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Mathilde Roignant

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Typology of the uses and non uses of glyphosate in fields crops and mixed crops/stock farming in Pays de la Loire

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Soutenu à Rennes le 13 septembre 2019

Devant le jury composé de :

Président : Mme Guenola Pérès
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Les analyses et les conclusions de ce travail d'étudiant n'engagent que la responsabilité de son auteur et non celle d'AGROCAMPUS OUEST

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Glossary:

The words and expressions defined below are followed by an asterisk for the first term appearing in the text

Annual plant: Plant that fructifies, disperses its seeds and dies less than a year after germination (Larousse 2018).

ANSES: National French Agency for Food Safety, Environment and Labor.

Antimetabolite: Chemicals analogs of the natural substrates of enzymes, where they bind to the active site but are not converted to the functional product. Antimetabolites block a biological process, such as biosynthetic pathway (Brilisauer et al. 2019).

BNV-d: National Bank sales distributors list sales and purchases of phytosanitary products in France. The declarative data produced by authorized distributors selling products are stored in it.

Crops system: set of technical modalities implemented on parcels treated in an identical way. Each cropping system is defined by the nature of the crops, their order of succession (rotation) and the technical itineraries applied to these different cultures (Pr Sébillotte)

DEPHY network: Demonstration network, Experimentation and production of references on the economic systems in phytosanitary, it is a major action of the Ecophyto plan.

DRAAF: Regional Direction of Agriculture of Food and Forest.

Enzymatic promiscuity: The ability of an enzyme to catalytically catalyse a chemical reaction distinct from that primarily catalysed by this enzyme.

Field crop: An agricultural crop grown on large areas (Dictionary Merriam-Webster).

Labor unit: for INSEE, the UTA (Annual Work Unit=labor unit in the study) is the unit of measurement for the amount of human labor provided on each farm. This unit is equivalent to the work of a person working full time for one year.

Mes parcelles: Recording tool of agricultural practices developed by the Chambers of Agriculture. It allows farmers to control their crops through the capture and retrieval of geographic and alphanumeric information about their farms.

Octagri: Customer Relations Management tool (CRM) of the chambers of agriculture.

Perennials: A plant with a growing period of several years, even when the underground parts (so-called perennial organs: rhizomes, bulbs, tubers, etc.) remain alone in winter (Larousse 2018).

Real Time Kinematic (RTK) is a satellite positioning technique based on the use of phase measurements of the carrier waves of signals emitted by GPS, GLONASS or Galileo systems.

SSP: Statistics and Foresight Service.

TFI: Treatment Frequency Index= \sum (Field Application Rate÷Registered Reference dose for the Crop Considered ×Proportion of Parcel Processed). It allows to access the degree of dependence of agricultural practices on the use of pesticides (Guichard, Mignolet, et Schott 2017).

Weed: It is said of a plant that grows spontaneously in a culture and whose presence is more or less harmful to it. (The harmfulness of weeds is explained by competitive effects with the cultivated plant, vis-à-vis water, light and minerals contained in the soil) (Larousse 2018).

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Introduction:

Glyphosate is the most widely used herbicide in the world (ww.epa.fr). It is a synthetic molecule, discovered in the 1950s by the Swiss chemist Henri Martin. Its property as a metal chelator (patent 1964) was used to make it an herbicide from 1974; Monsanto created the Roundup. Its authorization for herbicide uses on the European and French market is currently being questioned due to potential effects on human health. The glyphosate is currently ranked as a probable carcinogen by the World Health Organization since 2015. This ranking is not unanimous among other institutions. A new study on the risk for the health is being led by ANSES*. The development of plant resistant to the glyphosate questioned also the uses of the glyphosate on long term. The sale of glyphosate to individuals has been banned in France in January 2019. In Europe, the marketing authorization of glyphosate as an herbicide was last renewed in 2017 for 5 years instead of 10 as generally. The current authorization of glyphosate expires thus on December 15, 2022. Following the renewal of its authorization in 2017 until 2022, the French government, which voted against its renewal, announced that France would no longer use glyphosate within three years. Although this announcement of withdrawal in 3 years will not be effective, the possible exit of the use of the glyphosate in France and in Europe in the coming years raises the question of the feasibility to make without glyphosate, this systemic and total herbicide used in diverse agricultural sectors.

In this context of possible stop of glyphosate use in France, Pays de la Loire Chamber of Agriculture has launched a regional project on the feasibility of alternative techniques to the use of glyphosate in the different contexts of Pays de la Loire, region of north-western France, with various agricultural productions. Pays de la Loire chamber of Agriculture accompanies the farmers in their own and common development in the face of current challenges and represents all agricultural and economic agents of agriculture.

The project called Alt'R'Glypho contains two parts. The first part is that of my internship, it looks at the current uses and non uses of glyphosate in fields crops* and mixed crops/stock farming, in the objective of making a typology of the glyphosate uses and identifying the degree of glyphosate uses across systems and contexts.

What are the uses of glyphosate for fields crops and mixed crops/stock farming in Pays de la Loire?

What are the types and degrees of use of glyphosate?

What are the factors for reducing glyphosate?

The second part of the project contains experimentation and evaluation of innovative techniques, alternative to the use of glyphosate (a bio control molecule, the method of electric weeding, mechanical weeding tools).

The first part of the report presents the background and state of the art on the glyphosate molecule. The second and third part presents methodology, analyses and discussions of identified uses and non-uses of glyphosate from two data sources; data from Mes Parcelles* and data from surveys carried out by me with farmers in Pays de la Loire region. Part four presents the typology and cases of low users of glyphosate. Part five presents innovative alternatives to the glyphosate molecule.

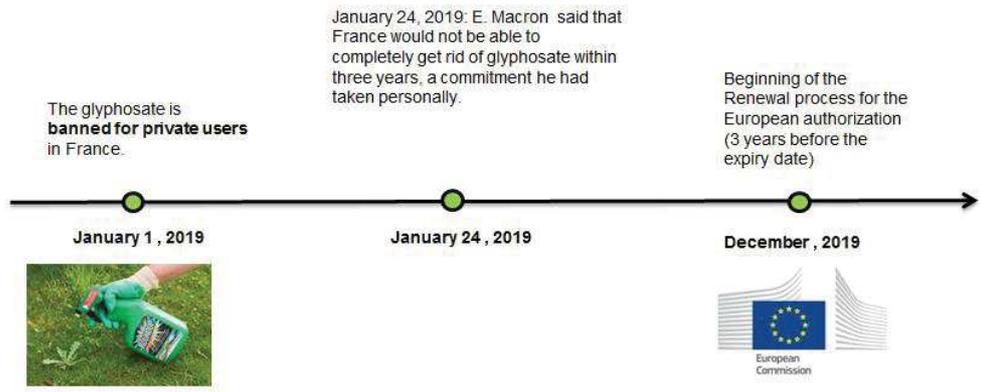
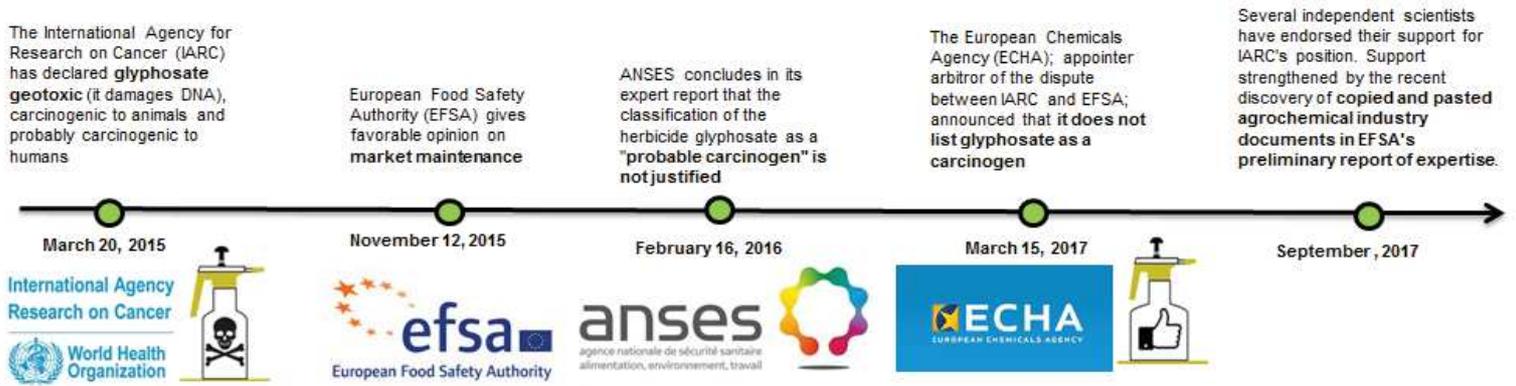


Figure 1: Facts, statements and dates about the glyphosate approval

I. Context and state of the art of the study

I.1 Context of the study

I.1.1 Facts, statements and dates on the glyphosate approval

The possible ban on glyphosate has been at the heart of scientific and political debates and in the news since 2015. Below and opposite (figure 1) are the main dates and statements that call into question the glyphosate approval in France.

March 20, 2015: The International Agency for Research on Cancer (IARC) first classifies glyphosate as a probable carcinogen for humans.

November 12, 2015: The European Food Safety Authority (EFSA) issued a favourable opinion for the maintenance on the market.

February 16, 2016: ANSES concludes that "given the limited level of evidence, a classification in Category 1A or 1B (known or suspected human carcinogen, CLP Regulation) cannot be proposed".

January 1, 2017: The glyphosate is banned for local communities for its use in areas open to the public in France.

March 15, 2017: The European Chemicals Agency (ECHA) announces that it does not classify glyphosate as a carcinogen.

September 2017: Several scientists show support for the IARC rankings by discovering many of the agrochemical industry's glued copies in EFSA's Preliminary Expert Report

October 24, 2017: MEPs (European deputies) adopt non-binding resolution calling for gradual ban on glyphosate within 5 years

October 25, 2017: Vote postponed for 10-year renewal of glyphosate.

November 27, 2017: The renewal of the molecule is finally validated for the next 5 years. In the wake E. Macron asks the government "to make the necessary arrangements so that the use of glyphosate is prohibited in France as soon as alternatives have been found and at the latest in three years". But this provision is not included in the EGALIM law.

May 11, 2018: ANSES announces the launch of a new study on glyphosate. This one, "independent" will aim to "settle" the controversy on the dangerousness of the herbicide

June 22, 2018 : The Agricultural minister presided by Stéphane Travert and the Ecological Transition minister presided by Nicolas Hulot launched a « task force led by the two ministries, with the support of INRA (National Institute of Agricultural Research), Acta (technical institutes) and APCA (chambers of agriculture) with a quarterly report »

January 1, 2019: The glyphosate is banned for private users in France.

May 29, 2019: Amendments for the prohibition, within three years, of glyphosate was rejected by the national assembly deputies.

December 2019: Beginning of the Renewal process for the European authorization (3 years before the expiry date).

