA Angers	1	Poster	Winter white lupin – triticale intercrop performances to secure lupin production and limit weed growth
LE CAMPION	Antonin	INRA	1	Poster	What role for the variety to control weed development in the designing of sustainable cereal cropping systems?
MEDIENE	Safia	AgroParisTech	1	Poster	Weed flora regulation by the insertion of temporary grasslands
DENEUFBOURG	François	FNAMS	1	Poster	Forage seeds production: interest of a sowing under cover crop for weed control
CAVAN	Nicolas	INRA/Arvalis Institut du végétal	2	Oral	Effect of reduced tillage on weed management: a SSP survey analysis (2011)
LECHENET	Martin	INRA/InVivo Agrosolutions	2	Oral	Which combinations of drivers for a low reliance on herbicides? Analysis of a national demonstration farms network
BONIN	Ludovic	Arvalis Institut du végétal	2	Oral	Weed management through the combination of agronomic methods: technical and economical analysis of a long term trial (2006-2014) in Epieds (27-France)
ADEUX	Guillaume	INP Ecole d'ingénieurs de Purpan	2	Oral	Impact and evolution of residual weed flora in cropping systems alternative to conventional maize monoculture
GABA	Sabrina	INRA	2	Oral	Weed species are critical to maintain agricultural production in low-input cropping systems

CAVAN	Nicolas	INRA/Arvalis Institut du végétal	2	Poster	Effects of reduced tillage on weed management – a methodology to use the SSP survey (2011)
SAVOIE	Antoine	INRA	2	Poster	Weed management with no herbicide. Example of pesticide-free cropping systems in arable crops assessed within a national experimental network: Rés0Pest
OMON	Bertrand	Chambre d'Agriculture de l'Eure	3	Oral	Work in a group of farmers on weed management, from the object cropping system. For a bigger independence regarding pesticide use
LAUNOIS	Lionel	Vivescia	3	Poster	Alopecurus myosuroides control : Agronomic practices to help herbicides
FROGER	Morgane	INRA	3	Poster	Accompanying DEPHY-FARM and DEPHY-EXPE networks in the characterization of the effect of cropping systems on weed flora
SCHAUB	Anne	ARAA	3	Poster	Identification of success keys in weed control strategy through a cross analysis of 3 cropping systems
GUIMARD	Amandine	Arvalis Institut du végétal	3	Poster	Which measures need to be implementing to get effective weed control? The case of graminea in cereal crops production in Centre and Ile de France
FONTAINE	Laurence	ITAB	3	Poster	Attending field experimenters to facilitate monitoring of weed flora in arable cropping systems
REBOUD	Xavier	INRA	4	Oral	Towards the conceptualization for an improved integrated management of the weed flora with extended targets of their life cycle
MEZIERE	Delphine	INRA	4	Poster	Impact of alley cropping agroforestry systems on weed communities
PETIT	Sandrine	INRA	4	Poster	Weed seed predation by carabid beetles
DARMENCY	Henri	INRA	4	Poster	What could we learn from the decline of segetal weeds?

IV. Oral contributions

- Changing cropping system and crop establishment practices to reduce the use of herbicides
  CADOUX Stéphane, SAUZET Gilles, VUILLEMIN Fanny

- Impact of cover crops on weeds and volunteers: observation during the intercropping and crop period
  METAIS Pascale, GEILLE Aurélie

- Effect of reduced tillage on weed management: a SSP survey analysis (2011)
  CAVAN Nicolas, LABREUCHE Jérôme, COUSIN Isabelle, WISSOCQ Adélaïde, ANGEVIN Frédérique

- Which combinations of drivers for a low reliance on herbicides? Analysis of a national demonstration farms network
  LECHENET Martin, PY Guillaume, CHARTIER Nicolas, TRESCH Philippe, MAKOWSKI David, MUNIER-JOLAIN Nicolas

- Weed management through the combination of agronomic methods: technical and economical analysis of a long term trial (2006-2014) in Epieds (27-France)
  BONIN Ludovic, ALIAGA Clémence, BARON Benjamin, VACHER Catherine

- Impact and evolution of residual weed flora in cropping systems alternative to conventional maize monoculture
  ADEUX Guillaume, GIULIANO Simon, PERDRIEUX François, RAMETTI Gaël, ALLETTO Lionel

- Weed species are critical to maintain agricultural production in low-input cropping systems
  GABA Sabrina, PERROT Thomas, CANEILL Jacques, BRETAGNOLLE Vincent

- Work in a group of farmers on weed management, from the object cropping system. For a bigger independence regarding pesticide use
  OMON Bertrand

- Towards the conceptualization for an improved integrated management of the weed flora with extended targets of their life cycle
  REBOUD Xavier

Changing cropping system and crop establishment practices to reduce the use of herbicides

CADOUX Stéphane*, SAUZET Gilles, VUILLEMIN Fanny
Terres Inovia, Avenue Lucien Brétignières, 78850 Thiverval-Grignon, France
*s.cadoux@terresinovia.fr – +33 1 30 79 95 08

Keywords: direct seeding, rapeseed intercropping, crop establishment, cropping system, rotation

Context:

Short crop rotations such as winter oilseed rape-winter wheat-winter barley are widely developed in France, notably in shallow clay-limestone soils. These situations, especially in the absence of ploughing, lead to a specialization of the weed flora, and to an increase in the weed seedbank and pressure. In rapeseed crops, one can regularly observe more than 50 bedstraws/m² and 200 geraniums/m² and yield losses. In these conditions, crop performance is fully dependent on the quality of crop establishment and the efficacy of herbicides which proves irregular (weed resistances, not always optimum application conditions, etc.). Due to this technical bottleneck, but also to incentives to reduce the use of pesticides (Ecophyto plan) and to constant regulatory changes, it is crucial to design more robust cropping systems, less favorable to weeds and thus less dependent on herbicides. Terres Inovia has tested different weed management strategies in shallow clay-limestone soils with high weed pressure in experiments and in farmer's fields.

Changes in crop establishment practices:

In the short term, we tried to set up new crop establishment practices to improve rapeseed growth dynamics. Two innovative levers were particularly efficient: direct seeding and rapeseed intercropping. Direct seeding with reduced soil flow helped reduce weed emergence by 85 to 95% whereas the efficacy of herbicides varied between 46 and 88%. Intercropping rapeseed with frost-sensitive legume crops had little effect on weed emergence but contributed to limit their development, due to an additional and complementary production of biomass. The effect was particularly significant when the aboveground biomass of the intercrop exceeded 1.5 kg / m² before winter. This threshold was reached on average with intercrops but not with sole rapeseed. The interest of these levers makes sense when combined in a strategy to optimize crop establishment. Two crop management practices were compared in an experiment with replicates conducted in farmer's fields: conventional (tillage, full doses of broadleaf herbicides, autumn insecticide, optimal fertilizer-N rate) and innovative (direct seeding, absence or half-doses of broadleaf herbicides, nonsystematic application of autumn insecticide, optimal fertilizer-N rate reduced by 30kgN/ha). Yield gains in innovative crop management (between +3.6 to +24 q/ha), due to improved rapeseed growth illustrate the fundamental role of a successful crop establishment in the performance of rapeseed. In these environments, these strategies based on avoidance and mitigation secures the success of rapeseed cultivation, more effectively than the stale seedbed strategies that promote continuous emergence, difficult to manage chemically or mechanically. However, they are insufficient to reduce the weed seedbank and the dependency on herbicides.

Changes in cropping system to penalize weeds sustainably:

Penalize sustainably pests and diseases in order to reduce pesticide dependency requires a redesign of the cropping system, taking into account a set of criteria related to initial diagnosis (soil, climate, pest pressure, etc.) and prospects (markets, regulation, etc.).

A cropping system experiment was carried out by Terres Inovia in shallow clay-limestone soils, in the frame of the « Rédusol » and « Phytosol[1] » projects. The aim was to evaluate the feasibility of reducing pesticides by 50%, N-fertilizer by 30%, while maintaining productivity and economic performances in reduced tillage conditions. The crop rotation of the conventional cropping system: winter oilseed rape-winter wheat-winter barley was compared to that of the innovative cropping system: winter pea/barley intercropping -intercropping rapeseed- winter wheat-winter barley-sunflower- winter wheat. In this innovative cropping system, weed control was improved in cereals. In peas, intercropping with a cereal improved weed control. However, the pea-rapeseed sequence increased the pressure of broadleaf weeds in rapeseed. Weed management in sunflower was complicated by difficulties in crop establishment. At the end of the experiment, yields and economic performances were maintained, and the objective of reducing fertilizer-N rate was reached. However, the goal of reducing the use of pesticides was not achieved (-25% versus -50%) and the use of total herbicides increased (+0.4 TFI). These results illustrate the need to prioritize the problems and adapt the solutions to the context. The SYPPRE[2] project allowed to go further in the redesign of cropping systems, through co-design including a variety of stakeholders (farmers, advisors, and researchers), and mobilization of up to date knowledge concerning the biology of weeds (Infloweb) and the effect of agronomic practices on the weed population dynamics. A cropping system based on a lentil-durum wheat-rapeseed intercropping-corn-sunflower-winter wheat-winter pea/barley intercropping-winter wheat-winter barley rotation, with sequences alternating direct seeding and reduced tillage with stale seedbed was proposed. The main objective of the diversification of crops, sowing seasons and the sequence of two spring crops, was to disrupt weeds and reduce herbicide dependency. This cropping system allowed *a priori* to reconcile profitability, productivity and reduced pesticide use and environmental impacts. It also reduced the risk for all weed species considered: geranium, bedstraw, meadow foxtail, bromine and ryegrass (Odera Systems simulations[3]). Testing this system for about twenty years will enable us to measure the actual effects.

Conclusion:

Changes in crop establishment practices are efficient to improve the weed control in the short-term in high weed pressure environments. But to make weed management sustainable on the long-term

[1] Projet PHYTO-SOL : project led by the Ministry of Agriculture, with the financial support of the National Agency for Water and Aquatic Environments by credits from the fee for diffuse pollution attributed to the Ecophyto plan.

[2] SYPPRE (Systèmes de Production Performants et respectueux de l’environnement) : project led the technical institutes Arvalis Institut du végétal, l’ITB et Terres Inovia with the support of the GIS HP2E

[3] The Odera-System tool is the result of a collaboration between Agro-Transfert, INRA and farmers in Picardy region with financial support from the ERDF, the Picardy Regional Council and the Seine Normandy and Artois Picardie Water Agencies.

and to be able to face future challenges more easily, it is also necessary to redesign one's cropping system. To get there, there is no single solution applicable everywhere. It is important to prioritize problems, mobilize knowledge, and adapt it to the given situation to design suitable cropping systems and define a transition pathway for their implementations.

Impact of cover crops on weeds and volunteers: observation during the intercropping and crop period

METAIS Pascale*, GEILLE Aurélie
ARVALIS Institut du végétal, Service Agronomie, Economie et Environnement, Station expérimentale, 91720 Boigneville
*p.metais@arvalisinstitutduvegetal.fr – +33 1 64 99 23 19

Keywords: cover crop, soil tillage, intercropping period, weed, volunteers

Introduction

Cover-crops during intercropping periods are more and more frequent, whether it is to fulfill regulation or to get agronomic services. Cover-crop presence may lead to different consequences on weed flora. It may have an impact on weed cycle development by modification of the environment (temperature, light, humidity…), competition or allelopathy. This may contribute to limit weeds density. However, cover-crop establishment may reduce soil tillage possibilities during the intercropping period both for stale seed bed and perennials weed management. In order to evaluate the impact of cover-crops on weed flora during the intercropping period and the next crop period, weed assessments were realized on field trials comparing cover-crops and bare soil.

Materials and methods

Weed flora assessments were realized both at intercropping period and in crops on two long term field trials with cover-crops: "cover-crop's species" trial and "environment" trial, located in Boigneville (91). Volunteers and weed of each species were counted in 6 to 12 frames of 0.25m² in each basic plot.

Cover-crop's species trial:

This trial was led from 2003 to 2013 in order to compare several cover-crop species or mix-species and observe consequences on crop establishment, yield and nitrogen availability. Six species were compared to a reference kept in bare soil by chemical weeding. After a first shallow cultivation, cover-crops are sown around August 15th with a Horsh Sème Exact. The drilling machine passed also on reference bare soil but without seed. Cover-crops where chemically wipe out at the end of November and next crops were established in March, usually by direct drilling. Assessments were done during intercropping period in 2010 (counting of volunteers only), 2011 and 2012 and in the crop in 2012. On bare soil, assessments were done before spraying.

Environment trial:

This trial was set up in 1992, in order to evaluate impact of soil tillage and cover-crops on nitrogen leak. Three factors are studied:

- Soil cover: bare soil, legume cover-crops, brassica cover-crops and mix cover-crops.
- Cover-crop destruction: ploughing or chemical destruction
- Soil tillage and seeding: ploughing (with or without previous shallow cultivation) or no-till and direct-drilling.

Assessments were done during intercropping period in 2011 and 2012, and in the crop before harvesting from 2012 to 2015.

Results and discussion

Effect of cover-crops on weed during intercropping period

Weed and volunteers density mainly depends on year. Multi-year analysis on data from “cover-crop species” trial indicates that cover-crops enabled to significantly reduce volunteers’ density during the intercropping periods, whatever the specie (figure 1). However, even if every cover-crops seems to reduce weed density compared to bare soil, only fertilized white mustard lead to a significant effect.

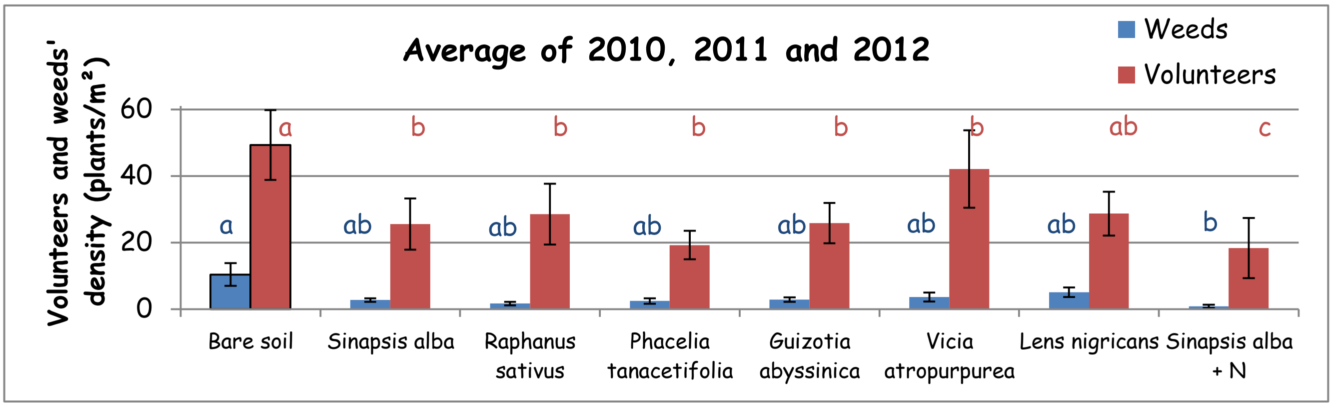

Figure 1: Volunteers and weeds' density depending on cover-crop's species

More than cover-crops’ species, it seems that cover-crop biomass influence weed and volunteers density. There is a negative correlation between cover-crop biomass and volunteers and weed density in 2010 and 2011 (respectively r^2=0.51 and r^2=0.87). This relation is not observed in 2012 but volunteers’ biomass decreases when cover-crop biomass increases.