Glyphosate use worldwide from 1994 to 2014

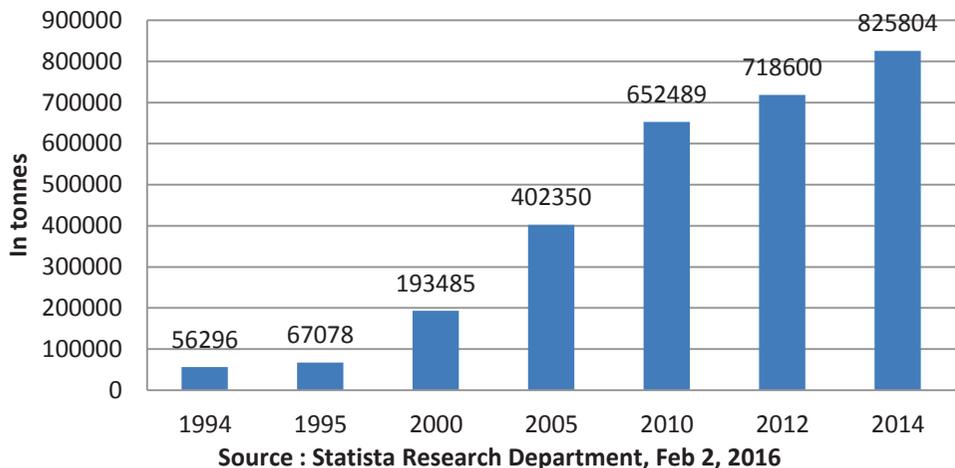


Figure 2: Quantity of glyphosate use worldwide from 1994 to 2014

Quantity of glyphosate and herbicides sold in France

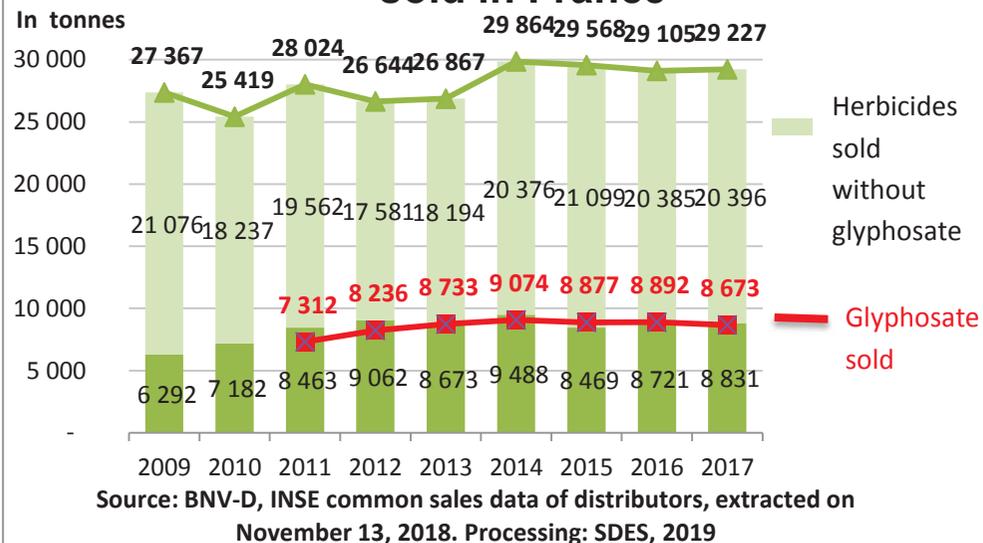


Figure 3: Quantity of glyphosate and herbicides sold in France from 2009 to 2017

Quantity of glyphosate bought in Pays de la Loire

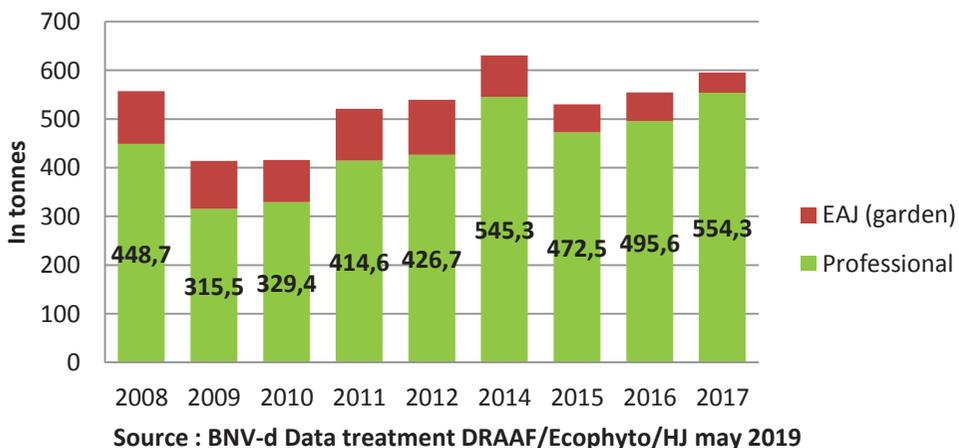


Figure 4: Quantity of glyphosate bought in Pays de la Loire from 2008 to 2017

Quantity of glyphosate bought per Pays de la Loire department

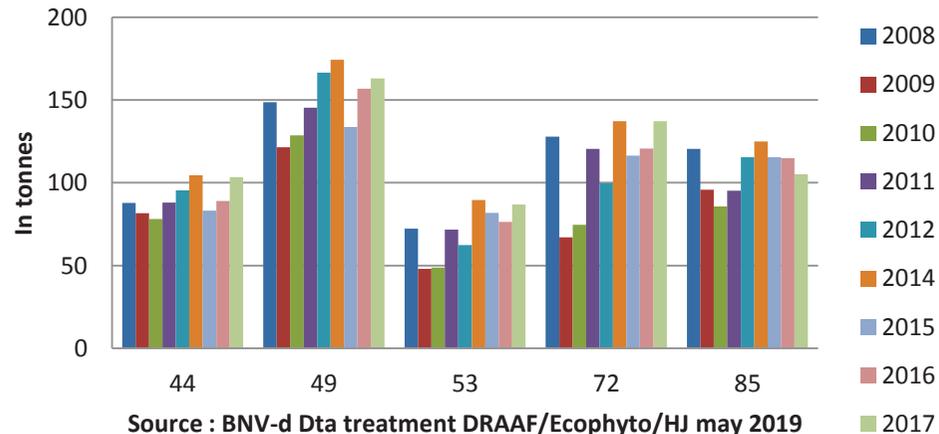


Figure 5: Quantity of glyphosate bought per Pays de la Loire department from 2008 to 2017

I.1.2 Quantity of glyphosate used

I.1.2.1 In the world

Since its approval on the market in 1974, the amount of glyphosate used has steadily increased worldwide to reach in 2014, 825000 of tons (figure 2). The creation of GMOs in the 2000s has greatly and continues to contribute greatly to the increase in glyphosate consumed, due to the number of GMOs created and to the weed resistances that are increasing and require higher amounts of glyphosate to be treated. In 2016, genetically engineered herbicide-tolerant crops account for about 56% of global glyphosate use (Benbrook 2016).

I.1.2.2 In France

Over the last three years recorded by BNV-d* 2015-2016-2017, the sale of glyphosate reaches an average of 8,673.5 tonnes, that is 30% of herbicide sales in France. The quantity of glyphosate used in France represents 1% of the total amount of glyphosate used worldwide. The quantity of herbicides sold has increased by 4% between the 2009-2010-2011 average and the 2015-2016-2017 average. Glyphosate's share of herbicide sales remained at 30% between these two periods (figure 3).

I.1.2.3 In Pays de la Loire

The last numbers include sales for professionals and those for EAJ (authorized use in gardens). The professionals are the distributors or buyers who hold an individual certificate for phytopharmaceutical products (certiphyto). Sales and purchasing figures by region and by departments may vary slightly depending on the registration code of distributors and buyers in the BNV-d (glyphosate may be sold by a distributor whose common code is in a different region than the glyphosate is bought). Since 2008, the DRAAF Pays de la Loire has listed herbicide purchases via the regional purchasing observatory (supplied by the distributors for pro and private water agency purchases). The figures for glyphosate purchases by department come from the analysis by M Hervé Jocaille (DRAAF Pays de la Loire) of the purchases recorded by municipality in this observatory coupled with BNV-d data. The 2013 year is not presented because the data are less sure.*

The purchase of glyphosate in Pays de la Loire region reaches 507.5 (professional) + 52.9 (EAJ) = 560.4 tons on average over the period 2015-2016-2017 (figure 4). The region consumes 6.4% of glyphosate sold nationally. The quantity of glyphosate purchased by professionals increased a little bit between 2009-2010-2011 and 2015-2016-2017 from 353.2 to 507.5 tonnes, the amount of glyphosate for garden use (EAJ) is decreasing from 97 to 53 tonnes (from 21.6% to 9.5% of glyphosate sales between 2009-2010-2011 and 2015-2016-2017).

The department Maine et Loire (49) is the one that consumes the most glyphosate and Mayenne (53) is the one that consumes the less in Pays de Loire. Glyphosate consumption in the 5 departments increased a little bit between 2009 and 2017 (Figure 5).

Adjust the dose to the target

L/ha of glyphosate (360 g/l) + Adjuvant

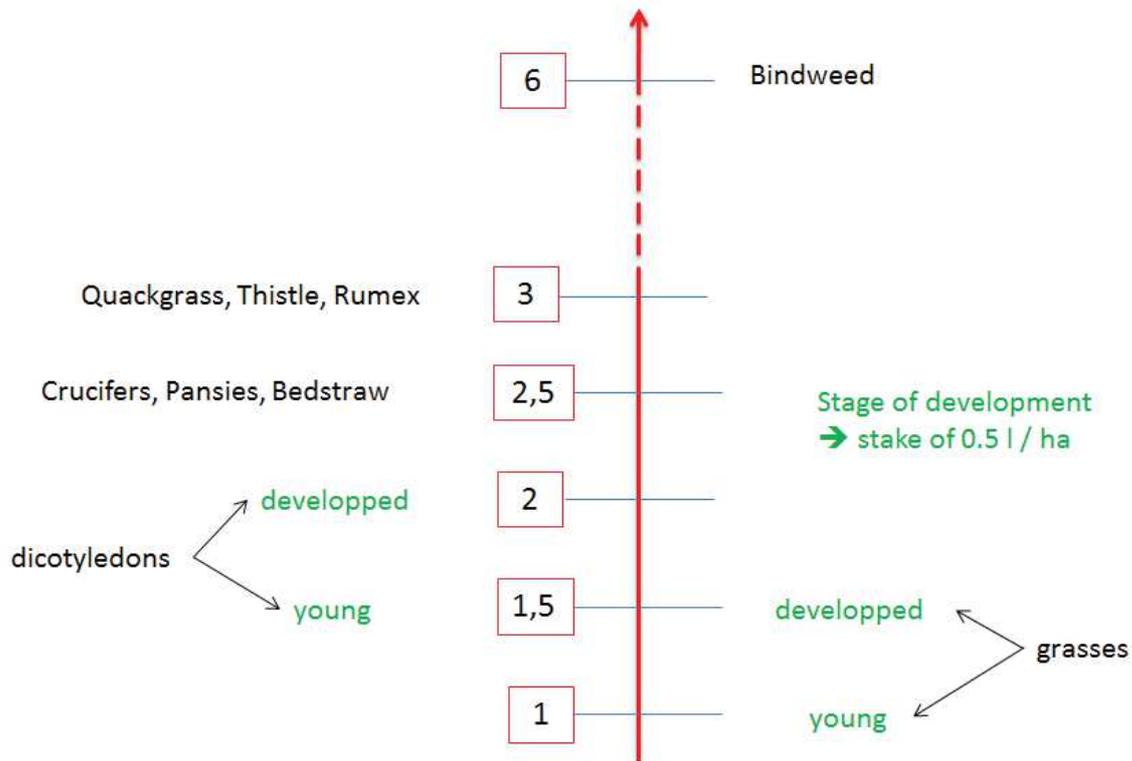


Figure 6: Adjust the dose of glyphosate to the weed targeted, translated from Arvalis, 2017

	Weeds targeted	L/ha of glyphosate (360g/l) needed		
		Only glyphosate	+ adjuvant	+adjuvant +2.4 D
Annuals	cereals regrowth (early run)	1-2	-	-
	rapeseed regrowth (3-4 leaves)	1	-	
	rapeseed (early elongation)	2.5	2	1.67
	annual grasses	1-2	-	-
	annual broadleaf weeds	1.5	-	-
	geranium	-	2	2.33
	goosefoot (15cm)	2.5	1.5	1.67
	mustard, phacelia, radish (developped)	3	2	1.67
Perennials	thistle (flower buds)	3	2	2.33
	milkweed	3	2.5	2.33
	bindweed (flowering)	6	4	2.33
	quackgrass (flowering)	3	-	-
	rumex	3	2	1.67

I.1.3 Glyphosate uses

I.1.3.1 Allowed uses in France compared to other countries

In France, glyphosate is only allowed in intercrops. It is used mainly to manage annual and perennial weeds between two harvested crops. Use on crops is allowed in some countries in Europe, in many American countries and elsewhere. One type of use on crops is that of desiccating crops and is done just before harvest. Glyphosate accelerates the maturation process and the drying of cereal grains and other crops on which this use is practiced (rapeseed, peas, cotton ...) but this use results in a certain amount of glyphosate residues in these crops harvested (Gilam, 2015). In Europe, the United Kingdom allows this use which permits in this northern European wet country, to ensure an harvest and better conservation of their crops. The second type of use on crops is for GM (genetically modified) crops tolerant to glyphosate. As early as 1994, GM crops called roundup ready (RR) soybean, corn, cotton were approved for planting in the US. The interest is to ensure a crop without weeds with the possibility of applying glyphosate on crops without affecting them thanks to their glyphosate tolerance gene. Since 1994, other countries have allowed GMO HT crops and other glyphosate tolerant crops have been introduced. The introduction of these GMO HT crops has been accompanied contrary to the expectations by an increase in the use of glyphosate and an increase in weeds resistant to glyphosate. The average rate per crop year (indicator of the intensity of glyphosate use) rose from 0.47 kg/hectare in 1993 to 2.08 kg/hectare in 2012 (4.4-fold) (Benbrook 2016). For a product with a glyphosate dosage of 360 g / l, it means the quantity per hectare was increased from 1.30 to 5.78 l / ha treated.

The maximum authorized total use rate in France is 2880g / ha / year (8 l / ha / year for a dosage of 360g / l) (Arvalis, 2017).

I.1.3.2 Differences of use between farms in France

In France, the use of glyphosate concerned 14% of surfaces in 2011 and 15% in 2014 (Reboud X. et al, 2017).

The use of glyphosate between farms can differ in terms of area treated and in terms of intensity of use via the dose applied per treatment.

Treatment rates depend on the weeds targeted, the conditions of application and the use of adjuvants. Depending on the target, annual or perennial weeds, the doses needed to manage them are different. Annuals* require lower doses. Perennials* require higher rates of 3l / ha for quack grass, thistles, rumex and up to 6l / ha for field bindweeds (figure 6). The stage of development as well as the area they take in the plot are two points of monitored vigilantly for the treatment of weeds. The use of adjuvants reduces the doses of glyphosate needed for the same effectiveness (figure 7)(Arvalis, 2017). Oils are an adjuvant that improves glyphosate penetration through the leaves. Wetting agents are useful adjuvants for contact products for plants that cannot be wetted (product drops do not spread). The use of wetting and oil at the same time has no additional benefits for dose reduction (Arvalis, 2019). For glyphosate, another type of adjuvant can be used, the ammonium sulphate-based salt that reduces the hardness of water. The addition of adjuvants based on ammonium sulphate, the usual dose of which is 1 l / ha makes it possible to reduce the dose thanks to the hygroscopic

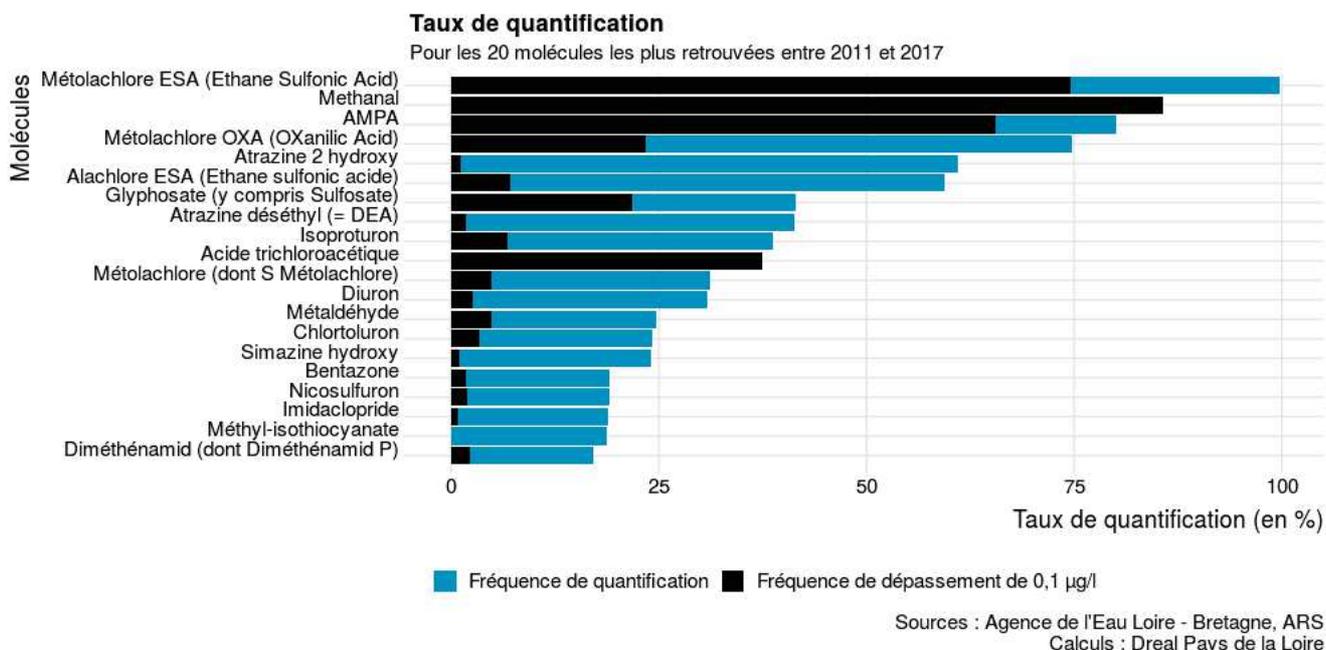


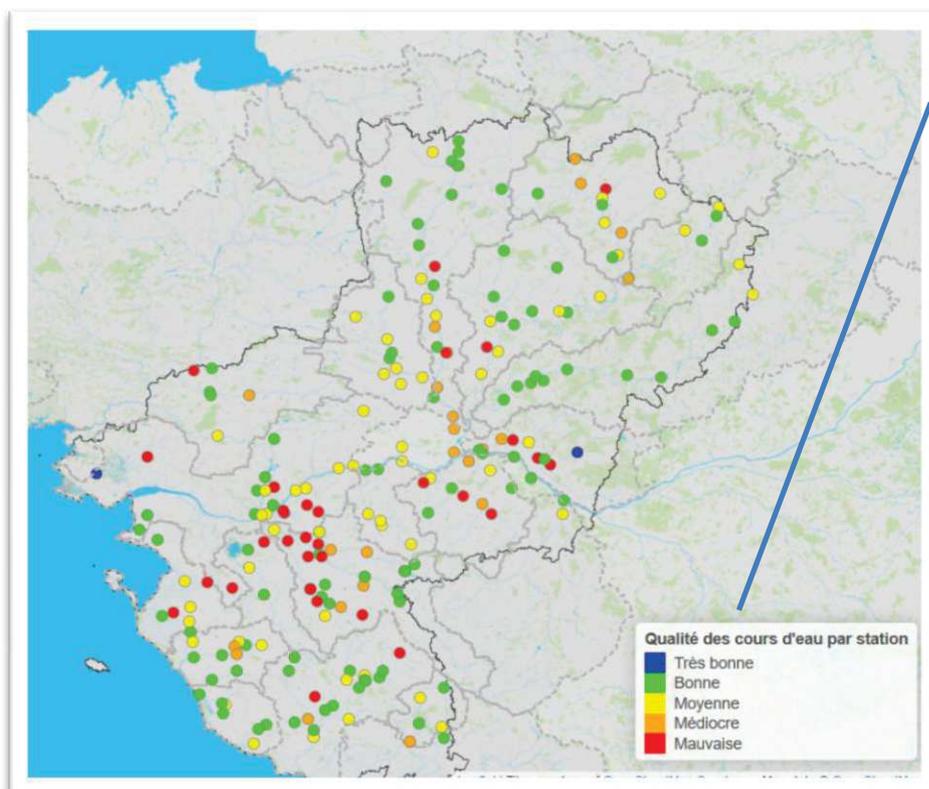
Figure 8 : Quantification rate of 20 molecules in Pays de la Loire water

Table 1: Glyphosate quantification and exceeding frequency

Glyphosate	2011-2014 average	2014-2017 average
Quantification frequency	32.5 %	42.5 %
Exceeding frequency at 0.1 µg /l	20 %	20 %

Table 2: AMPA; Aminomethylphosphonic acid; quantification and exceeding frequency

AMPA	2011-2014 average	2014-2017 average
Quantification frequency	75 %	77 %
Exceeding frequency at 0.1 µg /l	62.5 %	70 %



Water quality definition :

The classification of water quality by the SeqEAU method aims to qualify the ability of water to allow the proper functioning of the different biological compartments present in the watercourse. It is based on a list of molecules and 4 concentration threshold values specific to each molecule as well as for the cumulation of the concentrations taken. These 4 thresholds delimit 5 classes of quality, from very good to bad.

<http://apps.datalab.pays-de-la-loire.developpement-durable.gouv.fr/qualite-des-eaux/>

Figure 9 : Map of measurement stations by quality class in 2017 for Pays de la Loire region

effect of ammonium sulphate. The ammonium sulphate salt captures the moisture in the air, keeps the spray drops longer in the liquid phase and thus prevents desiccation of the treatment product containing glyphosate (Arvalis, February 2019).

In addition to adjuvants, reducing the volume of boiling reduces the amount of glyphosate used and even increases the effectiveness of glyphosate. Indeed, water contains Ca^{2+} ions that bind to glyphosate and thus reduce the amount of active glyphosate. In addition, glyphosate is very soluble in water, the water passes through the leaf cuticle which is hydrophobic in nature. The reduction of the volume of slurry thus makes it possible to reduce the relative share of Ca^{2+} ions and concentrates the drops of glyphosate, these two actions make it possible to increase the quantity of active glyphosate which enters the plant (Arvalis, April 2013). Doses can also vary according to abiotic parameters and depend on the farmers.

The areas treated between farms vary in particular according to the type of tillage adopted by the farmer. The analysis of the uses of glyphosate from the crops system* data of farmers belonging to the Dephy network* highlighted this difference in the area treated between type of soil tillage system. More than 60% of no-till areas were glyphosate treated in 2010-2011, compared to 40% for reduce tillage and less than 10% for systematic ploughing in 2010-2011 and 2013-2014 (Reboud X. et al, 2017).

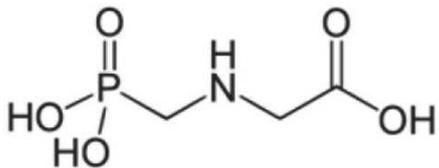
I.1.4 Residues of glyphosate and AMPA found in water

The water agency Bretagne-Loire conducts water sampling in the Loire region in order to estimate the quality of the water. The water quality assessment is based on the quantification rate and the frequency of exceeding a list of molecules. The quantification rate is the result of the division of the number of occurrences where the molecule is detected by the number of occurrences where the molecule is sought. The frequency of exceeding is the occurrence for which the molecule is detected at a concentration higher than 0.1 $\mu\text{g} / \text{l}$ (standard set by the individual EU as well as those of total pesticides)

AMPA; Aminomethylphosphonic acid; glyphosate degradation molecule (I.2.3.3); is the third molecule whose frequency of quantification is highest in the rivers of the region. Glyphosate is the 7th molecule with the highest frequency of quantization (figure 8). For rivers in Pays de la Loire region, the frequency of quantification of AMPA and that of glyphosate increased between 2011-2014 and 2014-2017, by 3% for AMPA and by 10% for glyphosate. The frequency of exceeding at 0.1 $\mu\text{g} / \text{L}$ remained at 20% for glyphosate, that of AMPA increased from 62.5 to 70% (table 1 and 2) (Agence de l'eau Bretagne-Loire) .

After having seen the elements of context in which the possible ban of glyphosate fits in France, we will see the properties and behaviours of the glyphosate molecule in order to reason the elements of previous contexts.