Intercropping period management (soil tillage and cover-crop management) seems also to impact cover-crop capacity to reduce weeds. In the “environment” trial, weed density are higher in direct drilling modalities than in ploughing. In no-till, *Senecio vulgaris* is very significantly more present in cover-crops than in bare soil, whereas in ploughing there is no significant difference of weed density between cover-crop and bare soil. Maybe the insufficient cover-crop establishment in 2011 led to *Senecio vulgaris* seed dispersal. These seeds grew in *Vicia faba* and again produced seeds because of a lack of management in this crop. So *Senecio vulgaris* is present in high density in 2012.

Effect of cover-crops on weed in following crop

No significant weed density difference was observed in crop between modalities with or without cover-crops. However, modalities with cover-crops seem to be more infested than bare soil if there are cultivate in no-till. This may be the consequence of trial rules of management: bare soil was weeding at intercropping period after weed density assessment. By consequence, seed dispersal and soil seed bank enrichment were limited in bare soil reference. Despite of this additional weeding in bare soil, there is no significant difference of weed density in crops between modalities with or without cover-crop.

Conclusion:

During the intercropping period, cover-crop's presence makes it possible to reduce volunteers' density. However, effect on weeds is more contrasted. In the first trial, cover-crops tend to limit weed development, significantly with fertilized white mustard. In the second, a strong development of *Senecio vulgaris* is observed in cover-crops in no-till modalities, leading to a significant weed density difference between cover-crops and bare soil during intercropping period.

The differences observed during the intercropping period are not visible in following crops. Despite less intervention to avoid seed dispersal in cover-crops, there is no significant effect of cover-crops on weed-density in crops.

Effect of reduced tillage on weed management: a SSP survey analysis (2011)

CAVAN Nicolas*[1,2,3], LABREUCHE Jérôme[2], COUSIN Isabelle[3], WISSOCQ Adélaïde[2], ANGEVIN Frédérique[4,1]

[1] GIS GC HP2E, INRA Transfert, 28 rue du Docteur Finlay, 75015 Paris, France

[2] ARVALIS – Institut du Végétal, Station expérimentale, 91720 Boigneville, France

[3] INRA, UR 0272 SOLS, 2163 av. de la Pomme de Pin, CS 40001 Ardon, 45075 Orléans Cedex 2, France

[4] INRA, UAR 1240 ECO-INNOV, avenue Lucien Brétignières, 78850 Thiverval-Grignon, France

*nicolas.cavan@orleans.inra.fr – +33 2 38 41 80 46

Keywords: survey, agricultural practices, no-ploughing, herbicides, cover cropping

Tillage is one of the most used options for weed management: it prevents seeds from germinating (thanks to a deep ploughing in allowed by the turnover of the soil top layer) or destroys weeds in an early growth stage. Reduced tillage (especially no-ploughing systems) limits the use of this mechanical option of weed management by farmers, who then need to adapt their practices. According to the last surveys from the French Ministry of Agriculture, (Agreste – Pratiques culturales 2001, 2006, 2011), the ratio of tillage land with no-ploughing management almost stagnated from 2006 to 2011 in France (+ 0.3 point per year, supposing a linear increase during the five year gap between two surveys), after a rapid increase from 2001 to 2006 (+ 2.6 points per year). Some hypotheses have been proposed to analyze the consequences of these new practices on weed management : i) changing from ploughing to no-ploughing tillage systems would imply an increase in using selective and/or non-selective herbicides; ii) the slowing down of fields conversion from ploughing to no-ploughing tillage would be due to difficulties in managing weeds.

Testing hypotheses is difficult because of a lack of data suitable to compare different tillage systems in the same agricultural and pedo-climatic (AP) context. The last survey on tillage crops led by the Ministry of Agriculture (Agreste – Enquête pratiques culturales 2011), based on 20 827 fields, may be precise enough to test the hypotheses. For each field, it contains the full crop management techniques of the crop harvested in 2011. Moreover, data on the five previous years (2006-2010) is available, including: sowed crop, yield, mineral fertilization, tillage practices (ploughing or no-ploughing tillage: NPT).

To analyze the survey results, every field has been classified in an AP context, by using a typology based on the i) harvested crop, ii) the type of previous crop, iii) the type of crop rotation, iv) the type of soil and v) the area of production. For statistical reasons, every AP context should be described by at least 30 surveyed fields (Agreste, 2014). We therefore simplified the typology used by defining 6 types of soil (based mostly on the texture of the soil surface but also on calcareous and hydromorphic properties of the soil), 7 types of crop rotations (based on the two ratios cereal / dicotyledons and autumn / spring crops; and the presence of grassland), 10 types of previous crops (described according to the quantity of residues produced, their decomposition rate and the harvest date) and 8 production areas (described by the farms main productions and the main tillage crops sowed).

52 groups of fields have been identified, each of them describing a precise AP context. Each group contains at least 26 surveyed fields, and is composed of two subgroups with at least 6 surveyed fields in one of the two following categories: the ploughed fields and the fields with NPT. With the survey data, indicators were defined to describe the main aspects of agricultural systems: tillage practices, crop performances, residues management, cover cropping management, and the crop management techniques (mainly sowing, fertilization and use of plant protection products). The indicators for use of plant protection products are active substance (AS, $g.ha^{-1}$) and treatment frequency index (TFI, no unit) for all those products, and for herbicides, fungicides, molluscicides and insecticides. In each group, a mean of these indicators was calculated for each subgroup: fields ploughed (m_{plough}) and fields with NPT (m_{NPT}).

First, all indicators were studied independently from each other. For each group, we calculated the difference between the means in the two subgroups: $d = m_{plough} - m_{NPT}$. If the mean of these differences was significantly different from zero, then the value of the concerned indicator was related to the tillage method, independently from the AP context. We then demonstrated that herbicides were more frequently used in NPT fields than in ploughed fields (+ 0.41 TFI, with + 0.17 only for glyphosate), mainly for weed management purposes (+ 0.37 TFI). However, the use of other plant protection products than herbicides (+ 0.22 TFI, with + 0.16 only for fungicides) is greater on ploughed fields.

Principal Components Analyses (PCA) have been realized to analyze the correlations between indicators (quantitative variables), and to compare the effect of reduced tillage on agricultural practices compared to the other factors (qualitative variables) defining the AP context. For each qualitative variable, a Fisher test was done on the coordinates of the individuals on the principal components.

We demonstrated that the crop species explains 95 % and 90 % of the variability of individuals coordinates on first and second components: the potato crop explains most of this result, as the use of plant protection product on it is quite higher than for other tillage crops (TFI 16.1 compared to 3.8 for all surveyed crops). Even if we removed the subgroups describing potato, the crop specie remains the qualitative factor explaining the largest part of variability of the individuals coordinates (90 % and 79 % on the two first components). For the second component, 5 % of this variability was explained by tillage practices: coordinates of NPT individuals and plough individuals were significantly positive and negative, respectively, and this component was mostly correlated to total and herbicides active substance applied to the fields (R^2=0.89 and R^2=0.84).

To simplify our analysis, we grouped most of the indicators in agronomic themes (tillage operations, crop residues management, sowing, N and PK fertilization, weed management, and use of non-herbicides products) and did a PCA for each theme. If the principal or the two principal components were more informative on the variability of individuals, they were used to replace the indicators.

A hierarchical clustering performed on the PCA isolated three clusters: first, autumn crops; then sunflower, spring barley and spring pea; and finally beetroot and maize. A PCA realized only on the two last clusters allowed us to include all indicators on cover crops. Although the variability of individuals coordinates on the first component is still better explained by the crop species and the type of crop rotation (77 % and 62 %, respectively), the variability for the second component is best explained by the tillage method (60 %). This component was mainly positively correlated to the chemical destruction rate of cover crop (R^2=0.68), the use of herbicides (R^2=0.55) and the sowing of a cover crop between to crops (R^2=0.41). On the contrary, it was mainly negatively correlated to phosphorus and potassium fertilization (R^2=-0.51) and to the use of protection plant products other than herbicides (R^2=-0.30).

As a conclusion, we demonstrated than the differences in practices on weed management between ploughing and NPT systems are mainly on herbicides use (higher in NPT systems): this confirmed our hypothesis. However, the used quantity of herbicides is more depending on crop species (such as potato) than on tillage method. Besides, this greater use of herbicides is partly compensated by a smaller use of the other types of plant protection products. Finally, the more frequent and longer implantation of a cover crop is the only other difference between ploughing and NPT method that could be used for weed management.

Which combinations of drivers for a low reliance on herbicides? Analysis of a national demonstration farms network

LECHENET Martin*[1,2], PY Guillaume[1], CHARTIER Nicolas[3], TRESCH Philippe[3], MAKOWSKI David[4], MUNIER-JOLAIN Nicolas[2]
[1] InVivo Agrosolutions, 83 avenue de la Grande Armée, 75116 Paris, France
[2] INRA, UMR1347 Agroécologie, BP 86510, 21000 Dijon, France
[3] IDELE, AGRAPOLE, 23 rue Jean Baldassini, 69364 Lyon, France
[4] INRA, UMR 211 Agronomie, BP 1, 78850 Thiverval-Grignon, France
*MLECHENET@invivo-group.com – +33 3 80 69 33 27

Keywords: cropping system, herbicide reliance, management strategy, production situation, regression tree

Managing weeds with low herbicide use is a critical stake for a global reduction of pesticide reliance. Integrated Weed Management strategies might be (i) diverse, (ii) based on combinations of several management measures, and (iii) adapted as a function of the diversity of local production situations (PS). The Ecophyto-DEPHY network is a unique national network of commercial farms committed to pesticide reduction, including more than 1000 arable cropping systems (CS) contrasting on their level of herbicide use (averaged herbicide Treatment Frequency Index ranging from 0 to 4.4), but also on their management strategies (MS) (e.g. crop rotation, tillage strategy, fertilization rates, mechanical weeding, etc.) and PS (e.g. climate, soil type, presence of livestock, access to particular outlets). Our objective is to identify the combinations of factors driving herbicide reliance across a diversity of PS. We measured herbicide reliance with the herbicide Treatment Frequency Index (TFIh) calculated for each CS (i) as an average over the crop sequence, (ii) on wheat and (iii) on maize. We used contextual and technical data collected on the network to compute a range of descriptors of the PS and the MS likely to influence herbicide reliance. Using partitioning methods, we built regression trees to identify different profiles of PS explaining a first level of variability in TFIh. Based on a second set of regression trees, we then identified MSs, i.e. combinations of farming practices, that discriminated the level of herbicide use within each PS type.

Herbicide reliance at the cropping system level

We identified six types of PS with average herbicide TFI ranging from 1.2 to 3.1 (Figure 1a). These PS differed in the presence/absence of livestock, several climatic factors (averaged temperature, amount and distribution of precipitations, relative air humidity and potential evapotranspiration), yield potential, and the possibility to cultivate industrial crops with high added value such as sugar beet, potatoes or seed maize.

In PS1, we compared the profiles of MS with the lowest and the highest herbicide reliance (respectively MS1, TFIh=0.4 and MS4, TFIh=1.5). Compared to MS4, MS1 displayed higher crop diversity, higher rates of temporary grassland and rustic crops (e.g. hemp and triticale), lower rates of straw cereals, oilseed rape and maize. The share of CS resorting to inversion tillage is 10% higher in

MS1 than in MS4, but the frequency of tillage operations is lower, in line with higher rates of pluriannual crops in MS1. N and P fertilisation rates are lower in MS1.

In PS4, MS1 (TFIh=1.4) and MS3 (TFIh=1.9) were respectively associated to the least and the most herbicide reliant CS. MS1 differed from MS3 in a higher proportion of herbicide application at low rates as well as on localised areas, a higher resort to inversion tillage (inversion tillage present in all CS from MS1 with various frequencies). Although in both cases winter crops represented more than 50% of cropping area, we found a higher sowing period diversity in MS1 than in MS4.

Herbicide reliance on winter wheat

We identified two types of PS associated with contrasting herbicide use (average TFIh = 1.6 and 2.2 in PS1 and PS2, respectively (Figure 1b). Compared to PS2, higher temperatures, solar radiation, and potential evapotranspiration were found in PS1 along with a lower amount of precipitation over year (803 mm in PS1 vs. 911 in PS2), hence a higher risk of water stress in PS1. 12% of CS from PS1 had an access to irrigation systems, whereas none in PS2. More than 50% of CS displayed high yield potential in PS1 whereas only 25% in PS2.

In PS1, comparing the least and the most herbicide reliant profiles of MS, respectively MS1 (TFIh=1.2) and MS5 (TFIh=2.7), we highlighted that MS1 was less based on winter crops, notably winter straw cereals and oilseed rape, but displayed a higher proportion of summer crops, and more particularly maize. CS from MS1 showed a higher proportion of herbicide application at low rates. They were associated with a significantly higher varietal diversity on wheat but also to lower rates of N fertilisation on this crop. In addition, cropping systems resorting to inversion tillage appeared more frequent in MS1 than in MS5.

Herbicide reliance on maize

We identified five types of PS with herbicide TFI ranging on average from 1.3 to 3.7 (Figure 1c). These PS differed in the presence/absence of livestock and in several climatic factors (averaged temperature, amount of precipitations, potential evapotranspiration and risk of drought). CS from dry PS logically displayed a more frequent access to irrigation systems.

In PS1, the least herbicide reliant profile of MS (MS1, average TFIh=0.7) was associated with lower rates of summer crops, and notably maize, but a higher crop diversity than the most herbicide reliant profile of MS (MS5, TFIh=2.1). Mechanical weeding on maize was frequent in MS1 but nearly absent in MS5, and systems from MS1 also displayed a higher proportion of herbicides applied at reduced rates. Although no difference was noticed on the frequency of inversion tillage on maize, the proportion of CS resorting to inversion tillage was slightly higher in MS1 than in MS5.

In PS3, the least herbicide reliant profile of MS (MS1, TFIh=1.3) displayed higher rates of winter crops, and notably oilseed rape, than the most herbicide reliant profile (MS2, TFIh=1.9). Herbicide applied at reduced rates on maize were more frequent in MS1 than in MS2, in addition to a higher resort to localised spraying in MS1. We noticed a higher frequency of inter-season cover crops in MS1 than in MS2. No difference appeared in the frequency of inversion tillage on maize between these two profiles but, conversely to the case of PS1, the proportion of CS performing inversion tillage was higher in MS2 than in MS1.

Conclusion

Low reliance on herbicides will not go through a "one-size-fit-all" combination of technical options, but depends on the set of constraints and opportunities in the considered PS. Here we found that the level of herbicide use varies with the context (probably mainly because the PS strongly determines the main features of CS). More interestingly, we found that low herbicide use is related with combinations of management options that might vary as a function of the context. Across the profiles of PS we identified, a range of promising profiles of MS emerged, based on more diversified crop sequences, a better balance between crop species and between cultivation periods, a resort to inversion tillage at CS level, herbicide dose reduction or mechanical weeding (although mechanical weeding was more frequently associated with low TFIh in maize-based CSs than in wheat-based CSs). In the light of the combinations of drivers we identified, our analysis depicted an overview of pathways to explore further to progress and reach low herbicide reliance.

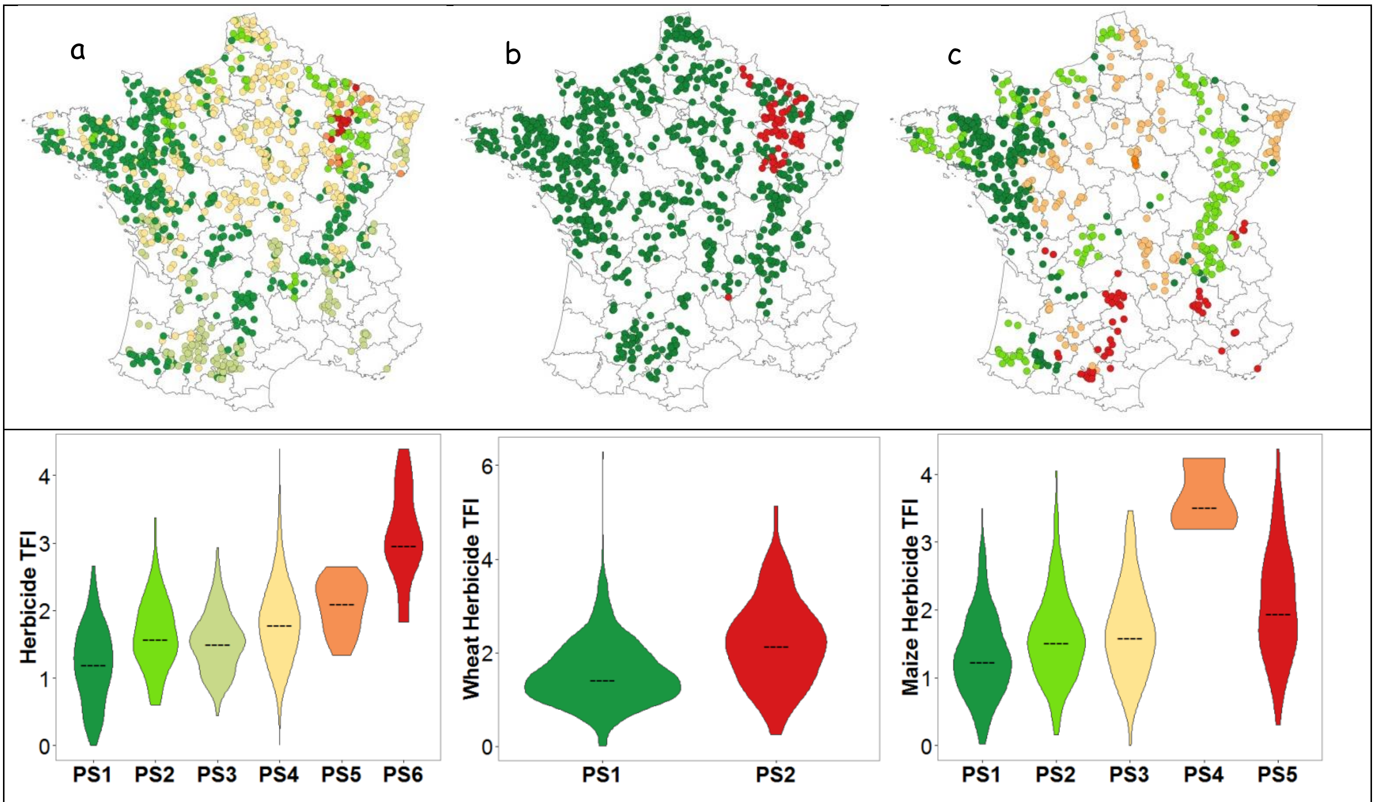

Figure 1: *Maps of DEPHY sites classified according to the PS identifed with regression trees. Six, two and five PS were identified for herbicide TFI calculated at the CS level (a), on wheat (b) and on maize (c) respectively. Under each map the distribution of herbicide is represented for each PS (colors between maps and plots are matching).*

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Weed management through the combination of agronomic methods: technical and economical analysis of a long term trial (2006-2014) in Epieds (27-France)

BONIN Ludovic*[1], ALIAGA Clémence[2], BARON Benjamin[2], VACHER Catherine[1]
[1] ARVALIS Institut du végétal, Station expérimentale, 91720 Boigneville, France
[2] ARVALIS Institut du végétal, 2 chemin du moulin, 27170 Ecardenville la Campagne, France
*l.bonin@arvalisinstitutduvegetal.fr – +33 1 64 99 22 00

Keywords: blackgrass, ryegrass, rotation, ploughing, delayed drilling

Weed management in cereals becomes a recurring concern. Actual cropping systems, lack of new modes of action and progression of resistant populations may in part be the cause. Moreover, the evolving regulatory environment at European level, with the Directive 2009/128 on the sustainable management of pesticides, and the national plan of reduction of pesticides (Ecophyto 2) worsens the situation. In this context, agronomical methods to reduce the weed pressure become essential.
ARVALIS Institut du Végétal studied in a long term trial in Normandy (Epieds - 27) during 9 campaigns (2006-2014) different agronomic methods to control weeds. The main objective of this experiment was to quantify the effect of these different agronomic methods (tillage, rotation, delayed drilling) on the evolution of the weed flora. The experimental site is designed with two tillage factors (ploughing and no till, implemented each year) crossed with 3 rotations: a monoculture of wheat; a Rape-Wheat Wheat-rotation (local reference) and long rotation Rape -Wheat- Spring Legume - wheat. The monoculture is conducted with at least two false stalebed, and always with a delayed drilling of wheat (usually late october) regardless tillage implantation (ploughing or no till). Conversely, the reference rotation is always carried out with an early drilling of wheat. Finally, the long rotation is carried out with two drilling dates of wheat, early (as in the reference rotation) or delayed. A total of 4 lines were differentiated (rape / wheat / wheat with early drilling of wheat; wheat monoculture with delayed drilling, rape / wheat / peas or faba bean / wheat with early drilling of wheat; rape / wheat / Spring legume / wheat with delayed drilling of wheat), ploughed and no till system. Each plot (24 m * 60 m) has a control area (10m * 24m) destroyed before shedding of weeds. The trial has no repetitions, considering the tillage history (ploughing and no till). Weed control with herbicides is optimized for every situation, as would a farmer.
A total of 26 weed species were counted in the control area, with large densities (in pl / m²) of grasses (blackgrass, ryegrass, annual bluegrass and brome). The individual effect of agronomic methods could be assessed, comparing each rotation, 2 to 2. The effect of ploughing is greater than any of other methods. Thus, the reduction is around 90% in monoculture, 70% in short rotation and close to 30% in long rotation, with delayed drilling and 60% by early drilling. These results confirm the leading role of ploughing in the overall weed control.
This finding is also observed for the comparison of the short versus long rotation. In no till system, the difference is minimal, with no effect of rotation. However, in ploughed conditions, the effect is very clear with a 75% decrease of the infestation. We also observe a flora change with less blackgrass

and ryegrass in long rotation, but more broadleaf weeds. The effect of shifting the drilling date is visible on wheat, with a very limited gain in ploughing plots (-18%). However, in no till situations, the reduction of infestation – due to delayed drilling - is close to 60%. The combination of agronomic methods is also interesting to reduce infestations but ploughing remains the essential factor that can greatly reduce populations. Therefore, without ploughing, and only with the effect of the rotation, cumulative infestations are similar. The introduction of ploughing, in addition to the long rotation, reduces the total infestation of 90%. From a qualitative point of view, floras are altered by the introduction of agronomic methods. Blackgrass is easily controlled by ploughing and by the combination of agronomic methods, in particular the diversification of the rotation associated with late drilling of wheat. Moreover, its germination is centered to the fall, with positive consequences for a delayed drilling. Ryegrass seems less sensitive to management by drilling dates. His behaviour can therefore be compared to that of blackgrass with a lesser influence of drilling date. Brome appears mainly in situations in early drilling and short rotation.

Among the indicators used in this trial, working time is equivalent between rotations, all combined soil tillage. However, soil tillage (ploughing or no till) is the most impacting factor on total working time (+ 1.6H / ha in average in ploughed situations). Similarly, fuel consumption (L / ha) is directly correlated to soil tillage regardless of the rotation. The gain in no-till is about 28 L / ha on average. The indicator directly related to the pressure in herbicide's use is TFI (Treatment Frequency Index). It shows a net benefit to the long rotation + delayed drilling date of wheat, compared to the reference rotation, with a drop of 0.75 TFI all combined soil tillage. The effect of tillage reduces 0.77 IFT across all rotations. The combination of agronomic methods (rotation + ploughing + delayed drilling of wheat) reduces herbicide TFI of 1.7 on average (1.5 versus 3.2 for the rotation Rapeseed / Wheat / Wheat in no-till). Finally, from an economic point of view (direct margins in € / ha except grants) from all rotations, ploughing gives off more margins than no till with a gain of 85€ / ha on average. Despite higher costs of mechanization in ploughing systems, weed problems in no-till associated with higher herbicides' programs costs, impacted the performance, which results in a drop of the direct margin. In no till, the long rotation with delayed drilling of wheat or not, has a higher margin than the reference rotation (+ 5€ to + 65 € / ha in average). However, in ploughing situations, the reference rotation is more profitable to all other rotations, in particular the long rotation (+ 142 € / ha in average).

In conclusion, the introduction of agronomic methods is always favorable for weed management. The most important effect observed in this long term trial is tillage, with a better control of grasses (blackgrass, ryegrass and brome). Moreover, the introduction of these methods not automatically degrades direct margin. Instead, they may in certain cases improve the margin by increasing the yield. TFI is also improved in those situations with decreases from 35 to 40%. However, all these methods studied in this trial cannot be transposed to all agricultural situations (agronomic constraints, soil and climate,...). Extrapolation to agricultural situations should be mitigated. Moreover it is necessary to set the best tailored options with the farmer, by giving priority to the most difficult situations.

Impact and evolution of residual weed flora in cropping systems alternative to conventional maize monoculture

ADEUX Guillaume, GIULIANO Simon*, PERDRIEUX François, RAMETTI Gaël, ALLETTO Lionel
INP-Ecole d'Ingénieurs de PURPAN, 75 Voie du TOEC, BP 57611, 31076 Toulouse Cedex 3, France
*simon.giuliano@purpan.fr – +33 6 50 42 79 40

Keywords: low input cropping systems, integrated weed management, mixed weeding, *Echinochloa crus-galli, Polygonum persicaria*

Introduction : In South-Western France, conventional maize monoculture (MM_{Conv}) is the dominant irrigated cropping system (CS). Its production exerts both quantitative and qualitative pressure on water resources due to important irrigation during the summer time and contamination by nitrate, from nitrogen fertilizers, pesticides and particularly herbicides (Tappe et al., 2002 ; Konstantinou et al., 2006). Herbicides represent 78% of the total number of applied doses of pesticides on maize, highlighting the importance of weed management in this crop. Therefore, it is essential to design CS that remain economically efficient and in which weed management does not primarily rely on the use of herbicides. This study evaluates the agronomic, economic and environmental performances of CS alternative to conventional maize monoculture. The performance of the weed management measures used within each CS was also assessed by following the dynamics of residual weed flora.

Material and Methods : The CS experimented since 2011 on two randomized blocks are:

-MM_{Conv} : reference maize monoculture (MM) defined by the main objective of maximizing the gross margin. This CS is characterized by annual plowing, bare soil during intercrop, chemical weeding (post-sowing/pre-emergence + remedial spray), a late variety and non-limiting inputs (water, nitrogen)

-MM_{LI} : a low input MM aimed at reducing 50% of the total number of applied doses of pesticides, 30% of irrigation, 25% of fertilization and energy use, and maintaining the same gross margin as MM_{Conv}. This CS includes annual plowing, mixed weeding (rotary hoeing, banded applications on rows and hoeing in inter-rows), a ray-grass/clover cover-crop sowed during the last cultivation and a mid-early variety.

-MM_{CT} : a direct seeded MM aimed at reducing work-time, energy use and nitrate and pesticide leaching by 50%. Weed management is only conducted through chemical means. This CS also includes a forage sorghum/ faba bean cover-crop and a mid-early maize variety.

-MSW: a three year maize/barley-soybean/soft wheat rotation aimed at limiting peaks of workload, the total number of applied doses of pesticides, irrigation and nitrate leaching. Maize is cropped the same way as in MM_{LI}. Plowing is only done prior to maize sowing.

The potential of weed infestation was calculated each year by meaning the maximal measured density of each specie during the two annual countings (early and late) achieved on 6 to 10 0.5 m² quadrats per plot. The early sampling was achieved after the first weeding operations, around the 6-8 leaf stage of maize, whereas the late sampling was carried out at maize flowering, after all weeding operations. Weed species biomass were also collected at the 8-leaf stage, flowering and maturity of maize. In 2014, two "weed free" zones were set up in each plot in order to evaluate the impact of residual weed flora on maize yield.

Results : Mean grain maize yields of MM_{Conv} (113q/ha±11) and MM_{LI} (107q/ha±25) are equivalent but MM_{Conv} shows less variable yields. MSW-Maize yields (91q/ha±18) are not significantly different from MM_{LI} or MM_{CT} (78q/ha±19). MM_{Conv} (1094€/ha), MM_{LI} (1098€/ha) and MSW (798€/ha) all present gross margins superior to MM_{CT} (465€/ha). The CS show a very different total number of applied doses of pesticides: MM_{CT} (3), MM_{Conv} (2.5), MSW (1.2) and MM_{LI} (0.9).

The three main weed species present in the experimental set-up are *Echinochloa crus-galli*, *Polygonum persicaria* and *Kickxia spp*. It was shown that weed biomass at maize maturity and maize grain yield are negatively correlated. In 2014, the analysis on the "weed free" zones show a trend: yield in the "weed free" zones is always superior to the yield of the rest of the plot. Potential yield of MM_{CT}, without weeds, is 2.2 t lesser than the other systems.

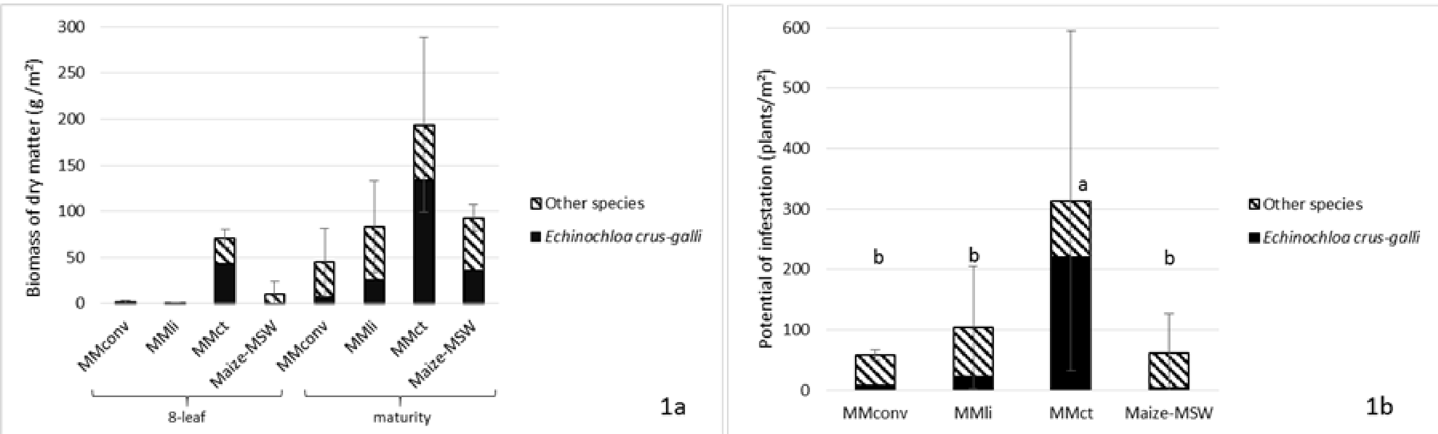

Figure 1:Weed biomass at the 8-leaf and maturity stage of maize on the 4 cropping systems (2011-2014)(1a) and Potential of weed infestation on the four cropping systems (2011-2014)(1b)(Letters indicate Tukey's statistical groups)

For the different systems, weed biomass at maize maturity (*Fig.1a*) represents 0.45 t DM/ha (with 41% of *P. persicaria*) for $MM_{Conv,}$ 0.7 t DM/ha (with 38% of *E. crus-galli*) for MSW-Maize, 0.84 t DM/ha (with 39% of *P. persicaria*) for MM_{LI} and 1.9 t DM/ha (with 67% of *E. crus-galli*) for MM_{CT}. In 2014, MM_{CT} presented a significantly more important weed biomass at the 8 leaf stage of maize.