Table 3: Glyphosate chemical name and formula

	<u>Glyphosate</u>
Usual Name of the active ingredient	
IUPAC name	<i>N</i> -(phosphonomethyl)glycine
Formula developed	
Formula	$C_3H_8NO_5P$

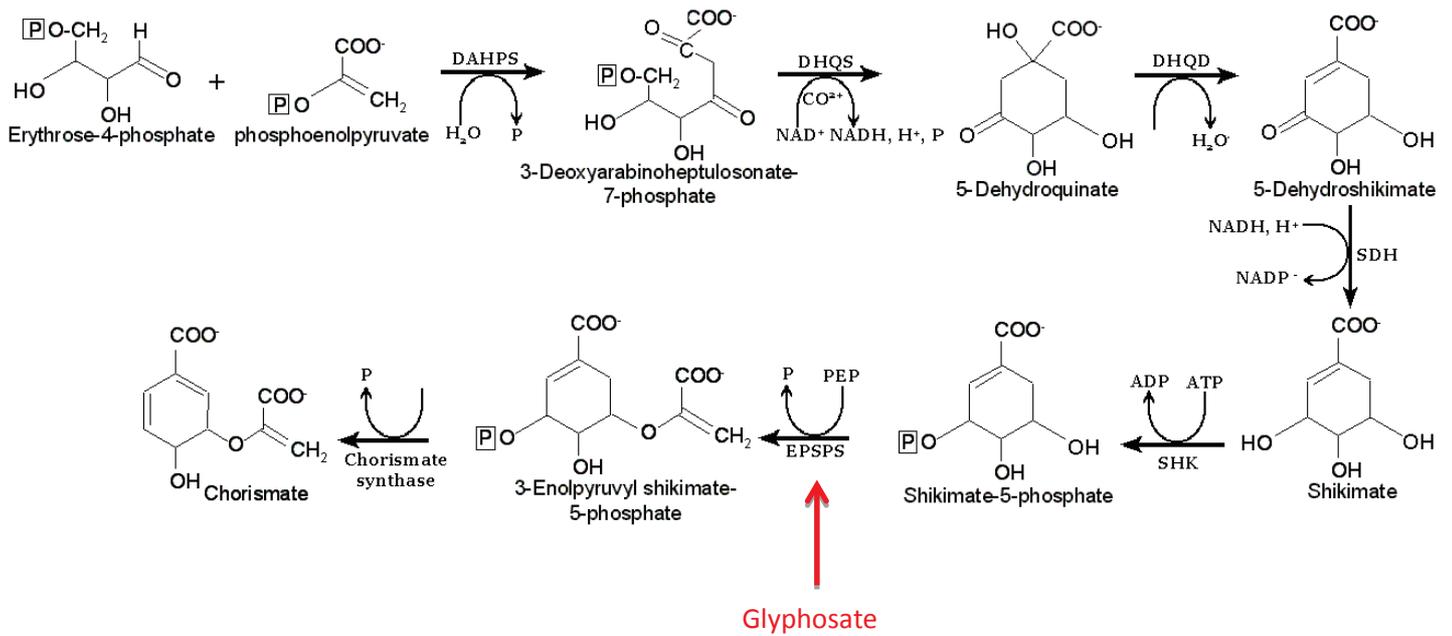


Figure 10 : Localisation of the glyphosate action in the shikimate pathway, adapted from Dosselaere et Vanderleyden 2001

I.2 State of the art on the glyphosate molecule

I.2.1 Glyphosate mode of action

The glyphosate is a systemic herbicide, it is absorbed by the leaves and then circulates throughout the plant to the underground parts (Sprankle et al, 1975). It is also a broad-spectrum herbicide; it affects almost all plant species. With dicamba and the 2.4D hormone, it is one of the third "total" herbicides allowed on the market in France (Arvalis).

Glyphosate acts on the biosynthetic pathway of shikimate. This biosynthetic pathway catalyses the conversion of erythrose 4-phosphate and phosphoenolpyruvate (PEP) via shikimate to chorismate (Dosselaere et Vanderleyden 2001). Chorismate is an essential precursor to the formation of the aromatic amino acids' phenylalanine, tyrosine and tryptophan. Each enzyme in this biosynthetic pathway is essential for the final formation of chorismate. This pathway is present in bacteria, fungi, algae, protists and plants, but is absent in animals.

Glyphosate acts at the last one stage (figure 10). It binds to the enzyme enolpyruvylshikimate-3-phosphatesynthase (EPSPS), thus blocking its activity and the formation of chorismate. The non-formation of the chorismate leads to the stop of development and eventually to the death of the plants (Mamy, 2004).

Its low cost compared to other herbicides, its total action and its systemic properties are probably the main reasons for its widespread use worldwide.

I.2.2 Effects and behaviour of glyphosate in soil

I.2.3.1 Glyphosate effects on soil microbial

In the long term, there is little effect of glyphosate on the parameter's microbial biomass and on the microbial mineralization. Glyphosate has little effect on microbial biological activity (Mamy, 2004).

I.2.3.2 Adsorption of glyphosate in the soil

Glyphosate is one of the herbicides adsorbed quickest in soils. It is therefore not very mobile, and its bioavailability decreases fastly. Adsorption is nevertheless less important in sandy or calcareous soils (Sprankle et al, 1975).

Glyphosate binds to the constituents of the soil by its phosphonic group. Once adsorbed, glyphosate loses its antimicrobial properties (Sprankle et al, 1975). The adsorption of glyphosate in soils is thus strongly dependent on the phosphate concentration in the soil. There is competition between glyphosate and phosphate for adsorptive sites. The more phosphate there is, the less adsorption is strong.

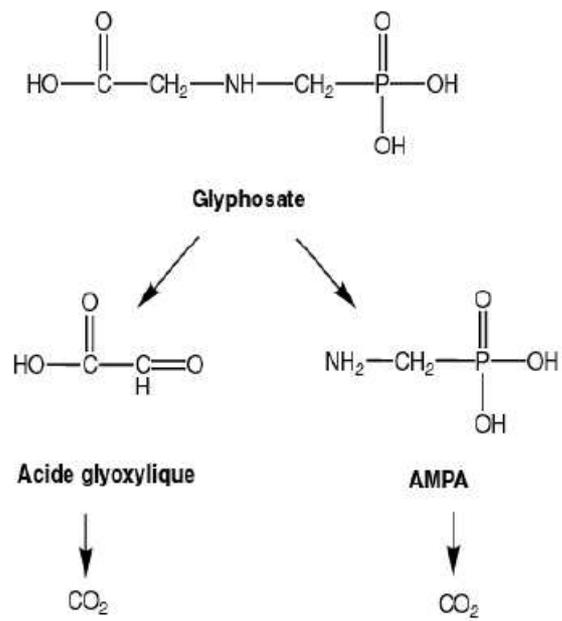


Figure 11: Pathways of glyphosate degradation in Soils (from Roberts, 1998)

As an amphoteric molecule, the adsorption of glyphosate in soils depends on the pH. Its absorption increases when the pH increases (Al rajab, 2007).

The amphoteric structure of glyphosate gives it complexing properties with metal ions of the soil, the most stable complexes with trivalent trivalent ions: Fe^{3+} , Al^{3+} and divalent Cu^{2+} . The presence of these ions increases the adsorption (Mamy, 2004).

The intensity of the adsorption depends also on the composition of the solution. The presence of CaCl_2 enhances the adsorption. The presence of Mn^{2+} manganese stimulates the mineralization of glyphosate as a likely cofactor (Moshier and Penner, 1978).

There is no consensus on the effect of organic matter on glyphosate adsorption. For some authors, soil content in organic matter has an influence on the glyphosate adsorption through hydrogen bond (Sprankle et al, 1975), and for others, the rate of organic matter in soils has no statistically significant influence on glyphosate adsorption (Gerritse et al, 1996 ; De Jonge et al, 2001).

1.2.3.3 Glyphosate degradation in the soil

The degradation of glyphosate in the soil when it is non-adsorbed is of mainly biological origin by mineralization. Chemical or photosynthetic degradation contributes very little to the degradation of glyphosate. The degradation of glyphosate produces two metabolites, glyoxylic acid and the main one in quantity aminomethylphosphonic acid (AMPA) (figure 11).

Glyphosate degradation is highly dependent on adsorption intensity (Sprankle et al ,1975). Depending on the rate and intensity of adsorption, his residence time can increase and the risk of accumulation too (Okada et al, 2017).

Depending on the soil, glyphosate may be more or less persistent. The half-life of glyphosate is highly variable between studies (Mamy, 2004).

The degradation of AMPA is also essentially biological. It is however slower and occurs indifferently under aerobic and anaerobic conditions. AMPA can persist in soils one year after application of glyphosate (Mamy, 2004).

1.2.3 Effects of tillage system on glyphosate sorption and degradation

Glyphosate sorption, persistence and so on degradation are similar between the surface of no tillage and conventional tillage soils (Zablotowicz et al. 2009). Pesticides transfer is more influenced by primary soils conditions and climatic conditions than by the type of tillage system. The explanation is that on one side, reducing tillage increase the biological activity able to degrade the glyphosate and another side, reducing tillage improve macropore connectivity which can increase the pesticide leaching, glyphosate notably.

Furthermore, as the adsorption of glyphosate is fast, the molecule is no more accessible by microbes. A study in Argentina (Alletto et al, 2010) has compared the dissipation of glyphosate and the accumulation of its main metabolite the AMPA over three soils, under long-term management of no-tillage and conventional tillage practices. They observed a first fast dissipation rate, which is due to the adsorption (no increase in the AMPA concentration). At the end, there were no difference between tillage practices and dissipation was not related to the microbial activity measured as soil respiration, which was higher for soil under no-till management (Alletto et al. 2010; Okada et al, 2017).

I.3 Objectives and progress of the internship

The objective of my internship; the part 1 of the Alt'R'Glypho project; is to carry out a typology of the uses and non-uses of glyphosate in fields crops and mixed crops/stock farming in Pays de la Loire for:

-Targeting more precisely the conditions of use of glyphosate in Pays de la Loire and the degree of glyphosate dependence of the systems.

-Identifying success factors in situations where some farmers dispense with glyphosate and allow their transfer.

For that, I conducted surveys in the form of interviews with 48 farmers in the region of Pays de la Loire, from mid-March to the end of June and I analysed data extracted from the tool Mes parcelles* on the glyphosate uses over the years 2016-2017-2018.

II. Analysis of the uses of glyphosate thanks to data extracted from “Mes parcelles” on the farming practices of Pays de la Loire farmers

II.1 Material and Method

II.1.1 Material

Mes parcelles * is a tool for recording farmers' farming practices. It makes it possible to forecast and record phytosanitary practices by plots. Mes parcelles was used by 3800 farmers in Pays de la Loire region in 2018. The number of current farmers in the Loire region is 34 344, of which 25308 medium and large (PBS = standard gross product > 25000 €). Mes parcelles accounts for about 28.6 % of the area under « field crops » in the Pays de la Loire (Annexe I).

I used several data from Mes parcelles for the last three years 2016, 2017 and 2018.

The extractions were made by M Thibault Petit for different indicators with an entry by culture or by non-nominative identifiers. In order to take into account only fields crops and mixed crop farmers, the APE (Main Business Activity) codes recorded on Octagri * were crossed with the corresponding identifier under Mes parcelles. The APE codes below have been kept to represent the field crops and mixed crop farms:

- 0111Z - Culture de céréales (à l'exception du riz), de légumineuses et de graines oléagineuses
- 0141Z - Élevage de vaches laitières
- 0142Z - Élevage d'autres bovins et de buffles
- 0145Z - Élevage d'ovins et de caprins
- 0146Z - Élevage de porcins
- 0147Z - Élevage de volailles
- 0149Z - Élevage d'autres animaux
- 0150Z - Culture et élevage associés
- 0161Z - Activités de soutien aux cultures

The indicators requested are:

- Per culture and per pair of culture previous / next, per plot for the years 2016,2017 and 2018

-treated surface by glyphosate - area of the plot - quantity of active ingredient applied (via the extraction of indicators quantity of glyphosate applied per treatment, treatment unit, dose of the treatment product)

-TFI* glyphosate and TFI herbicides.