The mean potential of infestation (plants/m², *Fig. 1b*) of MM_{Conv} (58±8) and MSW-Maize (39±1) is low and steady, while that of MM_{LI} (104±95) is more variable and MM_{CT} increased tenfold from 2011 (74±39) to 2014 (756±32). MM_{CT} presents a significantly more important weed biomass at maize maturity and potential of infestation of *E. crus-galli*, *Convolvulus arvensis* and *Digitaria sanguinalis*. Moreover, the potential of infestation of *C. arvensis* and *D. sanguinalis* is increasing in this system.

Discussion and Conclusion : The critical stage of competition between maize and weeds ranging from sowing to the 3-to-6 leaf stage (Page et al., 2012), the more important weed biomass of MM_{CT} at the 8-leaf stage could explain its lower yields. In contrast, MM_{CT}'s poor performance in the absence of weeds suggests that other factors, such as soil structure, can explain the variability of performances. The effective management of weeds in MM_{Conv} could be explained by the use of an anti-germinative herbicide before weed emergence. MM_{LI} presents a more fluctuating potential of infestation because of its curative management on the inter-row but does not impair conventional yields. The results obtained on MSW seem to confirm that rotation is an efficient weed management tool (Westerman et al., 2005). As a result of this 4-year experimentation, MM_{LI} appears as the most interesting alternative. It combines agronomic performance, herbicide reduction (-64%) and efficient weed management.

Weed species are critical to maintain agricultural production in low-input cropping systems

GABA Sabrina*[1,2], PERROT Thomas[1,2,3], CANEILL Jacques[4], BRETAGNOLLE Vincent[2,4]
[1] INRA, UMR1347 Agroécologie, 21000 Dijon, France
[2] LTER ZA « Plaine & Val de Sèvre », CNRS Centre d'Etudes Biologiques de Chizé, 79360 Beauvoir-sur-Niort, France
[3] CNRS, UMR7372, Centre d'Etudes Biologiques de Chizé, 79360 Beauvoir-sur-Niort, France
[4] AgroSup Dijon, UMR1347 Agroécologie, 21000 Dijon, France
*sabrina.gaba@dijon.inra.fr – +33 3 80 69 31 87

Keywords: agroecology, crop production, pollination, agricultural socio-ecosystem

The main challenge in agriculture today is the design of cropping systems which limit the use of chemical inputs, while controlling the pests and diseases of crops and maintaining production potential and farmers' incomes. Weeds are an emblematic example of this challenge, and a major obstacle to the objectives of the Ecophyto Plan. Indeed, herbicides are an important part of pesticides used in France. Among the alternatives to intensive agriculture, agroecology relies on the premise that biodiversity, its functions and ecosystem services (e.g. biocontrol, pollination) it underpin, could offset the use of chemical inputs (fertilizers, pesticides). However, to date, few studies have validated this assumption and, ecosystem services provided by biodiversity to agricultural production remains to quantify.
This is precisely the target aim of the ANR project Agrobiose (2014-2018) which aims to bring operational solution to face the Plan ECOPHYTO requirements. In this project, we test the hypothesis that the decreased use of herbicides would allow an increase in weed diversity but also in pollinators and auxiliaries diversity; this increased biodiversity will in return maintain or increase crop production thanks to the regulating services (biocontrol, pollination) it provides. Indeed, weed species are at the basis of food webs in agroecosystems, and thus play a crucial supporting role of biodiversity. Weed seeds are resources for carabidae insects (Marshall et al. 2003), but also for migratory birds such as skylarks (Eraud et al. 2015). Weeds also provide pollen and nectar for wild pollinators, including honeybees (Rollin et al. 2013, Requier et al. 2015). However, weed diversity has drastically declined since the 1950's (Kay & Sutcliffe 2000 Hyvönen et al. 2007). This loss of biodiversity is particularly remarkable in rare weed species (Richner et al. 2015). This loss of weed diversity originates from the massive use of herbicides with the aim of maximizing crop yields, because weed species in arable crops could lead to yield losses up to 23% worldwide (but currently 8%; Oerke 2006) due to competition for resources (water, nitrogen, light) with crops. Although this impact is widely accepted, many studies question the magnitude of this impact, especially in wheat which is the dominant culture in crop sequences (Steckel et al., 1990, Salonen 1992 Hamill and Zhang 1995 Zhang et al. 2000).
In this talk, we will expose the first results from the ANR Agrobiose project in three steps. First, we will present the results of an experiment conducted in 2013 and 2014 in farmers' winter cereals fields in the LTER Zone Atelier "Plaine & Val de Sèvre" (http://www.za.plainevalsevre.cnrs.fr /) whose

objective was to quantify the competition between crop and weeds plants along a wide range of cropping systems. In this experiment, we manipulated the supply of nitrogen fertilization and herbicides to quantify the effect of these two practices on weed diversity and on weed-crop competition. The results show (i) a lack of relationship between the use of herbicides (IFT, Treatment Frequency Index) and crop production, and (ii) between weed biomass and IFT.

Then, we will present results on the effect of crop insect pollination on oilseed rape and sunflower productions. About 35% of the main crops in the world rely on pollination services (Klein et al. 2007). Since 2013, we have quantified the effect of insect pollination on the production of oilseed rape and sunflower in farmers' fields. The analysis of the years 2013 and 2014 show that in absence of pollination by insect, crop production decreases from 50% to 75% in oilseed rape and sunflower, respectively (T. Perrot, PhD).

Finally, we will present a conceptual framework summarizing these elements and results obtained elsewhere (Bretagnolle & Gaba 2015), which highlights the key role of weed species in providing both (1) of provisioning services, ensuring the production of oilseed rape and sunflower, and of honey, (2) regulation services by ensuring the survival of honeybees between mass-flowering blooming seasons of oilseed rape and sunflower (3) socio-cultural services by maintaining rare and flagships plant and insect species, as well as ensuring a socio-cultural value of agricultural landscape.

All these elements question the systematic use of herbicides and, demonstrate that the presence of weeds in agro-ecosystems is crucial for crop production in farmlands.

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Work in a group of farmers on weed management, from the object cropping system. For a bigger independence regarding pesticide use

OMON Bertrand, Chambre Agriculture de l'Eure, 5 rue de la Petite Cité, 27008 Évreux cedex, France
bertrand.omon@agri-eure.com – +33 3 44 15 20 62

From highly different initial Farm Systems and Cropping Systems, on diversified landscapes in the département of Eure, during the 2000s, the Common Principle of the group of farmers fast became another crop management. Then the group focused on another weed management (2008 then FERME 2010 ; Dumas et al.).

1. How have the farmers worked in a group? How did the cropping system approach allowed them to progress?

Since 2007, a systemic description has been established then has become the subject of work for each farmer: the cropping system (CS; Sebillotte, 1990). This description allowed an exchange on the interactions between techniques, on the combination of techniques with partial effects. No doubt this consideration is the strongest source of change, individually and collectively.

The Decision-schema of weed management then became the intermediate subject of permanent work within the group: work together on the cropping system of the colleagues, in addition or not to private sessions with the assistant agronomist. During these periodic sequences, several things happen at the same time, both for the farmer which CS is observed and the others. It is all about co-design over time in order to evolve both individually and collectively.

Working this way also allows the farmers of the group to discover their differences, it relies on it. That was impossible in the approach of aiming at "conformity to promising practices". This characterized difference becomes itself a contribution to the evolution of each farmer. If the decision-schema is the articulation between "results to be achieved" and a "combination of management functions" (resulting in technical "levers"); then the analysis of their differences focuses both on the way they are satisfied (Expected Results), and on their combinations of techniques with partial effects.

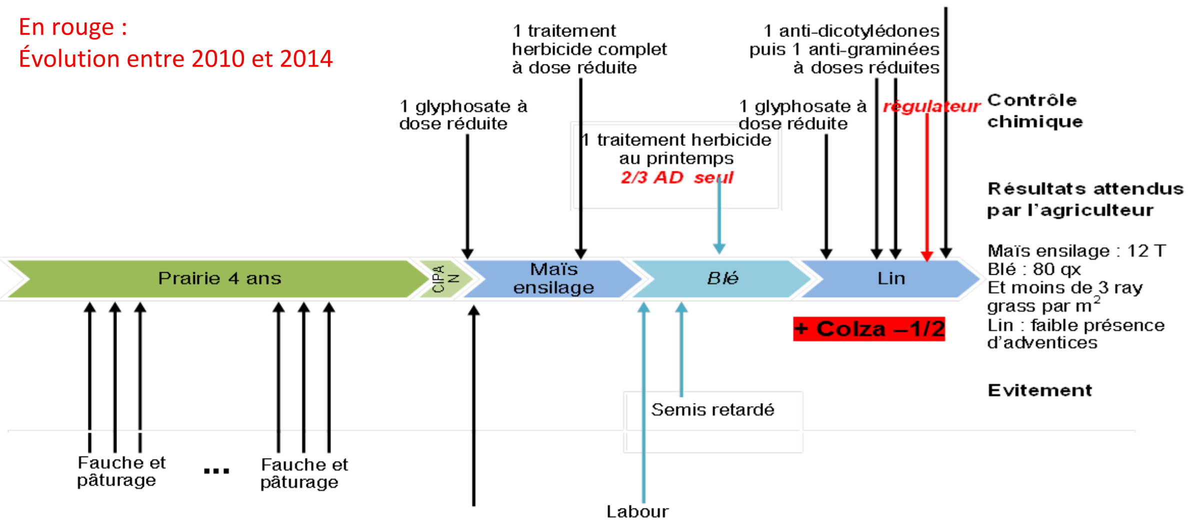
The Cropping Systems remain the object of discussion and guidance: on their implementation on parcels, in sharing some key moments during the campaign, then during the individual and collective Campaign Assessments. The latter allows the annual agronomic evaluation of the cropping system. In addition, the treatment frequency index (IFT) tells the level of polluting pressure associated with the level of agronomic weed control by comparison with the expected profits (not in absolute terms).

2. What evolution of the Cropping Systems and decision-making over time regarding weed management?

About the Expected Results: their level of requirement decreased for the greater part, whereas they discovered they could give up some "thresholds" and (for some of them) rely on the proven robustness of their systems. So, the level "not more than the 1st zone of competition over the crop" is very often their current demand.

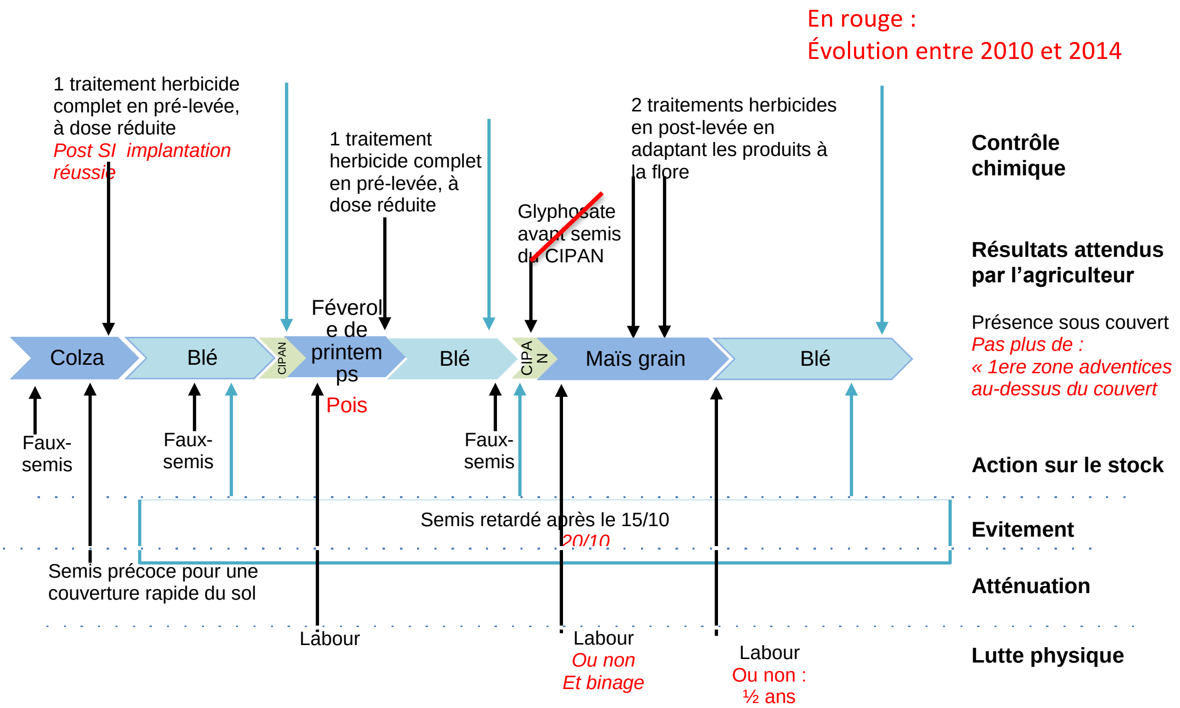
Three big types of systems are identified within the group:

CS with temporary meadow – Presence of rather frequent plowing: strong and sober in chemistry.



Fast progress observed after implementation – but also a weight of the initial control degree. Thus there is a parcel effect to be crossed with the CS effect (a chemical failure does not prevent return to balance). The resilience is strong. But it settles down slowly on an initially degraded CS.
IFT is between 25 and 60% of the regional reference.

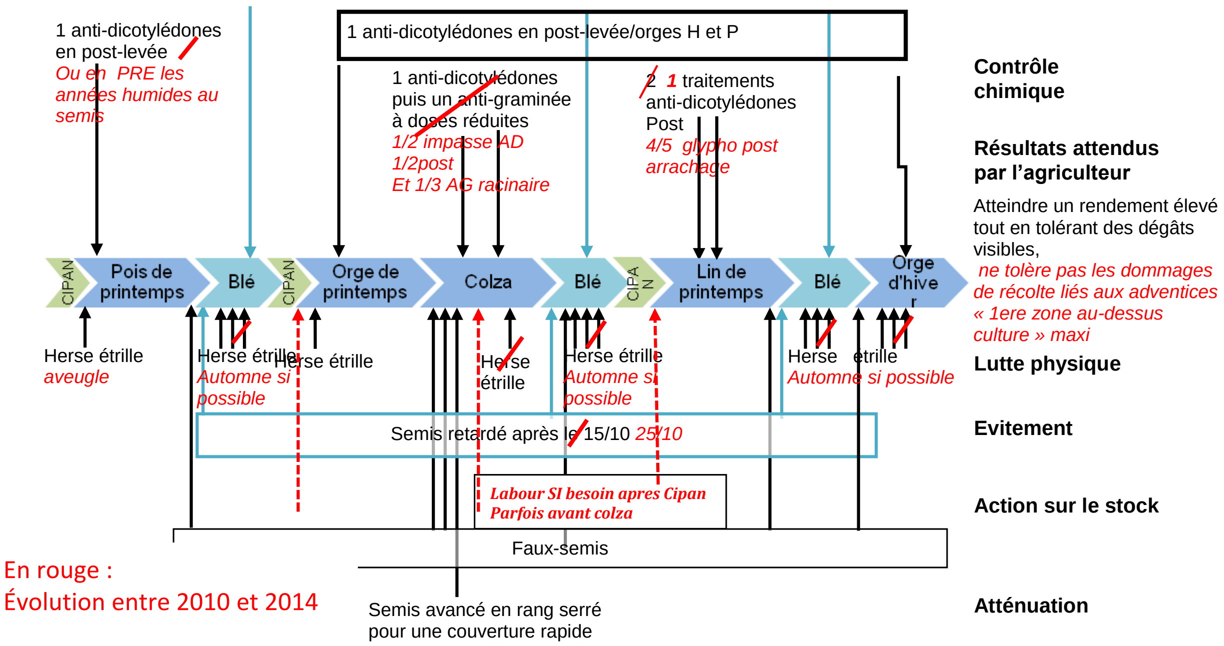
CS with 4 periods of sowing and frequent plowing: rather stable but remain dependent on the chemical success to reach the expected results:



Diversified flora but less specialized than in the following type. The return to balance is rather fast after an annual loss of control on a parcel.

IFT is between 40 and 70 % of the regional reference.

"Diversified" CS without 4th period of sowing and with few or no plowing: the tensest and the most dependent on chemistry:



There is a tense history with appearance of partial ineffectiveness and/or resistant grasses or poppies. The pressure is due to autumnal grasses and autumnal and spring dicots, as well as thistles. The need for specific treatments in addition of a basic fight is source of a stronger pesticide use. The systematization of CIPAN in absence of plowing strengthens the requirement to obtain the dead end in glyphosate. The balance between CS robustness and chemical control is around 1.3 IFT, when the implementation does not derive and when the adjustment is very reactive in case of loss of control (the plots of land which "cost" in IFT).

IFT is between 60 and 110 % of the regional reference according to the CS and the years.

3. What are the results regarding weed management and associated polluting pressure?

From the farmers' point of view, weed management is globally insured (from what was learnt in the campaign assessments with them).The plots of land in failure are rare, but with a level of chemical fight too high in their opinion, although it is lower than the current regional references (NODU 2012-2013-2014).

Over time, the stronger CS implemented (according to the group of farmers) are also the least consumers in herbicides.

The largest consumptions are often the facts of serious lack of control. On the contrary, the weakest consumptions are associated most of the time with a satisfactory weed control, considered "without regrets" during the campaign assessment. The annual grasses family brings the major difficulties in weed control, and at the same time regarding the gap of observed consumption (sometimes also thistles-poppies-glyphosate).

The notion of balance between robustness or resilience AND chemical fight is used with the group, so that the decrease in herbicide use is never independent from the design and systemic implementation. That allows the farmer decision-maker to wonder about this balance.

4. Go further

First it means deciding to go towards another balance point between CS robustness and chemical fight. For the farmers of the group, that will imply to work on the combinations with partial effects and at the same time on the way they tolerate the presence of weeds, with a better knowledge of the resilience offered by their different CS. Searching for a more efficient crop/weed competition is a lead for a lot of them: all can contribute to improve it, looking for techniques and innovation.

Another lead has appeared more recently, particularly for the farmers having CS in "limit of balance", from their capacity to find again resilience throughout a decision-making attitude directed to "the permanent adjustment" (Meynard et al., 2012).

It is about not letting a defect of control settle down in a plot of land enduringly, by proceeding to powerful temporary adjustments. It is like thinking of the CS as more "floating", like a developing object answering to big rules of decision to strengthen the robustness permanently, ie. to allow resilience, according to the plots of land which stay the basic unit where the interactions take place. In consequence, this adjustment allows avoiding the "year of excess" in lack of control, with an effect on the consumption over the years N, N+1 and N+n.

(Cf. case of organic farmers out of the group with "arable crops CS" also in limit of robustness – agronomic issues in common and shared with the group.)

5. Another weed management: how to accept a gap regarding the social norm?

Even more importantly than for other pests, the practices in combination for weed management are visible, are showcased: for instance, repeated false sowing whereas others are sowing or have finished all around, or introducing a crop which is not often cultivated locally, or else crushing a part of plot of land – even limited – as a fast reaction has a limited and very local overflowing.

This exhibition of changes of practices rarely attract the approving gaze of the peers on a different way of being satisfied, or on the definition of a "dirty" plot of land. It becomes acceptable only if the community knows that every chemical options were tried, which makes the change in this domain particularly difficult. The farmers of the group in the département of Eure live with it and testify.

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Towards the conceptualization for an improved integrated management of the weed flora with extended targets of their life cycle.

REBOUD Xavier, INRA Dijon, UMR Agroécologie, BP86510, 21065 Dijon cedex, France
Xavier.reboud@dijon.inra.fr – +33 3 80 69 31 84

Keywords: life cycle stage target, evolution of the weed flora, new control technics

This is not easy to manage weed flora in intensive agriculture without reliance on pesticides.
Still, some pioneers are testing and improving cropping systems prototypes that do not rely on a chemical weed control. Not all these innovative cropping system belong to an organic farming approach and search for the label. Among these pioneering systems, crop associations and / or varieties as well as cultivation within a perennial cover crop seems efficient key techniques that also induce a deep rebuilding of their agronomic system. When discussing these innovations with their holders, it appears that a key to their success relies in the deep knowledge of their situation that they have acquired during the phase of initial trials. Their more or less intuitive understanding combines with their degree of thinking out of the main stream and associated acceptation for taking an unevaluated risk. So, it looks legitimate to ask whether these prototypes of agricultural systems can be extended to a large range of situations. To support this finding, scientific achievements would be expected in at least two directions:

- what are the underlying mechanisms and effects that the choice of the given practices operate on the weed community present in the field, in particular regarding the stage(s) of the life cycle that is/are prevented.
- how can the realized practices be translated/explained in terms of agroecological principles that would open to some conceptualization of the weed management with generalization perspectives. This conceptualization should include the risk of circumvention of the practices by a modification of the weed flora. By 'modification of the weed flora' we mean both genetic evolution within a species (with selection of resistance genes) and change in species composition at the community level with possible entry of newcomers.

There is of course, some ambition of extending the knowledge on the biology of weeds that may underline their management. But beyond this ambition, there is a specific question on whether a better and , if necessary, renewed integrated weed management can be achieved within the actual system or depends on deep modifications that makes it a different paradigm for cropping systems.

I suggest classifying the innovations according to the stage of the weed life cycle that is first affected. With this key, it seems rather obvious that actual techniques to control weeds mainly concentrate on the germination and early seedling stages of the weed life cycle; especially as herbicide mostly target these biological events. With reference to some ecological processes, many major events enter into the success of the population or community dynamics. Several of them could be positively or negatively affected: reduced seed survival in the soil seedbank, seed or seedling predation, limited germination because of competition for nutrient, light or water resources, interference with acquisition of vegetative biomass, reduced release of the new generation of seeds, and the breaking of the replenishment of the seed stock... This comparison between agricultural practices and ecological success in more or less natural situations pinpoints stages of the plant life cycle that are largely neglected (because of the herbicide efficacy to avoid germination and/or seedling installation). Benchmark with countries outside Europe give some examples of practices that extend the targeted stages of the weed life cycle: mulches (Brazil), use of highly competitive varieties, crop seed coating with nutrients to boost the crop installation (India), enhancement of soil biological activity to reduce viability of dormant seeds, active destruction of the new generation of seeds by mechanic treatment when entering into the combine harvester (Australia).

Table 1 – General principles (and levers) to extend the capabilities of an integrated management of the weed flora

A_ Principle of ecological niche occupation to leave no vacant space

B_ Avoidance of plant development Principle including the presenting new environment characteristics

C_ Exhausting the soil seed bank including limitation of its replenishment and perennial plant coverage

D_ Principle of presenting a new situation out of species usual range of adaptation, including crop diversification along the rotation

E_ Optimization of practices; more than a particular principle it focuses on the link between detection and (localized) action including precision farming

An output of this reflection involves the prioritization of biological characteristics of weed to be evaluated by scientific teams. Another change that would foster the research to be handled would rely in the exploration of a paradigm where, like with other pests, the objective is not to eradicate the pest but develop ways of living while they are present but with no major impact.

V. Contributions: posters

- Winter white lupin – triticale intercrop performances to secure lupin production and limit weed growth
  CARTON Nicolas, MAULINE Martine, BOISSINOT François, PIVA Guillaume, NAUDIN Christophe, CORRE-HELLOU Guénaëlle

- What role for the variety to control weed development in the designing of sustainable cereal cropping systems?
  LE CAMPION Antonin, BERNICOT Marie-Hélène, FONTAINE Laurence, BONIN Ludovic, ROLLAND Bernard

- Weed flora regulation by the insertion of temporary grasslands
  MEDIENE Safia, COLBACH Nathalie, CHARRIER Xavier, DOISY Diana

- Forage seeds production: interest of a sowing under cover crop for weed control
  DENEUFBOURG François, BOUET Serge

- Effects of reduced tillage on weed management – a methodology to use the SSP survey (2011)
  CAVAN Nicolas, LABREUCHE Jérôme, COUSIN Isabelle, WISSOCQ Adélaïde, ANGEVIN Frédérique

- Weed management with no herbicide. Example of pesticide-free cropping systems in arable crops assessed within a national experimental network: Rés0Pest
  SAVOIE Antoine, BERTHIER Alain, CELLIER Vincent, COLNENNE-DAVID Caroline, DARRAS Sébastien, DEYTIEUX Violaine

- Alopecurus myosuroides control : Agronomic practices to help herbicides
  LAUNOIS Lionel

- Accompanying DEPHY-FARM and DEPHY-EXPE networks in the characterization of the effect of cropping systems on weed flora
  FROGER Morgane, CELLIER Vincent, FONTAINE Laurence, GUILLEMIN Jean-Philippe, RODRIGUEZ Alain, CORDEAU Stéphane

- Identification of success keys in weed control strategy through a cross analysis of 3 cropping systems
  SCHAUB Anne, DEYTIEUX Violaine, TOQUE Clotilde, PETIT Marie-Sophie, FONTENY Camille, MINETTE Sébastien, CADOUX Stéphane, TOUPET Anne-Laure, GELOEN Michaël, VIVIER Christophe, BIZOT Eric, FARCY Pascal, MUNIER-JOLAIN Nicolas, AUDEBERT Guillaume, REAU Raymond

- Which measures need to be implementing to get effective weed control? The case of graminea in cereal crops production in Centre and Ile de France
  Edouard BARANGER, Delphine BOUTTET, Amandine GUIMARD

- Attending field experimenters to facilitate monitoring of weed flora in arable cropping systems
  FONTAINE Laurence, CADILLON Adeline, MONTAGNY Charlotte

- Impact of alley cropping agroforestry systems on weed communities
  MEZIERE Delphine, BOINOT Sébastien, CADET Emilie, FRIED Guillaume

- Weed seed predation by carabid beetles
  PETIT Sandrine, AUGUSTE Cyrille, BIJU-DUVAL Luc, CHARALABIDIS Alice, DUCOURTIEUX Chantal, LABRUYERE Sarah, RICCI Benoit, TRICHARD Aude, BOHAN David

- What could we learn from the decline of segetal weeds?
  DARMENCY Henri, GUILLEMIN Jean-Philippe

Winter white lupin – triticale intercrop performances to secure lupin production and limit weed growth

CARTON Nicolas*[1], MAULINE Martine[1], BOISSINOT François[2], PIVA Guillaume[1], NAUDIN Christophe[1], CORRE-HELLOU Guénaëlle[1]

[1] ESA d'Angers, UP LEVA, SFR 4207 QUASAV, 55 Rue Rabelais, 49007 Angers, France

[2] Chambre régionale d'Agriculture des Pays de la Loire, 9 Rue André Brouard, 49105 Angers, France

*n.carton@groupe-esa.com – +33 2 41 23 55 55

Keywords: lupin, intercropping, weeds, interspecific competition, field trials network

Lupin offers the opportunity for Western France livestock farming to increase its self-sufficiency for proteins because it provides grains with a protein content approaching that of soybean (32 to 38%) with less antitrypsin factors. Its high nitrogen fixation rate and its strong taproot make lupin a suitable crop to diversify cropping systems. However, low and unstable yields hinder its adoption by farmers. Biotic factors and notably weeds are the major obstacles. The objective of our study is to identify a way to increase benefits of lupin and minimize their variability while reducing herbicide use.

Previous studies showed a better weed control in cereal-legume intercrops than in legume sole crops. Last few years, winter white lupin – triticale intercrop has been grown following some farmers and their cooperative's initiative. The originality of this intercrop lies in the fact that triticale is introduced to facilitate lupin crop and its harvest contributes to secure economic yield. Lupin is sown as in sole cropping and triticale is sown at 30% of its density in sole cropping.

This poster provides a diagnosis of this intercrop's performances, based on a 9-site experiment in 2014/2015 where sole cropped lupin was compared with lupin-triticale intercrop. Lupin sole crop management was based on that of the intercrop. Crop management varied between sites but was always in low input systems (pre-emergence herbicide except on one organic field, hoeing on one site and no Nitrogen fertilization except on one field). Measurements of crop and weed biomass were carried out at flowering and maturity, as well as yield and Nitrogen content. The same field network will be studied in 2015/2016.

Averaged over sites, the results show that lupin yield was not significantly reduced by triticale (2.02 T/ha vs. 2.45 in lupin sole crops) even though the response varied between sites. Triticale brought an interesting additional harvest (average over sites: 2.15 T/ha). In this additive intercropping design, weed biomass at flowering and at harvest were significantly reduced by triticale (respectively by 63% and 56%). Further studies will be performed to investigate the role of Nitrogen and light to explain these differences, as well as intercrop effects on weed flora composition.

What role for the variety to control weed development in the designing of sustainable cereal cropping systems?

LE CAMPION Antonin*[1], BERNICOT Marie-Hélène[2], FONTAINE Laurence[3], BONIN Ludovic[4], ROLLAND Bernard[1]

[1] INRA UMR IGEPP, Domaine de la Motte au Vicomte, 35653 Le Rheu, France

[2] GEVES, 25 rue Georges Morel, 49071 Beaucouzé, France

[3] ITAB, 9 Rue André Brouard, 49105 Angers, France

[4] ARVALIS – Institut du végétal, Station Expérimentale, 91720 Boigneville, France

*alecampion@rennes.inra.fr – +33 2 23 48 51 16

Keywords: cultural weed control, organic farming, winter wheat competitiveness, breeding

In the move toward low-input farming systems, the reduction of the herbicide TFI is very constraining because of the lack of efficient alternative methods to control weeds. Under organic farming conditions cultural weed control is also a major agronomic concern. Also identifying and then breeding winter wheat varieties with high competitive potential offer a potentially promising option to include in integrated weed management strategies.