- Per identifier for the year 2016,2017 and 2018 for corn and soft wheat

-TFI glyphosate and TFI herbicides combined

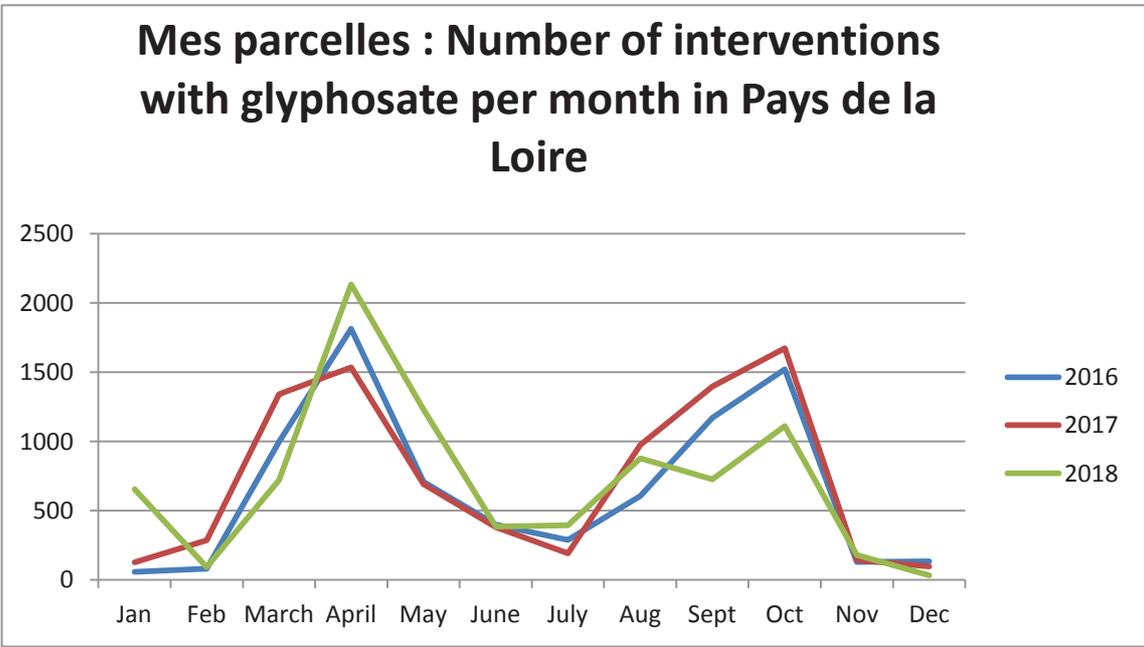


Figure 13 : Number of interventions with glyphosate per month in Pays de la Loire by farmers in mes parcelles for 2016, 2017 and 2018

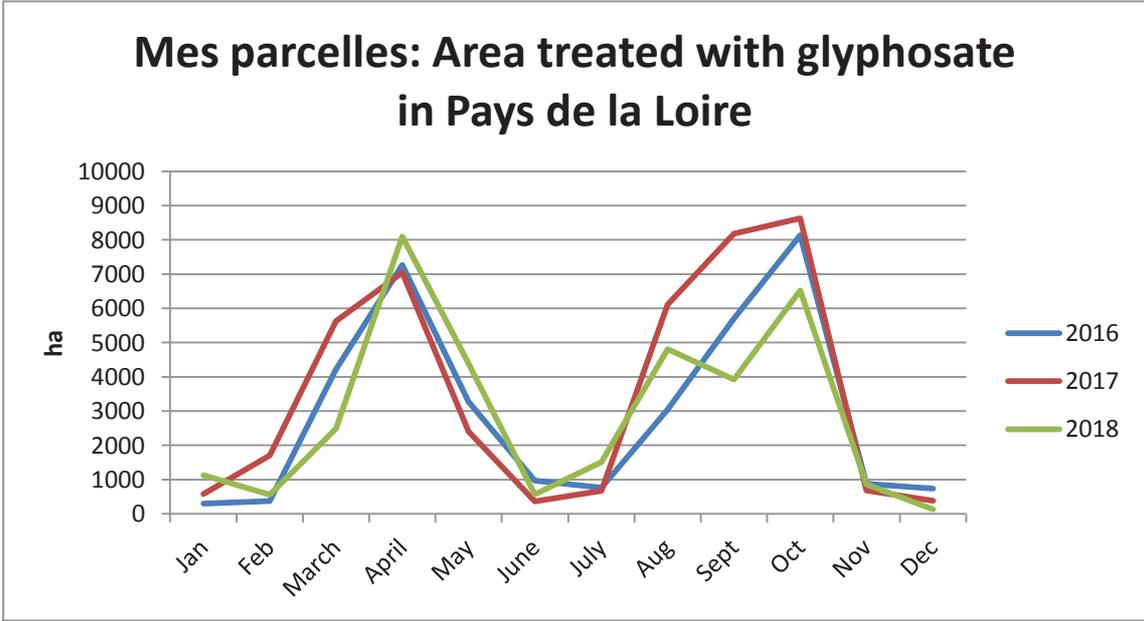


Figure 14 : Area treated with glyphosate in Pays de la Loire by farmers in mes parcelles for 2016, 2017 and 2018

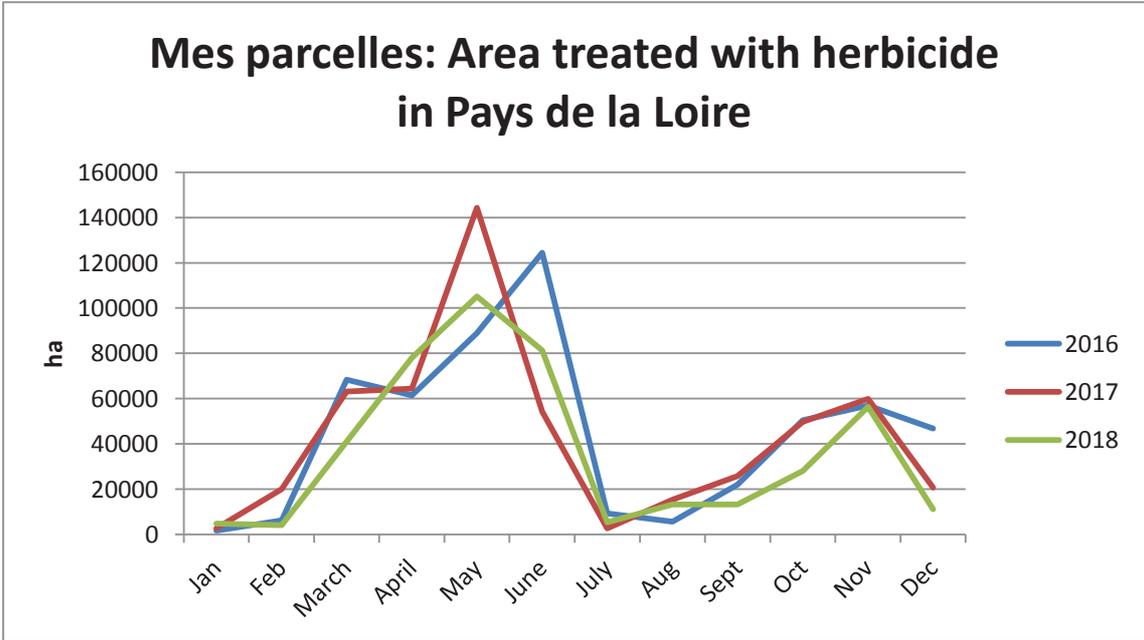


Figure 15 : Area treated with herbicide in Pays de la Loire for 2016 ,2017 and 2018

- Per month for the years 2016, 2017 and 2018

The number of glyphosate applications per month for several years.

II.1.2 Method

The data have been cleaned (detection and removal of errors present on the data stored in the files extracted from Mes parcelles and were analysed under microsoft excel.

The winter crop * taken into account are - soft wheat winter, winter barley, winter rape, winter triticale, durum wheat winter, winter oats, winter rye.

The spring crop * taken into account are -corn silage, grain corn, sunflower, spring barley, spring oats, durum wheat spring, soft wheat spring, spring rape, rye spring, spring triticale.

The study of the effect of the previous plant on the application of glyphosate before the next crop is made from data whose registration number over the 3 years 2016-2017-2018 is strictly greater than 15 and whose standard deviation is lower strict at 1.1 l / ha.

All the results expressed in liter / ha in the rest of the report and on the graphs are obtained from the grammage per hectare and converted into liters for a concentration of 360g / L.

The averages expressed are always the triennial averages over the years 2016,2017 and 2018. Standard deviations are in brackets.

II.2 Results

II.2.1 Percentage of uses and Period of application

18.67% of the farmers registered in fields crops or mixed crops-breeding sectors (APE codes) use glyphosate per year in Pays de la Loire (average on 2016-2017-2018).

The major part of glyphosate applications in Pays de la Loire takes place before spring and winter sowing (figure 13). The area treated with glyphosate for farmers in Pays de la Loire is similar between spring and winter (figure 15). The area dedicated to winter crops is 15.4 % higher than for spring crops according to mes parcelles. The difference rate at the region wide according to Agreste resources is of 18% (table 3). For comparison, the area treated with herbicide is largely higher in spring than in winter (figure 15).

Table 4: Area in winter and spring crops registered in mes parcelles and in Pays de la Loire

Pays de la Loire Average area on 2016-2017- 2018 :	Mes Parcelles	Region Wide (Source Agreste)
Winter crops in ha	173277	621100
Spring crops in ha	127165	432100
Total	300442	1053200
Difference between winter and spring crops area	46112=15.4 %	194000=18%

List 1 = List of crops analysed in the 2 figures below: corn, sorghum, soft wheat, durum wheat, triticale, barley, rye, sunflower, rapeseed, soybean, linen, faba bean, feed pea, lupine, beetroot and hemp