Co-funded by FSOV-GNIS, a study led in France during three years has evaluated the potential for competitive winter wheat genotypes and reached to capture the main variety traits involved in competitive ability. Several winter wheat varieties with contrasted phenotypical and phenological traits were assessed in a multi-site experiment composed of six sites conducted under organic farming conditions (nine genotypes compared) with natural weed infestation, and two sites conducted under conventional farming system (15 genotypes compared) where weed infestation was simulated by the sowing of an Italian rye-grass. The conventional trials were split in weed-free and weedy plots to allow the estimation of yield losses between the two production modes. The effect of variety in weed competition was demonstrated but was highly determined by the environmental and agronomical context: weed type, infestation rate, pedo-climatic conditions. In trials comparing weed-free and weed plots the height was the major trait involved to compete with a high density of Italian rye-grass. This result is partially confirmed under organic conditions. However, the natural infestation of weeds in these trials made the results harder to exploit because of the heterogeneity in weed repartition. But global analyses performing by year showed a significant effect of the genotype in weed suppression in 2013 and 2014, and in the three years of the experiment when considering the weed-to-crop biomass ratios (weed biomass/wheat biomass). « Caphorn », a semi-dwarf winter wheat variety, choosen for its weak ability in ground covering, has facilitated the development of a higher weed biomass, although “Energo” a tall height variety showed a lower weed-to-wheat biomass ratio which revealed his ability to produce biomass in weedy conditions. Wheat germination rates have shown a great influence in weed infestation. Indeed, under organic farming conditions, emergence losses can be very penalizing.

This project on three years has enabled us to verify the benefit of choosing adapted varieties to compete with weeds. This criterion is interesting because it could be easily used by farmers disregarding of the production management system. However, the impact of this weed control strategy is quite restricted and highly determined by the environmental context, which is consistent with weed management strategies developed in organic farming which are based on a combination of several methods and agricultural practices. A better soil covering obtained by an adapted variety choice is one of them.

Weed flora regulation by the insertion of temporary grasslands

MEDIENE Safia*[1], COLBACH Nathalie[2], CHARRIER Xavier[3], DOISY Diana[1]
[1] AgroParisTech, UMR211 Agronomie, 78850 Thiverval-Grignon, France
[2] INRA, UMR1347 Agroécologie, EcolDur, BP 86510, 21000 Dijon, France
[3] INRA, UE1373 FERLUS, 86600 Lusignan, France
*safia.mediene@agroparistech.fr – 01 30 81 45 84

Keywords: weed community, temporal dynamics, previous effect, above-ground flora, seed bank

Crop diversification is often presented as a powerful tool to limit the use of herbicides in cropping systems. The aim of this work is to better understand the effect of temporary grassland insertion on weeds communities to assess whether they represent an effective tool to manage weeds in cereal-based successions.

We propose in this presentation to provide an overview of the studies conducted by the research unit of Agronomy in the experimental long-term SOERE ACBB at the INRA research center of Lusignan (Western France). The Observatory and Experimental System for Environmental Research - Agroecosystems, Biogeochemical Cycles, and Biodiversity is used to evaluate the direct effects of temporary grasslands on weed flora (direct interaction related to the competition with grassland cover) and indirect effects via seed bank modification (long term effect at the crop succession scale).

Our studies suggest several effects of temporary grass on weed communities (Médiène *et al.*, 2012 and 2013 ; Doisy *et al.,* 2014) :
(i) Temporary grasslands reduce weed abundance to values close to those in chemical weeded crops.
(ii) Low fertilized grasslands also decrease species abundance, but they have a higher richness and functional diversity, in particular because of legume species appearance. This modification may represent an interest for biodiversity in cropping systems.
(iii) Dynamic changes in weed communities seem to be fast: one year after grassland installation, some problematic weeds are reduced (annual erected dicots) and all the annuals are reduced two years later. Species composition changes are also observed in seed bank after three years of grassland but lower than the above-ground flora (Médiène *et al.,* 2013 ; Doisy *et al.,* 2014 in preparation). Grass cover prevents a part of weed seed production to replenish the soil seed bank (especially large seeds, lightweight and with featuring attributes etc.), which has been demonstrated in experiments conducted during a phD in the unit (Doisy *et al.,* 2014).

To conclude, insertion of temporary grasslands seems to be effective for weed regulation, both quantitatively and qualitatively, by modifying the composition of communities. However dynamics between weed above-ground flora and seed bank are different. Our results suggest the need to maintain grassland in place at least three years before observing changes in seed bank, which may have an impact on weed flora in succeeding crops.

Forage seeds production: interest of a sowing under cover crop for weed control

DENEUFBOURG François*, BOUET Serge*
FNAMS, Impasse du Verger, 49800 Brain-sur-l'Authion, France
*francois.deneufbourg@fnams.fr, serge.bouet@fnams.fr – +33 2 41 80 91 00

Keywords: seed production, forage crop seed, sowing under cover, weed, weed control

The sowing under cover is a usual practice for the production of fodder seeds because of the slow establishment of these cultures (sowing under another culture during the autumn or the spring). It also offers interesting solutions for weed control compared with the sowing during summer on bare soil. Weedcontrol is particularly important for seed productions, with a necessary good quality of harvesting (standards of purity in seed lots).

An experiment carried out during 3 years (since 2012 to 2014) on the experimental station FNAMS of Brain sur l'Authion (49) compares several modalities of sowing for 2 species produced for seeds (tall fescue and red clover) in an experimental design with 4 repetitions. The results obtained with wheat are presented with an illustration for the red clover harvested in 2014 (table 1).

The aim of these multiannual trials is triple: i) to obtain a good establishment of seed crop and to optimize the yield without damaging the cover crop yield, ii) to limit weed invasion and to reduce inputs, iii) to reduce production costs.

Results

Impact on the wheat (year n): the presence of the young forage crop doesn't affect the wheat yield, except with the red clover which penalizes systematically the cereal from 5 to 15 % with a simultaneous autumn sowing.

Crop management and results on forage seed crop (year n+1):

- for tall fescue, the seed yields are comparable or superiors for sowing during spring in the winter wheat compared with the reference with simultaneous autumn sowing. The sowing during summer on bare soil confirms very low yields.
- For red clover, the sowing under crop doesn't improve the productivity compared with the sowing in bare soil but can also decrease it (table 1). On the other hand, a good control of weeds is obtained after the cover harvesting, with important reductions of herbicides and IFT for crop sowed under cover.

Overall, the two crops succession profitability seems very positive for the sowing under cover with, in particular, a strong reduction of the posts "sowing" and "weeding" (table 1).

Table 1: Main results on 2 modalities with red clover seed production (RC), in 2013 then 2014

Modality	Wheat (harvest 2013)			Red clover (RC) seed crop (harvest 2014)				
	Yield (q/ha)	IFT* herbicide (nb trait.)	Weed note** jul-13 (J harvest)	Yield (q/ha)	IFT * herbicide (nb trait.)	Weed note** march-14	Weed note** may-14 (after forage cutting)	Direct costs** (sowing + weeding)
T1 – Wheat then RC sowing on bare soil during summer (réf.)	76.7 a	2.1 (1 tr.)	11.8	6.64 a	3.6 (4 tr.)	31.1	6.3	386 € /ha (141 + 245)
T4 – Wheat with RC sowing under crop during spring	76.0 a	2.1 (1 tr.)	9.0	5.26 b	1.3 (2 tr.)	21.3	2.3	137 € /ha (34 + 103)

* IFT: Treatment Frequency Index = applied dose (l ou kg /ha) / registered dose (l ou kg /ha) (sum of herbicides)

** Weed note = adds notes attributed for each adventitious observed, according to scale of Barralis (0 - 7)

** Direct costs (inputs + mechanisation + labour cost) for 2 main posts (FNAMS methodology)

Effects of reduced tillage on weed management – a methodology to use the SSP survey (2011)

CAVAN Nicolas*[1,2,3], LABREUCHE Jérôme[2], COUSIN Isabelle[3], WISSOCQ Adélaïde[2], ANGEVIN Frédérique[4,1]

[1] GIS GC HP2E, INRA Transfert, 28 rue du Docteur Finlay, 75015 Paris, France

[2] ARVALIS – Institut du Végétal, Station expérimentale, 91720 Boigneville, France

[3] INRA, UR 0272 SOLS, 2163 av. de la Pomme de Pin, CS 40001 Ardon, 45075 Orléans Cedex 2, France

[4] INRA, UAR 1240 ECO-INNOV, avenue Lucien Brétignières, 78850 Thiverval-Grignon, France

*nicolas.cavan@orleans.inra.fr – +33 2.38.41.80.46

Keywords: survey, tillage practices, no-ploughing tillage, herbicides, cover cropping

Tillage is one option for weed management: it prevents seeds from germinating (thanks to a deep ploughing in of those seeds) or destroys weeds in an early growth stage. Reduced tillage (especially no-ploughing systems) limits the use of this mechanical option of weed management by farmers, who then need to adapt their practices. Some hypotheses have been made on these new practices: i) changing from ploughing to no-ploughing tillage systems would imply an increase in using selective/non-selective herbicides; ii) the slowing down of fields conversion from ploughing to no-ploughing tillage would be due to difficulties in managing weeds. This work presents a methodology to test these hypotheses.

Testing hypotheses is difficult because of a lack of data suitable to compare different tillage systems in the same agricultural and pedo-climatic (AP) context. The last survey on tillage crops led by the French Ministry of Agriculture (Agreste – Enquête pratiques culturales 2011), based on 20 827 fields, may be precise enough to test them. For each field, it contains the full crop management techniques of the crop harvested in 2011. Moreover, data on the five previous years (2006-2010) is available, including: sowed crop, yield, mineral fertilization, tillage practices (ploughing or no-ploughing tillage: NPT).

To analyze the survey results, every field has been classified in an AP context, by using a typology based on the harvested crop (13 possibilities), the previous crop (40 possibilities), the type of crop rotation, the soil (175 possibilities) and the area of production (22 regions in France). For statistical reasons, every AP context should be described by at least 30 surveyed fields (Agreste, 2014). So a simplification of available data is necessary to study tillage crop surfaces repartition between tillage practices and for a combination of qualitative factors.

First, 7 tillage methods (TM) have been described, by the characteristics (mixing, fragmenting and turnover) of the main disturbing tillage operation for soil structure. Then, we simplified our qualitative factors and defined 6 types of soil (based mostly on the texture of the soil surface but also on calcareous and hydromorphic properties of the soil), 7 types of crop rotations (based on the two ratios cereal / dicotyledons and autumn / spring crops; and the presence of grassland), 10 types of previous crops (harvest date, quantity of residues produced and their decomposition rate) and 8 production areas (farms main productions and the main tillage crops sowed).

The land repartition between the TM for each qualitative factor (or combination of them) has been studied for 2011. Some results, in particular on tillage strategy (on the 2006-2011 period) are expressed only with two tillage practices: ploughing and NPT. Finally, 52 groups with a specific AP context have been identified (by decreasing the minimum limit to 26 surveyed fields, with 6 fields representing both tillage practices: ploughing and NPT) to study the effect of a tillage reduction on these agricultural systems.

Weed management with no herbicide. Example of pesticide-free cropping systems in arable crops assessed within a national experimental network: Rés0Pest.

SAVOIE Antoine*[1], BERTHIER Alain[2], CELLIER Vincent[2,3], COLNENNE-DAVID Caroline[4], DARRAS Sébastien[5], DEYTIEUX Violaine[2,3]

[1] INRA, UEPAO, Inra centre Val de Loire, 37380 Nouzilly, France

[2] INRA, UE 115, Domaine Expérimental d'Epoisses, 21110 Bretenière, France

[3] Réseau Protection Intégrée des Cultures INRA/CIRAD

[4] INRA, UMR 211 Agronomie, 78850 Thiverval-Grignon, France

[5] INRA, UE Grandes Cultures Innovation Environnement - Picardie, 2 chaussée brunehaut, 80200 Estrées Mons, France

*antoine.savoie@tours.inra.fr – +33 2 47 42 75 69, +33 6 33 35 62 23

Keywords: experimental network, cropping system, pesticide-free, agroecology, DEPHY Ecophyto

The aims of the Rés0Pest network are to identify and collect knowledge in order to design arable cropping systems using less pesticide, including herbicide: identify technical barriers, test alternative techniques and gain knowledge on agronomic practices and biological regulation of populations to improve the management of pests (including weeds).

Started in 2012, the network includes eight long term field experiments implemented in research experimental units (INRA) and in agricultural high school (Toulouse), in different crop productions in France.

The objectives of the network are as follows:

- to design and to test in a long-term field trials cropping systems under a pesticide constraint (no pesticide is allowed) and to assess their agronomic, environmental and socio-economic performances;
- to study the effects of pesticide-free cropping systems on pest populations and natural biological regulations.

Moreover, these cropping systems have to reach other goals: (i) crop productions (yield quantity) have to satisfy market specifications (yield quality) (i) environmental impacts such as fossil energy consumption and greenhouse gas emissions have to be reduced (ii) economic profitability for farmers have to be maintained.

In this network, the assessed cropping systems were designed using Integrated Pest Management principles and agronomical practices were combined in order to limit pest damages and to enhance biological regulation.

Each of the eight experiments has been designed separately; nevertheless, all of them use common techniques for weed management: (i) at the cropping sequence level (extended crop sequences, diversification of the crops and sowing date, alternation of till and no-till, intercropping, catch crop to reduce N leaching, …), (ii) within the crop year (false seedbed tillage, mechanical weeding, sowing date and density, …).

The difference between the free-pesticide systems and the organic systems is the use of mineral fertilizers of synthetic origin in order to achieve high yields. This practice also impacts weeds and the development of other pests. The Rés0Pest network will bring new interesting references both for conventional systems and for organic systems.

All experiments include common measurements and observations in order to conduct an agronomic assessment, especially to monitor weed flora evolution. Over the first three-year period, we analysed feasibility of the technique combinations. The height experiments will be maintained for at least three years more, so cumulative effects of these free-pesticide systems could be studied particularly on weed populations.

Alopecurus myosuroides control : Agronomic practices to help herbicides

LAUNOIS Lionel, VIVESCIA, 2 rue Clément Ader, BP 1017, 51685 Reims Cedex 2
lionel.launois@vivescia.com – +33 3 26 64 73 53, +33 6 82 86 87 99

Keywords: Wheat, foxtail, spring crops, tillage, direct seed, cover crops

Within the geographical area of VIVESCIA, the number of parcels with herbicide resistant weeds is increasing every year. Weeds are most frequently grassy weeds (essentially foxtail), that became insensitive to the main herbicides families: sulfonylurea, "FOPs", "DENs"…

In these situations, the efficiency of herbicides not belonging to the above mentioned families, is incomplete and weeds control more frequently fails. Agro-chemical techniques are unable to guarantee a sufficient performance (and to preserve production potential), it is now necessary to implement every non chemical techniques before planting the crop, in order to reduce weeds pressure.

To improve our members/farmers awareness on the importance of changing their practices, Vivescia decided to implement 2 platforms for agronomical trials : Bouconville and Trémilly. First trials started in August 2014 for winter wheat and the intent was to assess the effectiveness on foxtail of several practices ahead of sowing :

- Impact of stubble ploughing and of cover crops
- Tillage : ploughing / low tillage
- Winter cereal sowing date shifting
- Sowing method : direct seeding/classical sowing
- Introduction of a spring crop

We also tested herbicides in contexts of light and heavy infestation.

These experiments enabled us to prioritize the effectiveness of the different leverages, helping farmers to choose the best way to cultivate according to their operating constraints.

Accompanying DEPHY-FARM and DEPHY-EXPE networks in the characterization of the effect of cropping systems on weed flora

FROGER Morgane[1], CELLIER Vincent[1], FONTAINE Laurence[2], GUILLEMIN Jean-Philippe[3], RODRIGUEZ Alain[4], CORDEAU Stéphane*[5]

[1] INRA, UE115 Domaine Expérimental d'Epoisses, 21100 Bretenière, France

[2] ITAB Angers, Maison de l'agriculture, 9 rue André Brouard, 49 105 Angers cedex 02, France

[3] AgroSup Dijon, UMR1347 Agroécologie, BP 87999, 21079 Dijon, France

[4] ACTA Midi-Pyrénées, Station Inter-instituts, 6 chemin de la côte vieille, 31 450 Baziège, France

[5] INRA, UMR1347 Agroécologie, 21000 Dijon, France

*stephane.cordeau@dijon.inra.fr – +33 3 80 69 32 67

Keywords: methodology, weeds, diagnosis, cultural practices, cropping system

To characterize weed pressure in agricultural fields of the DEPHY Ecophyto networks, the "weeds" working group of the CASIMIR project, helped by crop and weed experts working for the french crop institutes, developed two methods (CASIMIR DEPHY-FARM and CASIMIR DEPHY-EXPE) to survey weeds in main crops. The objectives of these methods are: (i) with short-term concern, assess the efficacy of farming practices to manage weeds within the crop season, (ii) with long-term concern, assess the effect of cropping system (farming practices and crop sequence) on the dynamic of the weed communities.

The CASIMIR DEPHY-FARM method is based on walk away surveys made within a 2000-m² reference plot where the trained person walks across the survey area ("W" path). The weeds are identified and their density is visually assessed using a "Barralis" modified scale. Their dominant phenological stages are also recorded. This simple and quick method intends to be used in the DEPHY FARM network.

The CASIMIR DEPHY-EXPE method is based on surveys performed on eight 16-m² plots with one quadrat in each. Weed species are identified. The density of each species is visually estimated with a "Barralis" modified scale within the 16-m² plots and precisely counted in the quadrats. On both, the dominant phenological stage of each species is recorded. At the end of the second surveys, the above ground biomass of each weed and crop species is yield to assess the crop-weed competition. This method which is more complex and time-consuming intends to be used in the DEPHY EXPE network.

Surveys are performed twice a year: firstly before winter weedings (in winter crops) or before post-emergence weeding (in spring crops) to observe emerging flora; then before the closed-canopy occurred to assess the flora competed crop.

To design these methods, the CASIMIR project benefited from the expertise of the RMT Florad. To assess their feasibility, methods were performed in the RotAB and Rés0Pest networks. They are also discussed and criticized by engineers of the DEPHY networks and other professionals from agriculture through a web survey.

Identification of success keys in weed control strategy through a cross analysis of 3 cropping systems

SCHAUB Anne*[1], DEYTIEUX Violaine[2], TOQUE Clotilde[3], PETIT Marie-Sophie[4], FONTENY Camille[1], MINETTE Sébastien[5], CADOUX Stéphane[6], TOUPET Anne-Laure[3], GELOEN Michaël[7], VIVIER Christophe[8], BIZOT Eric[8], FARCY Pascal[2], MUNIER-JOLAIN Nicolas[9], AUDEBERT Guillaume[10], REAU Raymond[11]

[1] ARAA (Association pour la Relance Agronomique en Alsace), 2 rue de Rome, BP 30022, Schiltigheim, 67013 Strasbourg cedex, France

[2] INRA, Domaine d'Epoisses, 21110 Bretenières, France

[3] ARVALIS – Institut du végétal, Station Expérimentale, 91720 Boigneville, France

[4] Chambre régionale d'agriculture de Bourgogne, 1 rue des Coulots, 21110 Bretenière, France

[5] Chambre régionale d'agriculture de Poitou-Charentes, Agropole, 2133 route de Chauvigny, CS 45002, 86550 Mignaloux-Beauvoir, France

[6] Terres Inovia, Centre de Grignon, avenue Lucien Brétignières, 78850 Thiverval-Grignon, France

[7] Chambre d'agriculture de la Nièvre, 25 Bd Léon Blum, CS 40080, 8028 Nevers Cedex, France

[8] Chambre d'agriculture de l'Yonne, 14 bis Rue Guynemer, CS 50289, 89005 Auxerre Cedex, France

[9] INRA, UMR1347 Agroécologie, BP 86510, 21000 Dijon, France

[10] INRA, UE1373 FERLUS, 86600 Lusignan, France

[11] INRA, UMR Agronomie, 78850 Thivernal-Grignon, France

*a.schaub@alsace.chambagri.fr – +33 3 88 19 16 75

Keywords: decisional-model, weed management strategy, collaborative workshop, cross analysis

The "Joint Technology Network for innovative cropping systems" conducts workshops allowing for exchanges and collaboration on cropping system experiments between experimenters from research, development and education institutes. One of the workshops dealt with the simultaneous analysis of weed management strategies of three different cropping systems. The aim was to identify failure and success factors of weed control in each cropping system. Cross analysis in workshop led to understand strategical logic and produced kwowledge serviceable to inspire farmers and advisors or to improve strategies.

The 3 cropping systems have been experimented for several years in different pedo-climatic conditions (Epoisses and Courgenay in the Burgundy region, Lusignan in the vicinity of Poitiers). They share quite similar weed management techniques: 3-4 different sowing periods, occasional ploughing, cover crop competing weeds during long intercrop period, false seed beds, late sowing date for wheat and mechanical weeding. The combination and application of these technics in weed management strategies lead to a low use of herbicides in all three cropping systems, and a satisfying weed control in two of them. However, only one system reached good economic performances.

A decisional-model diagram shows how the pilot of the cropping system manages weeds. This "fish bones" diagram describes the aims to be achieved by the pilot (for instance: no thistle circle bigger than 2 m^2) and the solutions combinations he uses (techniques, decisional rules). The technical combinations are classified by action modes (for instance: action on the initial seed bank, physical control, etc). For each system, the experimenter explained his weed management strategy with a decisional-model diagram and the observed results on weed control. By asking questions to the experimenter, the group specified for each system the weed management strategy and the way it was applied under field conditions to achieve the pilot's aims. The group pinpointed similarities and specificities between the three strategies and their implementation in the field. For instance, the false seed bed technique was used differently in the three cropping systems (in terms of used equipment, tillage depth and speed, period, soil conditions, etc) in order to suit the specific expectations of the pilot and biophysical conditions.

Furthermore, successes and failures of each strategy were explained and options for their improvement or their implementation into the field were proposed. The workshop procedure led to the identification of success keys in weed management in satisfying cropping systems (weed control, low herbicides use and high profitability). What techniques can be combined? What decision rules in order to adapt the field implementation of techniques to the context of the year? What is the validity domain of a strategy? The group helped the experimenter to step back and to identify essential technical messages capable of inspiring farmers and provoking changes in their cropping systems.

Which measures need to be implementing to get effective weed control? The case of graminea in cereal crops production in Centre and Ile de France.

Edouard BARANGER, Delphine BOUTTET*, Amandine GUIMARD
ARVALIS – Institut du végétal, Station expérimentale, 91720 Boigneville, France
*d.bouttet@arvalisinstitutduvegetal.fr – +33 1 64 99 22 77

Keywords: weed control, weed graminea, cereal crops systems

We observe the development of non-tillage and increase of autumnal crops to the detriment of spring crops in cereals crops systems in Centre and Ile de France. Moreover, the erosion of herbicide's efficiency, the selection of herbicide resistance and more and more herbicide' forbidding lead to an infestation of ray-grass and black grass. This is negative for yield, for the health quality of crop and for environment. This is why the regional commission "weed control of cereal crops", led by ARVALIS - Institut du vegetal, wanted to know what are possibilities to make efficient weed control and which are techniques to put in place to resolve weed control issues. So, we described cropping systems and analysed practices using interview available from 34 farmers. 11 farmers were in low weed pressure, three of them getting back to normal. 22 farmers were in high weed pressure, only one of them return to normal. All cropping systems are still dependent on herbicides. The levers implement are the addition of a spring crop, the practice of tillage and shallow non inversion tillage. If improvements are possible concerning the using of these levers, others levers can be put in place. Now, we are not able to give a completion date for the back to a wholesome situation. Even if, we can think that agricultural machinery will offer news solutions, we need ton now that weed control will be more difficult. The getting back to normal will be a lengthy, difficult, technical and expensive process.

Attending field experimenters to facilitate monitoring of weed flora in arable cropping systems

FONTAINE Laurence*, CADILLON Adeline, MONTAGNY Charlotte
Institut Technique de l'Agriculture Biologique (ITAB), 149 rue de Bercy, 75595 Paris cedex 12
*laurence.fontaine@itab.asso.fr – 02 41 18 61 56

Keywords: weeds, protocols, assessment, tool-box, educational material

The question of how to assess the evolution of weed flora in experimental or farmer fields in arable cropping systems often arises, either to assess the impact of a particular practice or more generally to assess the effects of cropping system on weed flora. Experimenters conducting such monitoring are first to define their objectives and then choose the most appropriate evaluation methods. Once the protocols are chosen and implemented, very practical issues can be raised about the operational implementation of the measures listed in the monitoring protocols. Supported by several research programs, ITAB and its partners have developed materials to support the approach of experimenters.

A tool-box has been proposed and made available to experimenters, to help them 1/ to choose monitoring methods they will mobilize (depending on the objectives and the means available) and 2/ to implement them in a practical way. The "Weeds tool-box RotAB" was designed within the RotAB Network, a dozen of long-term experiments assessing innovative arable cropping systems in organic farming (through the research project "Réseau AB Dephy" leaded by ITAB, funded by EXPE Dephy Ecophyto). This tool-box was built by crossing the practical experiences of the experimenters of the RotAB Network (representatives of Chambers of Agriculture, organic farmers groups, Arvalis, INRA ...), with a strong support of experts from RMT Florad (ACTA, INRA). The various measures and ratings used by each were inventoried and characterized. Two menus are available, distinguishing essential methods to implement from additional monitoring methods claiming more resources and skills. A set of "method practical sheets" is also available, to explain how to implement the methods, providing advice, process and "tricks" for experimenters. The "Weeds tool-box RotAB" is available on-line on the internet sites of ITAB, RMT Florad and Ecophyto-PIC.

More recently, the question of the practical implementation of the protocol "Casimir Dephy Ferme" (presented in another poster) has occurred. To analyze the questions and any problems encountered in the use of this protocol, an online survey and a few targeted interviews were conducted among experimenters. Then the practical on-field implementation of the protocol was carried out jointly by engineers involved in Ecophyto experiments (in Ain and Drôme area) and the project manager, in order to have concrete feedback. Both approaches have enabled the drafting of methodological recommendations for the practical implementation of the protocol Casimir Dephy-Ferme. In particular, a film concretely presents its use.

To assist experimenters to the recognition of weeds species, often quoted as a difficulty, recognized references are recalled in both materials presented above: ACTA “weeds culture guide”, internet site “Infloweb”, on-line identification keys…

Impact of alley cropping agroforestry systems on weed communities

MEZIERE Delphine*[1], BOINOT Sébastien[1], CADET Emilie[2], FRIED Guillaume[3]
[1] INRA, UMR SYSTEM, 2 place Viala 34060 Montpellier, France
[2] INRA, UMR Agroécologie, 21065 Dijon, France
[3] ANSES, Laboratoire de santé des végétaux, 34988 Montferrier-sur-Lez, France
*delphine.meziere@supagro.inra.fr – +33 4 99 61 29 17

Keywords: agroforestry, shade, tree understory, diversity, abundance

Alley cropping agroforestry, i.e. the combination of crops and trees within the field, allows intensification and diversification of productions, while providing some other ecosystem services such as carbon sequestration or biodiversity conservation in the agroecosystem. Still recent, research on temperate agroforestry has not focused yet on the impact of tree/crop association on weeds and other bioagressors for crops. However, weeds are among the main issue mentioned by farmers in agroforestry (survey results in France and Europe, AGFORWARD project). Indeed, the spontaneous vegetation that grows on the tree rows, is considered as a source of infestation for the crops sown in the alleys between tree rows. Additionally, we can hypothesize that the modifications of microclimatic conditions in the field due to the trees (reduction of available light radiation, modification of soil temperature and moisture…) impact the weeds growing in agroforestry systems. This might result in different weed community characteristics, in terms of harmfulness and weed-related biodiversity for the agroecosystem, compared to pure crop fields. In order to design weed management options that are adapted to agroforestry, it is first necessary to better know the weed communities in these new agroecosystems. Thus, the objectives of this first weed survey in alley cropping agroforestry systems were (i) to compare the composition, abundance, and spatial distribution of arable weed communities in agroforestry vs. pure crop control, and (ii) to assess the effect of the distance to the tree line on the structure of weed communities within the crop alley. For this purpose, weed communities were studied in experimental fields of INRA Montpellier (19 years-old agroforestry fields), presenting contrasting levels of shade, and in a pure crop control field (without tree nor herbaceous strips within the field but the same cropping system). Our results from two spring surveys (before and one month after tree budbreak) showed a lower weed density (number.m^{-2}) and a different composition in agroforestry compared to the pure crop control. The number of species per m^2 (alpha diversity) was similar in agroforestry and pure crop control, however the total number of weed species over all samples of a given field (gamma diversity) was higher in agroforestry (samples taken within the crop alley only) than in the pure crop field. We did not observe increased weed density close to the herbaceous strips, however there were significantly more species there compared to the center of the alleys. Additional fields, in commercial fields, are going to be surveyed for the long term from 2016 on, to provide data allowing us to test the robustness of the results of this first study of weed communities in agroforestry.

Weed seed predation by carabid beetles

PETIT Sandrine*, AUGUSTE Cyrille, BIJU-DUVAL Luc, CHARALABIDIS Alice, DUCOURTIEUX Chantal, LABRUYERE Sarah, RICCI Benoit, TRICHARD Aude, BOHAN David
INRA, UMR 1347 Agroécologie, BP 86510, 21000 Dijon, France
*Sandrine.petit2@dijon.inra.fr – +33 3 80 69 30 32

Keywords: biological regulations, diet, agricultural practices, landscape

A number of field studies converge to suggest that carabid beetles are the key players of weed seed predation in European farming systems. More recently, a nationwide study conducted in the UK evidenced that (i) the higher the number of weed seeds available on the soil surface, the higher the number of seed-eating carabids in the field and (ii) the higher the number of carabids in the field, the lower the number of weed seeds that that return to the seedbank from one year to the next. These findings suggest that carabids beetles deplete a substantial amount of weed seeds before they return to the seedbank and thus that this predation could be a potential way of reducing the growth of specific weed species in arable fields. We present here a review of available knowledge on weed seed predation by carabids notably (i) what are the most common specific associations between a carabid and a weed species and the drivers of preferential consumption, a synthesis of annual losses of seeds due to invertebrate predation estimated in international studies. We will also present the main local and landscape management options that could be used to enhance the intensity of weed seed predation in arable fields.

What could we learn from the decline of segetal weeds?