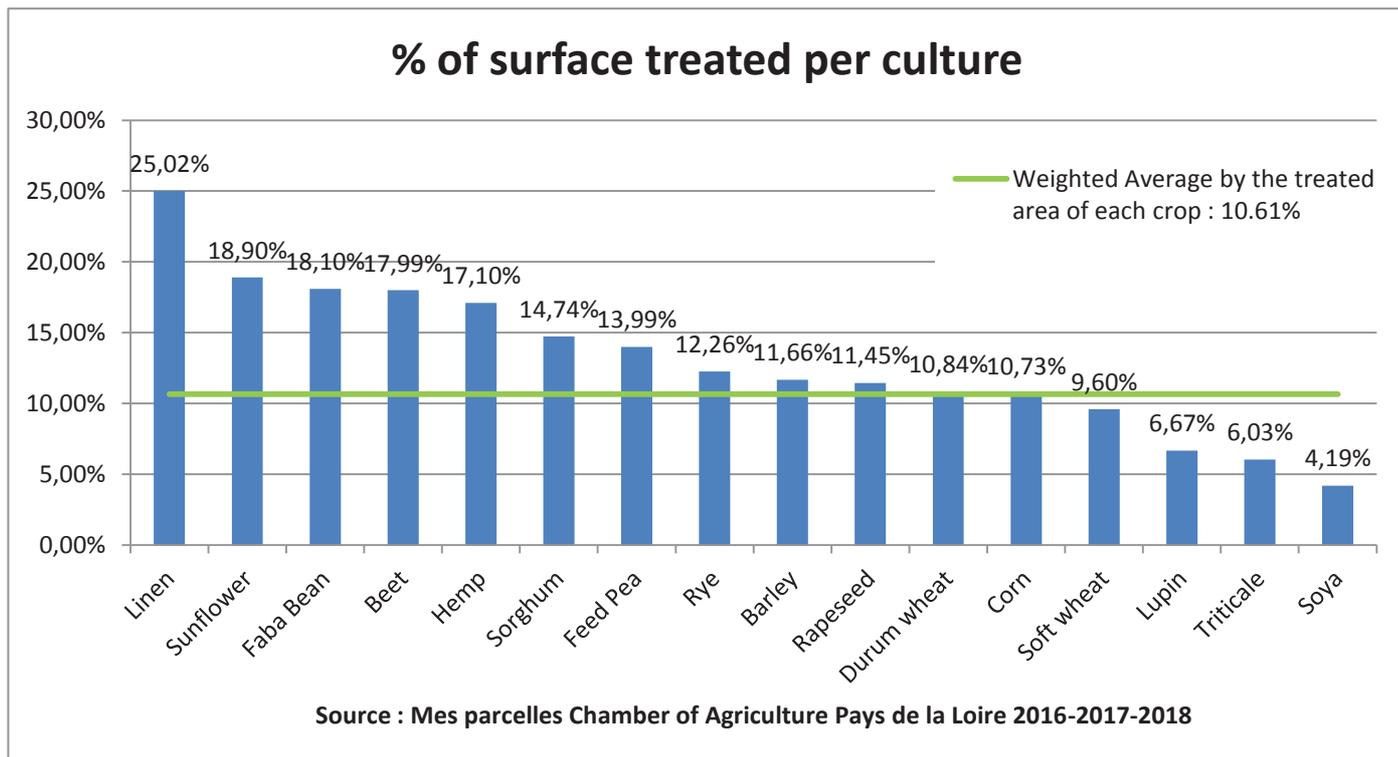


Figure 16 : Percentage of area treated with glyphosate per culture

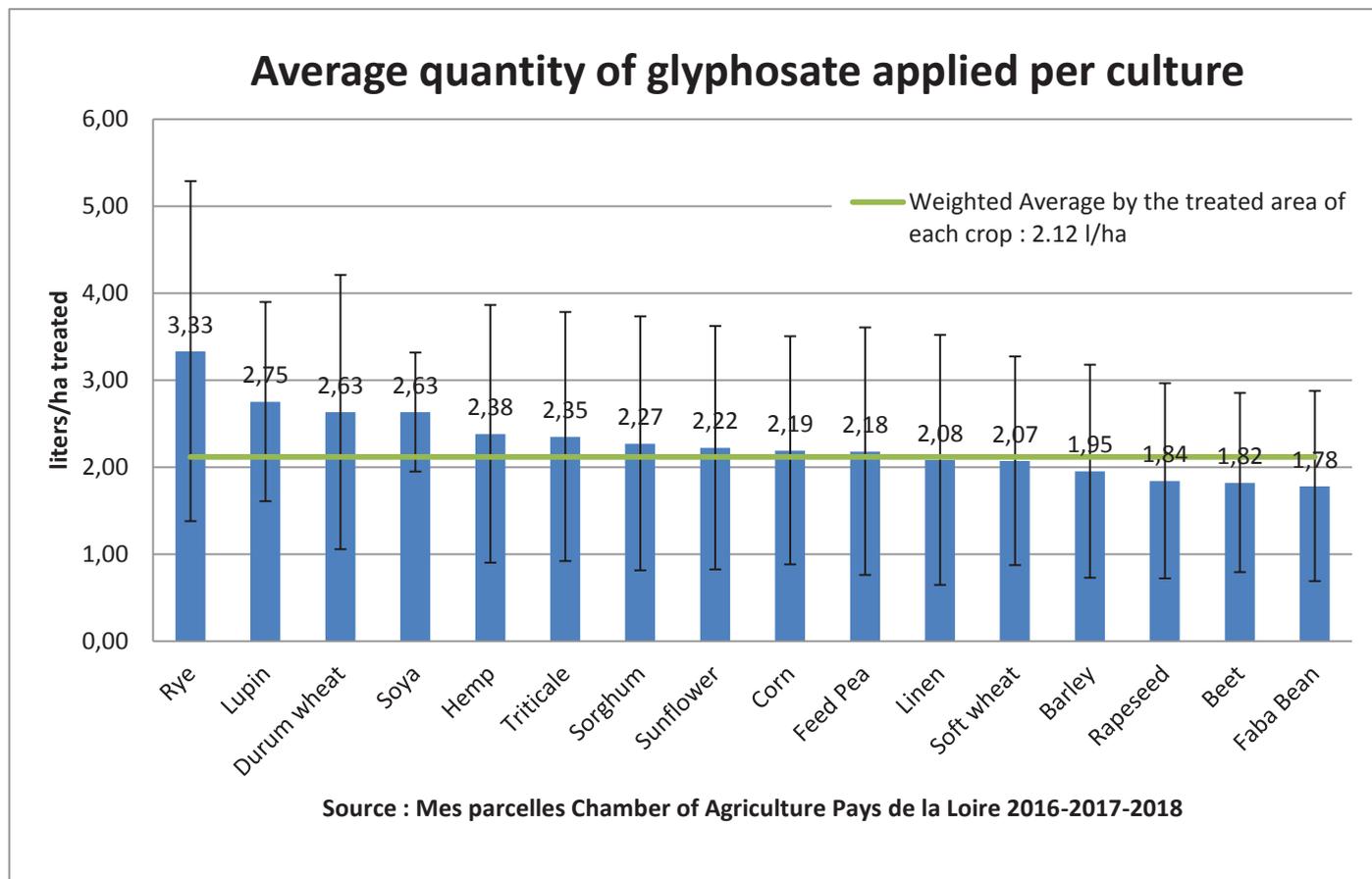


Figure 17 : Average quantity of glyphosate applied per culture

II.2.2 Uses per culture

On all the areas of crops in List 1 (corn, sorghum, soft wheat, durum wheat, triticale, barley, rye, sunflower, rapeseed, soybean, linen, faba bean, feed pea, lupine, beet and hemp), The area-weighted average of glyphosate-treated surfaces is 10.64% for a weighted average dosage of 2.12 l / ha treated (+/- 1.25) (figure 16 and 17).

In terms of area, an average of 32775.83 ha of the 308462.52 hectares of crops in List 1 taken into account by mes parcelles receive a glyphosate treatment per year. At the scale of the region, taking the same % of 10.64%, the surface treated with glyphosate would be 114369 ha out of 1076366, 33 which are in cultures of list 1.

When treated with glyphosate, 97.4% of the treatments are done on more than 90% of the plot area.

- For Spring crop* / Winter crop*

The difference in % of treated area and treatment dose between winter and spring crops is very small, 1.2% difference (9.9% of areas under winter crops and 11.2% of areas under spring crops are treated) with a difference of 0.12 l / ha between winter and spring for the dose. Thus, there is a slight increase in tendency in the intensity of use measured by the quantity in l / ha for the spring crops.

- Per crops (figure 16 and 17)

The average area treated per crop varies from less than 10% for durum wheat, lupine, triticale and soybeans to 25% for linen.

Straw cereals seem to be less treated in terms of cultivated areas: rye, barley, durum wheat, common wheat, triticale are on the right side of the graph (figure 16).

Oleaginous crops, hemp and linen are more treated in terms of surfaces. One explanation may be the reduced availability of herbicides in crops for linen and hemp.

18.90% of area in sunflower is treated. This high percentage could be explained by the fact that farmers in reduced tillage system often cultivated this crop and as they don't use the plough to manage weeds, they usually treat on a superior area (Reboud X. et al, 2017). The differences of average quantity between crops is small between crops (less than 1 l of difference, excepted for the rye), it is not the crop that explain

The crop that is treated at the highest rate per hectare is rye, at 3.33 l / ha (+/- 1.95). 10.7% of the areas intended to be in corn are treated at an average dose of 2.19 l/ha (+/- 1.31). 9.60% of the areas intended to be in soft wheat are treated at an average dose of 2.07 l/ha (+/- 1.2). 18.90% of the areas intended to be in sunflower are treated at an average dose of 2.22 l/ha (+/-1.40). 18.10% of the areas intended to be in Faba bean are treated at an average dose of 1.78 l/ha (+/-1.09).

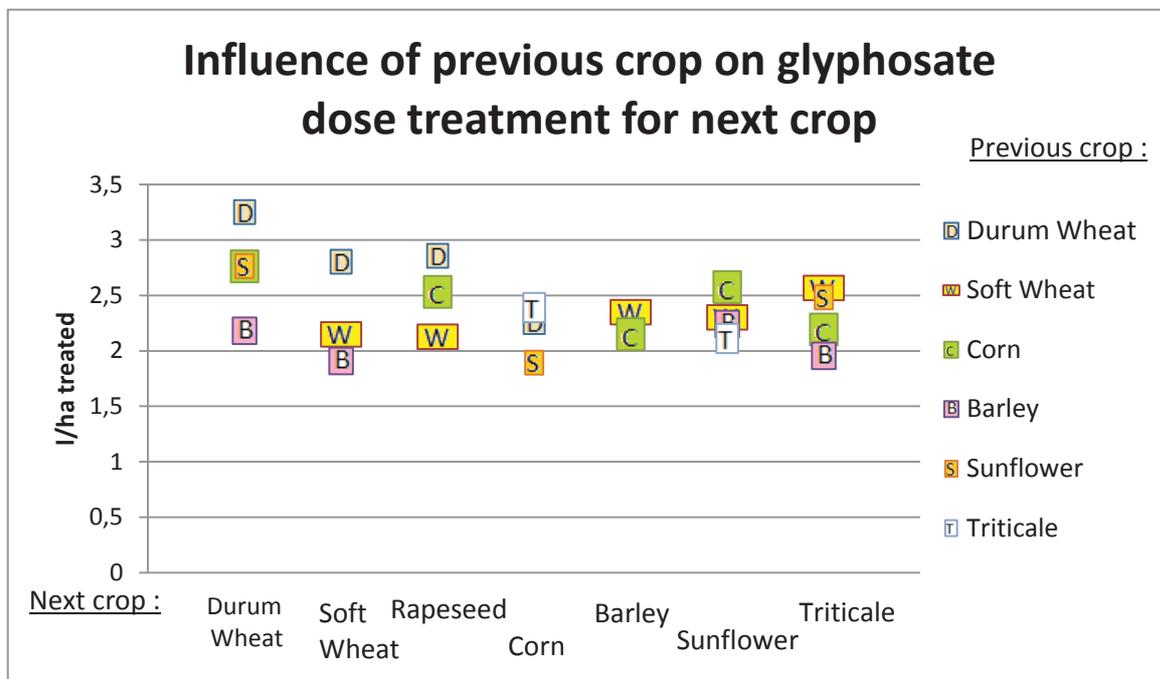


Figure 18 : Influence of previous crop on glyphosate dose treatment for next crop

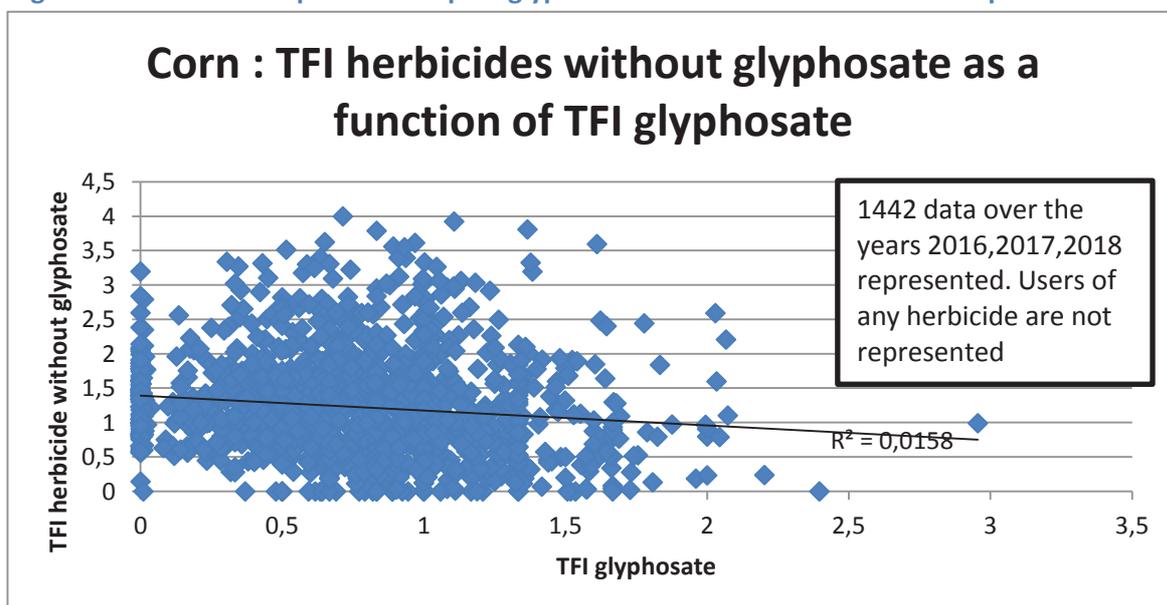


Figure 19 : TFI herbicide without glyphosate as a function of TFI glyphosate for corn for the years 2016,2017 and 2018

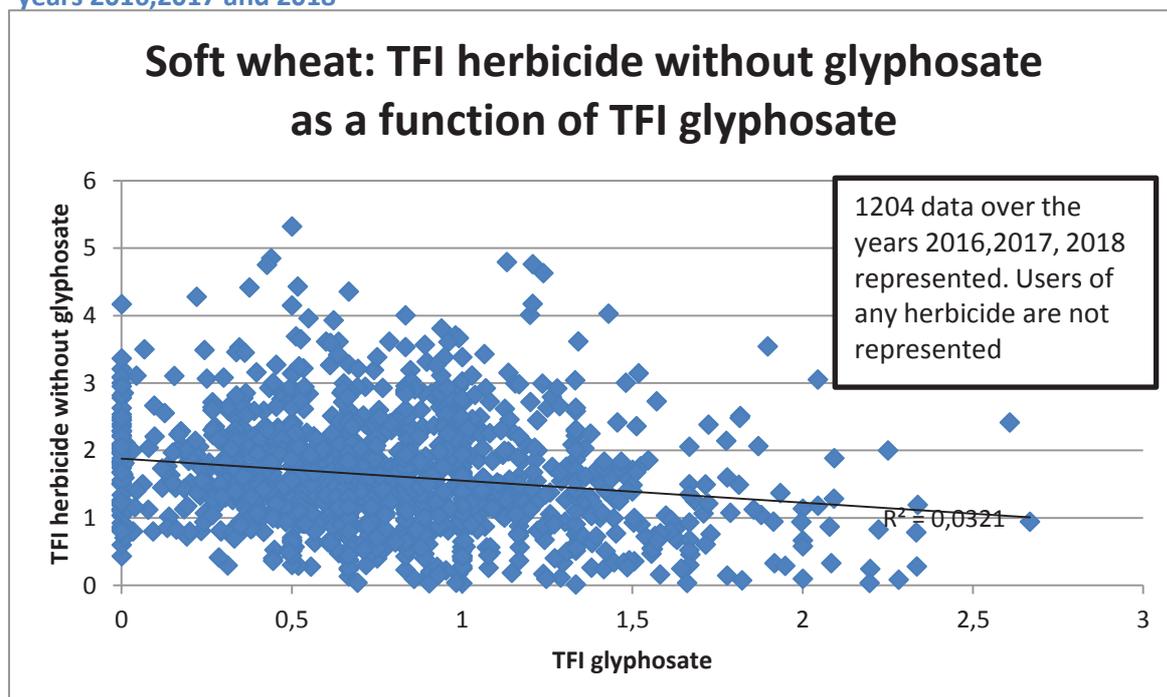


Figure 20 : TFI herbicide without glyphosate as a function of TFI glyphosate for soft wheat for the years 2016,2017 and 2018

II.2.3 Influence of precedent

The differences in average doses of glyphosate between precedents for the same next crop are small (figure 18). Standard deviations are less than 1.1 l / ha. Effect of the previous crop is very small on the dose treatment for a same next crop. This could be explained by the fact that glyphosate is applied between crops and the goal of the treatment is to clean the plot before sowing.

However, dose differences are higher for durum wheat, soft wheat and rapeseed than for corn, barley, sunflower and triticale crops. On average, a higher quantity of glyphosate is applied for previous durum wheat, for the following crops durum wheat, common wheat and rapeseed.

II.2.4 Link between glyphosate and herbicide

For corn and soft wheat, there is no linear relationship between the amount of glyphosate and herbicide applied in culture (figure 19 and 20: very low R^2 and distribution of points in all the 2D space). Low use of glyphosate does not necessarily imply increased use of herbicides in culture.

II.3 Discussions

The sample of mes parcelles represents more than a quarter of the list 1 (=COP products =Cereals, Oilseeds and Protein crops) (28.61%, annexe I) for Pays de la Loire region and the difference in area cultivated between winter and spring crops is close (15% for mes parcelles vs 18% for agreste regional data). Mes parcelles seems to be a correct representation of the regional use of glyphosate. According to this sample, 10.64% of the areas in list 1 are treated with glyphosate, this is slightly less than the national average including all sectors which amounted to 14% in 2015. Considering the viticultural and arboricultural sectors present in significant proportion in Pays de la Loire would increase this percentage of surface treated.

18.67% of the farmers in Pays de la Loire in fields crops or mixed crops/stock farming use glyphosate per year. Thus, the use of glyphosate concerns only a small part of farmers per year and the use of glyphosate is not systematic and is not really widespread.

The data cleaning changes the database. It allows to delete errors due to bad data entries but can delete real data that is extreme in relation to the average. Extreme values are thus not taken into account. However, the elevated standard deviations show the significant variability of data and thus of doses between farmers for the same crop.

The average amount of glyphosate applied (2.22 l/ha) is clearly above the one from Dephy analysis which is 1.68 l/ha on average, which can be explained by the fact that Dephy network gather people who are explicitly imply in a pesticide reduction. By comparing with Arvalis' recommendations for glyphosate dose efficiency on target, this average dose of 2.22 L / ha could be reduced by optimally adjusting doses to the target.

Transition: The analysis of Mes parcelles data allowed studying the uses and intensities of use of glyphosate by culture at the regional scale. The surveys will make it possible to study the uses and factors of use between farm types.

Table 5: Types of uses taken into account in the survey

« Usage du glyphosate »	Meaning :
1	Fight against perennials
2	Cover crop destruction
3	Cleaning before sowing
4	Destruction of pastures

Table 6: Example of table completed with farmers glyphosate uses

Usage du glyphosate	Culture précédente	Culture suivante	Date	Produit grammage + adjuvants	Quantité en l	Adventices ciblées Annuelle / vivaces	100% surface ?	Systématique ?	Autre règles de decision + Zones
1 (exemple)	Couvert végétal	Mais		360 g/l Sulfate ammonium	1.25		oui	non	
1+3	Colza	Blé		360 g/l	3	Repousses de colza + rumex qui relève dès récolte	oui	non	Selon infestation des parcelles
4	Prairie temporaire		printemps	360g/m , huile	3.5	chiendent	oui	oui	
...									

Le système de culture actuel
Quelle combinaison de leviers pour la gestion des adventices ?

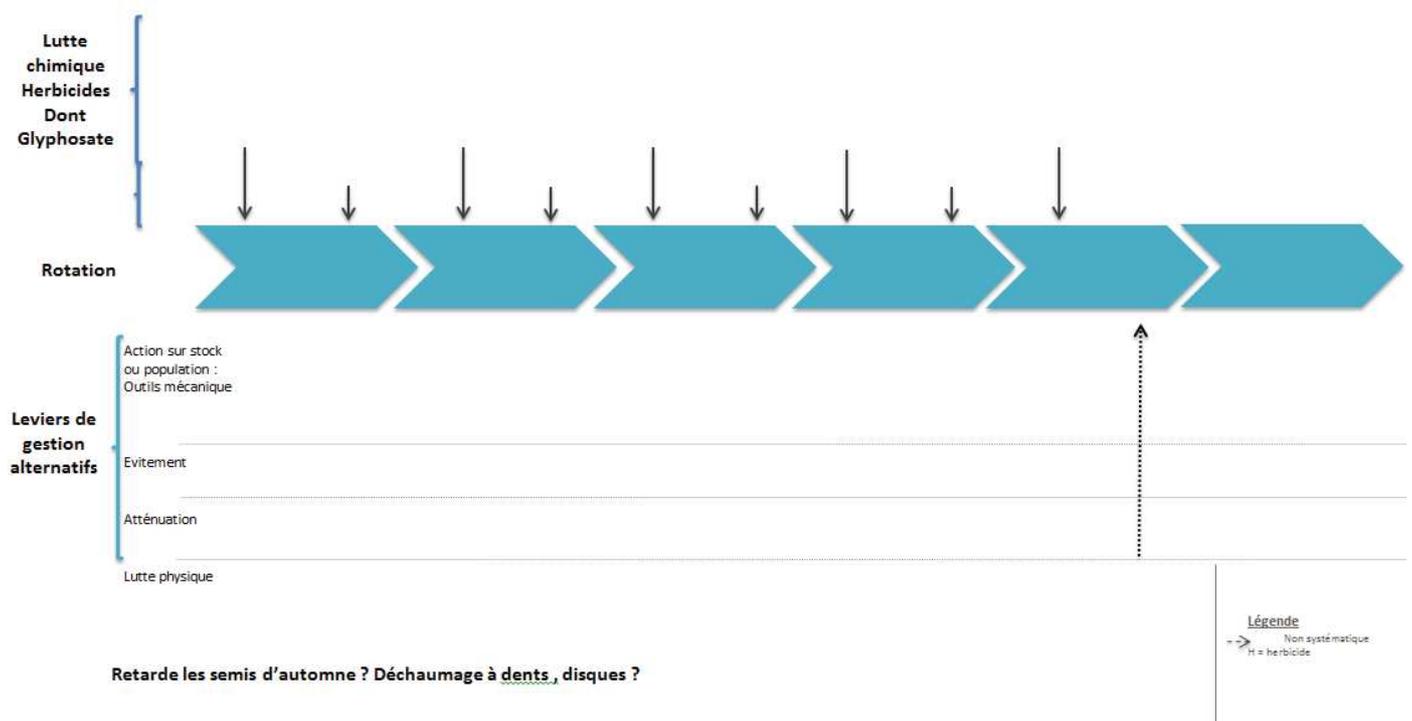


Figure 21: Decision-making scheme of weed management levers

III. Analyses of the uses of glyphosate via a survey in the form of interview with Pays de la Loire farmers

III.1 Material and Method of the farmer survey Alt'R'Glypho

III.1.1 Content of the farmer survey

I built the survey the first weeks of the internship and modified it after the first surveys. Due to some modifications the first weeks, for some indicators I only kept the surveys for whom the indicator was given by the farmer. The survey was in French. The questions, closed or open, allowing to collect data in figures and texts, are presented below for the 3 parts of the survey.

Part 1 : Description of the farm

- Type of farm: Animals production and ETO (checked on Octagri)
- Distinction of different areas within their plot or not (based on different textures or other criteria)

Part 2 : Crop production campaign 2017-2018

- UAA of the farm
- Crops production and hectares for each one
- Crop rotations including intercrops
- Choice and composition of the intercrops. What criteria do they make their choice of intercrops and their composition?
- Type of tillage system: How many years and for what crops?
- What is the frequency of ploughing on the farm?
- What is the share of UAA using glyphosate?
- How many liters of glyphosate do you use throughout the year? For which product weight?

Part 3 : Use of glyphosate

From the 4 types of use considered in the survey (table 4), farmers described their uses of glyphosate (table 5 : the type(s) of use, after and before which crop, dose and grammage of the product, use of adjuvants, weeds targeted, on 100% of the surface or not, systematic or not, depending on the plots or not). Uses mentioned are for the campaign 2017/2018. The uses can and are often concomitant. For example, 3 + 1 means use of glyphosate for pre-plant cleaning and control of perennial weeds* in one treatment.

- TFI herbicide without glyphosate and TFI glyphosate per farm are derived from Mes parcelles data and only relate to farmers having Mes parcelles up to date.
- Completing the decision-making scheme of weed management levers (figure 21)

Part 4 : Discussion

- Is your use of glyphosate increasing, reducing, stable? Since ?
- Do you think you can reduce your doses of glyphosate use?

Table 6: Number of farmers surveyed per department

Department	Number of farmers surveyed
44 Loire-Atlantique	2
49 Maine et Loire	13
53 Mayenne	8
72 Sarthe	8
85 Vendée	17
Pays de la Loire	48

Table 7: ETO of the farms surveyed

ETO (Economic and Technical Orientation)	Number of farms
Cattle milk	14
Meat cattle	9
Polyculture	9
Granivores	6
General cultures	4
Pigs	3
Other herbivores	2
Mixed cattle	1
Total	48