DARMENCY Henri*[1], GUILLEMIN Jean-Philippe[2]
[1] INRA, UMR1347 Agroécologie, BP 86510, 21065 Dijon, France
[2] AgroSup Dijon, UMR1347 Agroécologie, BP 86510, 21065 Dijon, France
*henri.darmency@dijon.inra.fr – +33 3 80 69 31 86

Keywords: arable weeds, specialists, biology, sustainable farming systems

The decline of many segetal weeds during the past seven decades, including the extinction of a few species, is most often discussed in terms of a protection approach of an endangered flora of high natural value. The National Action Plan launched by the Ministry of Ecology to protect segetal plants is a sign of a high concern for their value and enters now in the actual implementation phase at different spatial and social scales (http://www.developpement-durable.gouv.fr/Plan-national-d-actions-en-faveur,32610.html).

In the framework of this approach, a CASDAR project implements a research project to bring a dynamic view of the situation, in particular to pinpoint farming systems and current cultural practices that are favorable to segetal plants, to value the identification of weeds and segetal plants as bio-indicators of farming sustainability (in relation to ecological intensification *versus* inputs level of individual fields and/or whole farms), and to estimate ecosystemic services due to segetal plants (e.g. resources for pollinators) (http://www.florad.org/moodle/course/view.php?id=38). The ethnological expectations of the project focus on the real appropriation of issues and actions by local stakeholders (farmers, technicians,…), and the farmer's perception of segetal plants according to the local situation: sol type, age of the farm, integration into the supply chains, education level, current regulations and constraints, technical support, financial assistance, etc.

Research activities could also focus on the causes and mechanisms of the regression of the segetal species. From our point of view, there is no better lesson for the future than an example of a set of farming practices leading to the effective eradication of formerly important weeds. Besides farming intensification, there could be other factors than increased fertilizer use and herbicides. Blackgrass is an example of segetal weed that evolved resistance to many recent herbicides and does not regress.

Farming systems are not fixed entities, so that research and development in agronomy could improve them in view of optimized productivity. This trend can still led to regression of more segetal species. However, the regression of these species make them minor weeds with little impact on todays' productivity, so that they are perceived as un-interesting components of the flora not worth to be studied. This willful negligence closes an entire domain of knowledge on tools, knowhow and farming practices that met biological characteristics of the segetal species and resulted in efficient control of their abundance. On the contrary, the relationships between the traits and the practices deserve to be studied in details in order to be able to identify potential levers to achieve a sustainable weed control. Efforts should strive to improve the links and coordination between the classical tools of weed management and the biological properties of the segetal plants and their response to changing environment.

VI. List of participants

NAME	First Name	Organization	Mail
ADEUX	Guillaume	INP-EI Purpan	guillaume.adeux@agro-bordeaux.fr
ANGEVIN	Frédérique	INRA	Frederique.Angevin@grignon.inra.fr
AUDEBERT	Guillaume	INRA	guillaume.audebert@lusignan.inra.fr
BARANGER	Edouard	ARVALIS Institut du végétal	e.baranger@arvalisinstitutduvegetal.fr
BARATON	Eric	Chambre d'agriculture Deux-Sèvres	eric.baraton@deux-sevres.chambagri.fr
BIDAULT	Marie-Christine	Chambre d'agriculture Charente	mariechristine.bidault@charente.chambagri.fr
BILON	Rebecca	Observatoire des ambroisies	rebecca.bilon@dijon.inra.fr
BIZOT	Eric	Chambre d'agriculture Yonne	e.bizot@yonne.chambagri.fr
BLERIOT	Olivier	INRA	olivier.bleriot@mons.inra.fr
BONIN	Ludovic	ARVALIS Institut du végétal	l.bonin@arvalisinstitutduvegetal.fr
BONNY	Sylvie	INRA	bonny@grignon.inra.fr
BORDIN	Thierry	Chambre régionale d'agriculture Centre-Val de Loire	thierry.bordin@centre.chambagri.fr
BOUILLE	David	Chambre d'agriculture Ille-et-Vilaine	david.bouille@ille-et-vilaine.chambagri.fr
BOUQUET	Constance	FNChasseurs	cbouquet@chasseurdefrance.com
BOUTTET	Delphine	ARVALIS Institut du végétal	d.bouttet@arvalisinstitutduvegetal.fr
CADOUX	Stéphane	Terres Inovia	s.cadoux@terresinovia.fr
CARTON	Nicolas	ESA Angers	n.carton@groupe-esa.com
CAVAN	Nicolas	ARVALIS Institut du végétal/INRA	nicolas.cavan@orleans.inra.fr
CELETTE	Florian	ISARA-Lyon	fcelette@isara.fr
CELLIER	Vincent	INRA	vincent.cellier@epoisses.inra.fr
CHAN-HON-TONG	Anne	MAAF	anne.chan-hon-tong@agriculture.gouv.fr
CHARON	Xavier	SYNGENTA FRANCE SAS	xavier.charon@syngenta.com
CHARTIER	Nicolas	IDELE	nicolas.chartier@idele.fr
CHAUMONT	Emilie	Chambre d'agriculture Saône-et-Loire	echaumont@sl.chambagri.fr
CHAUVEL	Bruno	INRA	bruno.chauvel@dijon.inra.fr
CHORRO	Benoit	COREA	b.chorro@coreapc.fr
COLAS	Floriane	INRA	floriane.colas@dijon.inra.fr
COMBES	Philippe	LIMAGRAIN COOP	philippe.combes@limagrain.com
CORDEAU	Stéphane	INRA	stephane.cordeau@dijon.inra.fr
COTINET	Patrice	Chambre d'agriculture Morbihan	patrice.cotinet@morbihan.chambagri.fr
DARMENCY	Henri	INRA	henri.darmency@dijon.inra.fr
DARRAS	Sébastien	INRA	sebastien.darras@mons.inra.fr
DE NARDO	Gaëlle	Chambre d'agriculture Yonne	g.denardo@yonne.chambagri.fr
DELOS	Marc	MAAF DGAL	marc.delos@agriculture.gouv.fr

DENEUFBOURG	François	FNAMS	francois.deneufbourg@fnams.fr
DENIEUL	Céline	InVivo AgroSolutions	cdenieul@invivo-group.com
DOISY	Diana	AgroParisTech/INRA	Diana.Zafrani@grignon.inra.fr
DORÉ	Thierry	AgroParisTech	thierry.dore@agroparistech.fr
DREUX	Laure	INRA	laure.elliott-smith@grignon.inra.fr
DREYFUS	Jérémy	APCA	jeremy.dreyfus@apca.chambagri.fr
DRON	Christian	DRAAF Île-de-France	christian.dron@agriculture.gouv.fr
DUBAR	Marie-Noëlle	DRAAF Rhône-Alpes	marie-noelle.dubar@agriculture.gouv.fr
ELBAZE	Gérard	INVIVO CAMPUS	gelbaze@invivo-campus.com
FALCHIER	Michel	Chambre régionale d'agriculture Bretagne	michel.falchier@bretagne.chambagri.fr
FALOYA	Vincent	GIS PICLég	vincent.faloya@rennes.inra.fr
FAVRELIÈRE	Elise	Agro-Transfert	e.favreliere@agro-transfert-rt.org
FONTAINE	Laurence	ITAB	laurence.fontaine@itab.asso.fr
FROGER	Morgane	INRA	morgane.froger@dijon.inra.fr
GABA	Sabrina	INRA	sabrina.gaba@dijon.inra.fr
GALLINE	Jean-Charles	ANSES	jean-charles.galline@anses.fr
GASSMANN	Benoît	Chambre régionale d'agriculture Alsace	b.gassmann@alsace.chambagri.fr
GAUTELLIER VIZIOZ	Lise	ARVALIS Institut du végétal	l.gautellier@arvalisinstitutduvegetal.fr
GAUTIER	Pascal	SYNGENTA FRANCE SAS	pascal.gautier@syngenta.com
GAUTIER-HAMON	Gerard	MAAF	gerard.gautier-hamon@agriculture.gouv.fr
GELIN	Sandrine	INRA	sandrine.gelin@lyon.inra.fr
GIBOT-LECLERC	Stéphanie	AgroSup Dijon	stephanie.gibot-leclerc@dijon.inra.fr
GIULIANO	Simon	INP-EI Purpan	simon.giuliano@purpan.fr
GUILLEMIN	Jean-Philippe	AgroSup Dijon	jean-philippe.guillemin@agrosupdijon.fr
GUIMARD	Amandine	ARVALIS Institut du végétal	a.guimard@arvalisinstitutduvegetal.fr
HUBERT	Claire	MEDDE	claire.huberT@developpement-durable.gouv.fr
HUGUET	Bertrand	SRAL ILE DE FRANCE	bertrand.huguet@agriculture.gouv.fr
IOOS	Romain	UNEAL	romain.ioos@uneal.fr
JACQUES	Stéphane	MEDDE DGPR	stephane.jacques@developpement-durable.gouv.fr
JOURDIN	Yohann	Chambre d'agriculture Seine-et-Marne	yohann.jourdin@seine-et-marne.chambagri.fr
JULLIEN	Jérôme	MAAF DGAL SDQPV	jerome.jullien@agriculture.gouv.fr
JUMEL	Francis	SYNGENTA FRANCE SAS	francis.jumel@syngenta.com
LABREUCHE	Jérôme	ARVALIS Institut du végétal	j.labreuche@arvalisinstitutduvegetal.fr
LAFLEURIEL	Philippe	Coopérative Dauphinoise	p.lafleuriel@groupe-dauphinoise.com
LAFORGUE	Coline	CFPPAH	coline.laforgue@educagri.fr
LAMBERT	Charles	Freelance	charles.lambert@planetmail.com
LANGLET	Tiphaine	Chambre d'agriculture Cher	t.langlet@cher.chambagri.fr
LAUNOIS	Lionel	VIVESCIA	lionel.launois@vivescia.com
LAURENT	Amandine	Agrosup Dijon	am.laurent25@gmail.com
LECHENET	Martin	Invivo Agrosolutions/INRA	martin.lechenet@dijon.inra.fr
LECLECH	Nathaël	Chambre régionale d'agriculture	nathael.leclech@lorraine.chambagri.fr

		Lorraine	
LEFLON	Martine	Terres Inovia	m.leflon@terresinovia.fr
LEUBA	Muriel	DRAAF Picardie	muriel.leuba@agriculture.gouv.fr
LOOS	Matthieu	Chambre d'agriculture Indre-et-Loire	matthieu.loos@cda37.fr
LOSSON	Corentin	INRA	corentin.losson@versailles.inra.fr
LOZE	Perrine	BASF France - Division Agro	perrine.loze@basf.com
MANFRONI	Jean-Baptiste	BAYER SAS	jean-baptiste.manfroni@bayer.com
MARIE	Frédéric	CentrExpé	fm.centrexpe@orange.fr
MARNOTTE	Pascal	CIRAD	pascal.marnotte@cirad.fr
MARTIAL	Raphaël	Chambre d'agriculture Landes	raphael.martial@landes.chambagri.fr
MASSAI	Isabelle	Chaire d'Entreprises AgroSYS	isabelle.massai@supagro.fr
MASSOT	Fabien	SYNGENTA FRANCE SAS	fabien.massot@syngenta.com
MEDIENE	Safia	AgroParisTech	safia.mediene@agroparistech.fr
MÉROT	Emmanuel	Chambre d'agriculture Loire-Atlantique	emmanuel.merot@loire-atlantique.chambagri.fr
MESSÉAN	Antoine	INRA	antoine.messean@grignon.inra.fr
MÉTAIS	Pascale	ARVALIS Institut du végétal	p.metais@arvalisinstitutduvegetal.fr
MÉZIÈRE	Delphine	INRA	delphine.meziere@supagro.inra.fr
MINETTE	Sébastien	Chambre régionale d'agriculture Poitou-Charentes	sebastien.minette@poitou-charentes.chambagri.fr
MULLER	Olivier	MAAF DGAL SDQPV	olivier.muller@agriculture.gouv.fr
MUNIER-JOLAIN	Nicolas	INRA	nicolas.munier-jolain@dijon.inra.fr
NIVET	Laurent	UNILET	laurent.nivet@unilet.fr
OMON	Bertrand	Chambre d'agriculture Eure	bertrand.omon@agri-eure.com
PARDOUX	Jean Pierre	Chambre d'agriculture Somme	jp.pardoux@somme.chambagri.fr
PASQUIER	Catherine	INRA	pasquier@grignon.inra.fr
PELLETIER	Elisabeth	GIS GC-HP2E	e.pelletier@terresinovia.fr
PETIT	Sandrine	INRA	sandrine.petit2@dijon.inra.fr
PIEKACZ	Christian	DuPont Solutions France SAS	christian.piekacz@dupont.com
PIERRON	Sylvain	Dow AgroSciences	spierron@dow.com
PILLET	Emeric	Cellule d'animation nationale DEPHY	emeric.pillet@apca.chambagri.fr
PILORGÉ	Etienne	Terres Inovia	e.pilorge@terresinovia.fr
PITON	Jacques	DRAAF Haute Normandie	jacques.piton@agriculture.gouv.fr
POTOK	Stéphanie	INRA Transfert	stephanie.potok@paris.inra.fr
POURCELOT	Mickaël	InVivo AgroSolutions	mpourcelot@invivo-group.com
POUZET	André	Terres Inovia	a.pouzet@terresinovia.fr
QUILLIOT	Emilien	ITB	quilliot@itbfr.org
REBOUD	Xavier	INRA	xavier.reboud@dijon.inra.fr
RIBEROLLES	Emilie	Chambre d'agriculture Yonne	e.riberolles@yonne.chambagri.fr
RODRIGUEZ	Alain	ACTA	alain.rodriguez@acta.asso.fr
RONCEUX	Aïcha	Agro-Transfert	a.ronceux@agro-transfert-rt.org
SAVALLE	Cyrille	Agriculteur	clsavalle@aol.com
SAVOIE	Antoine	INRA	antoine.savoie@tours.inra.fr
SCHAUB	Anne	ARAA	a.schaub@alsace.chambagri.fr

SCHMIDT	Katia	Chambre régionale d'agriculture Aquitaine	k.schmidt@aquitaine.chambagri.fr
SEXE	Mathias	Emc2	Mathias.sexe@emc2.coop
TAILLIEZ LEFEBVRE	Delphine	InVivo AgroSolutions	Dtailliez-lefebvre@invivo-group.com
TAVERNIER	Michaël	CAPSEINE	mickael.tavernier@capseine.fr
THOMAS	Camille	InVivo Agrosolutions	cthomas@invivo-group.com
TOQUE	Clotilde	ARVALIS Institut du végétal	c.toque@arvalisinstitutduvegetal.fr
TROUCHE	Luce	INRA	Luce.Trouche@grignon.inra.fr
VACCARI	Vincent	Dijon Céréales	vincent.vaccari@dijon-cereales.fr
VACHER	Catherine	ARVALIS Institut du végétal	c.vacher@arvalisinstitutduvegetal.fr
VACHON	Céline	Chambre régionale d'agriculture Limousin	celine.vachon@limousin.chambagri.fr
VALLÉE	Romain	INRA	romain.vallee@inra.mirecourt.fr
VAN VAERENBERGH	Chris	Chambre d'agriculture Aisne	chris.vanvaerenbergh@ma02.org
VISSAC	Philippe	ACTA	philippe.vissac@acta.asso.fr
VUILLEMIN	Fanny	Terres Inovia	f.vuillemin@terresinovia.fr


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