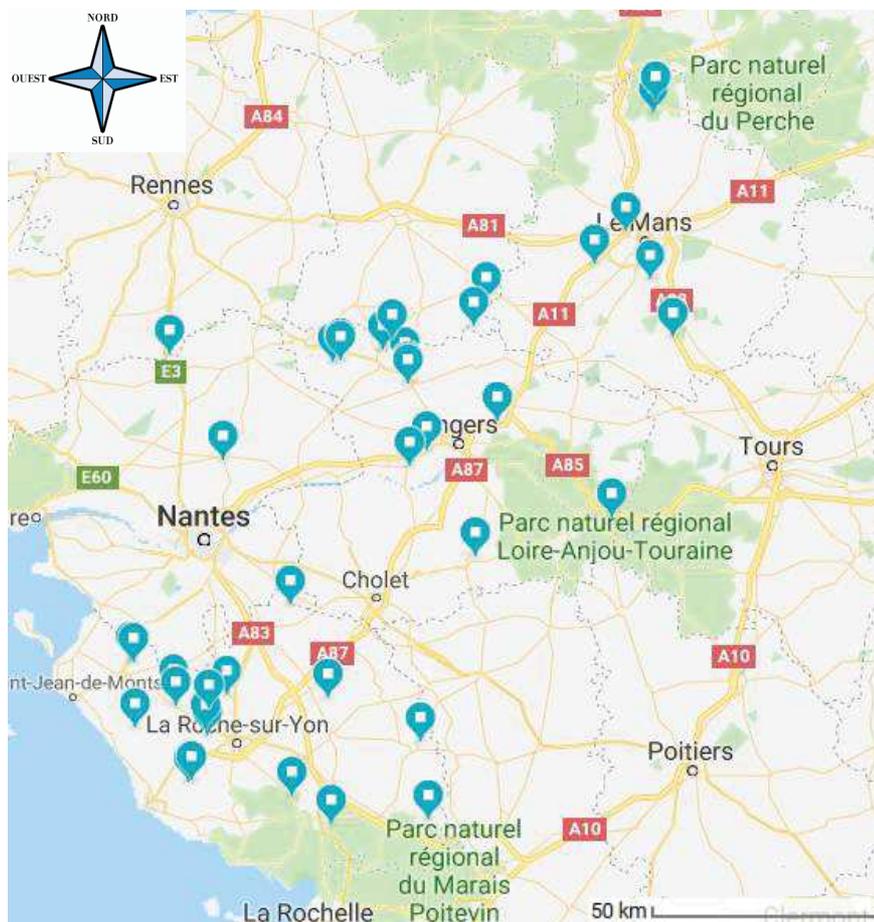


Figure 22: Map of the farmers surveyed

Table 7: Categories of soil tillage and their definition

Type of tillage system	Definition and frequency of the ploughing
DS	Direct Seeding=no ploughing over 6 years and no tillage in 2017-2018 other than sowing
RT	Reduce tillage=no ploughing over 6 years but other tillage in 2017-2018
Ploughing rare	Ploughing <1 time/3 years
Ploughing occasional	1 time/3 years < ploughing <1 time/2 years
Ploughing frequent	1 time/2 years < ploughing <1 time/year
Ploughing systematic	Ploughing=1 time/year

Table 8 : Farms per type of tillage system

Type of tillage system	Number of farms	Number who don't use glyphosate
DS	5	
RT	21	3
Ploughing rare	10	1
Ploughing occasional	6	1
Ploughing frequent	4	
Ploughing systematic	1	1
Ploughing systematic in marais poitevin	1	
Total	48	6

- What are the top 3 brakes in the list below to stop glyphosate on your farm? Or other
 - Time traction in the field
 - Cost
 - Mechanical alternatives more complex or random efficiency
 - Lack of outlets / surface for lengthening rotations
 - Mental load that can result from the choice of more technical practices
 - Soil conservation (erosion, biological activity) +Environment (carbon storage, preservation of biodiversity)
 - Fear of Sorrowing
 - Calendar constraints / dates of interventions
 - Size of weed seed stocks in the soil
 - Texture of the soil (s)
- Discussion about the Levers below at glyphosate stop

Substitution levers :

Redesign of the cropping system:

- | | |
|--|--|
| <ul style="list-style-type: none"> ○ Soil work: false seeding, stubble cultivation, ploughing. Which ? For what purpose? ○ Other herbicides (new or selective) ○ Destruction of cover crops by roll ○ Bio control ○ Pasturing by animals ○ Thermal weeding or electric weeding | <ul style="list-style-type: none"> ○ Diversification rotation (spring / winter crops, cereals / root crops) –lengthening ○ Association of cultures ○ Choice of varieties (genetics) ○ Density and sowing dates ○ Permanent plant cover ○ Seed of multi-annual temporary grasslands |
|--|--|

- Training on application conditions and mind about precision farming to manage weed
- General Outlook: What do you think about the possible stopping of glyphosate for French agriculture: An Opportunity? A risk ?
- Does a dose limitation per hectare per year seem like a good compromise? Yes / No (If yes, how much / hectare / year?)

III.1.2 Farm s surveyed

The choice of the farmers surveyed has been made from a list of farmers contacts provided following my request by several agricultural agronomic advisors from the chamber of agriculture of different localities of the region.

- Location

The location of the farmers surveyed is shown on the map opposite, figure 22. The number of farmers surveyed varies between departments (table 6), this sampling is partly due to the number of contacts that I received from the advisors by locality in each department. I tried to take into account the different pedo-climatic conditions that can be met in the region.

- Type of soil tillage

On the 48 farmers classified per type of soil tillage (table 8 and table 7 for the definition), there is an overrepresentation of farmers in reduced tillage (RT and SD). This is a choice in the way to study the practices of these farmers who use little tillage for the general reason of

Average amount of glyphosate per type of use

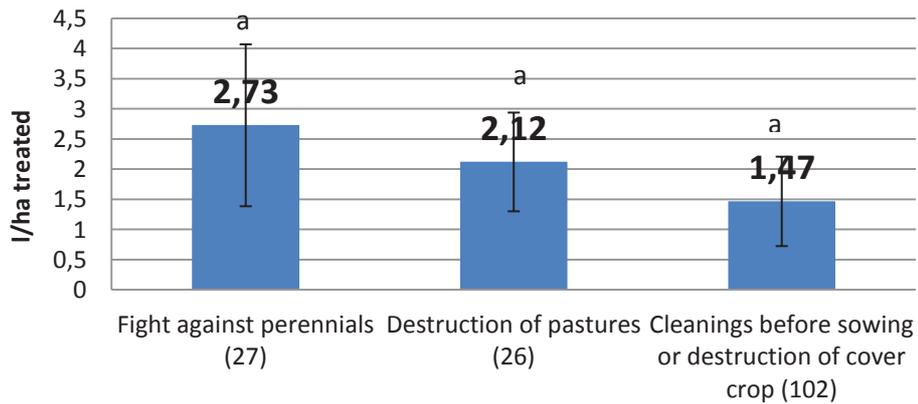


Figure 23 : Average amount of glyphosate per type of use

Share of each crop in % of the total crop area

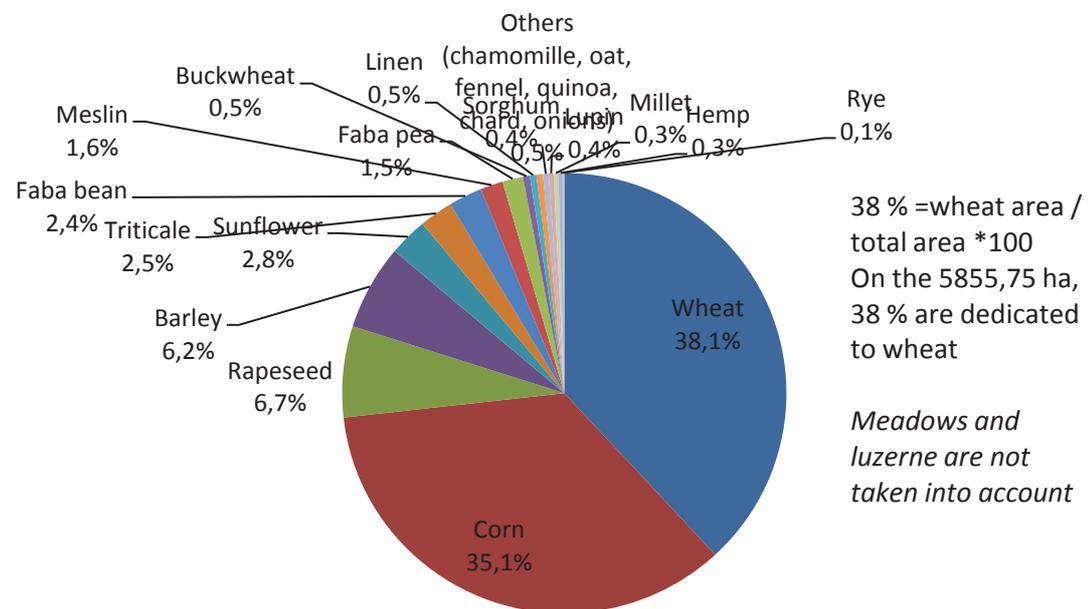


Figure 24: Share of each crop in % of the total crop area

Share of crop area treated with glyphosate in % of the total area of these crops treated with glyphosate

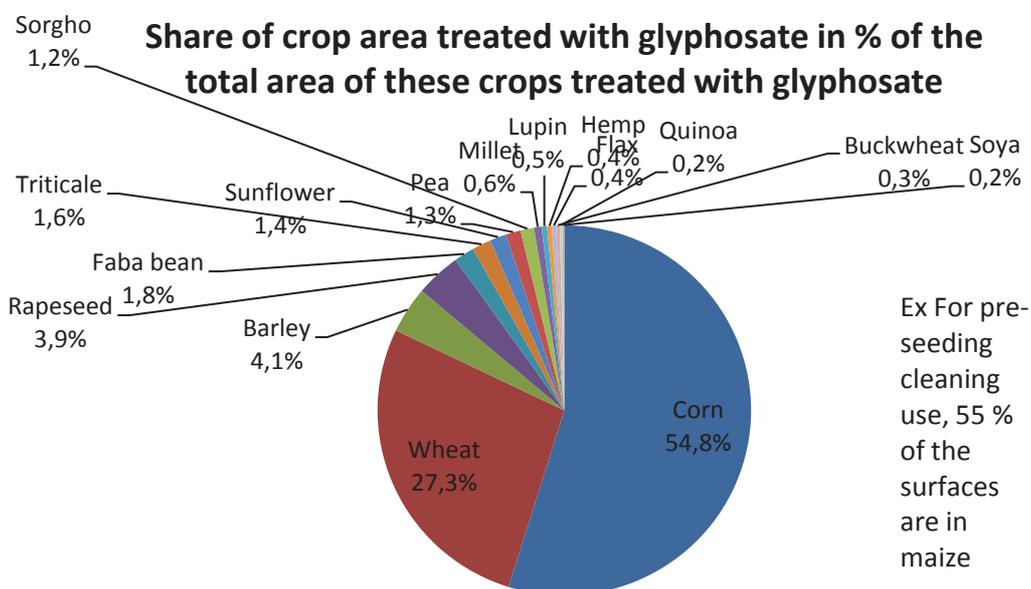


Figure 25: Share of each area of crop treated in % of the total area of these crops treated with glyphosate

preservation of the biological activity but who consequently dispense their plots with this lever of weeds management. This sampling was made possible through contacts given by advisers dealing with farmer groups in reducing tillage. On the 48 farmers, there are 6 farmers who do not use glyphosate are for three of them in RT, 1 in occasional ploughing, 1 in systematic ploughing (table 8). As with the study of glyphosate uses from the depy (Dephy 2017) database, there are no DSs that do not use glyphosate.

III.1.3 Methodology

Surveys were conducted face to face in the form of interviews in French. The survey lasted around 1.25 h per farmer.

The analyses are carried out on excel and R for the statistical description, average comparison tests and linear regression. On the abscissa of the graphs, in brackets is the number of farms taken into account.

III.2 Results

III.2.1 Quantitative analysis of Farmer surveys Alt'R'Glypho

III.2.1.1 The uses of glyphosate

III.2.1.1.1 By type of uses

For the uses of glyphosate classified in 4 types, 155 answered have been collected. The averages of glyphosate quantities applied are different in trend between types of use. Of the 155 responses, 27 perennial applications of glyphosate were reported by 24 farmers at an average rate of 2.73 l / ha. 26 uses of glyphosate were reported for grassland destruction by 20 farmers for an average treatment rate of 2.12 l / ha. 102 uses of glyphosate were mentioned for cleaning before seeding or destruction of intercrops for an average dose of 1.47 l / ha (figure 23).

For use against perennials, the standard deviation is very high. It can be explained by the intended target. The perennial bindweeds require a higher amount of glyphosate to be damaged than the perennial rumex or thistle, for example. Various perennial and annual weeds are cited by farmers. The perennials encountered by the farmers listed from the largest to the least number of times cited are Rumex, quack grass, thistle, bindweed, mercurial, *Agrostis stolonifera*, knotweed. The annual weeds encountered by farmers listed from largest to lowest number of times cited are Paturin, Rye grass, chickweed, wild oats, foxtail, bromegrass, ravenella, veronica, datura, millet.

III.2.1.1.2 By area

Many different crops (16) are concerned by a treatment before sowing affected by glyphosate use before sowing (figure 24). The crops represented are the one for the use « cleaning before sowing ». On the 85 answered for this use, 29 farmers out of the 43 farmers who make corn declared to treat with glyphosate whatever the precedent, that is

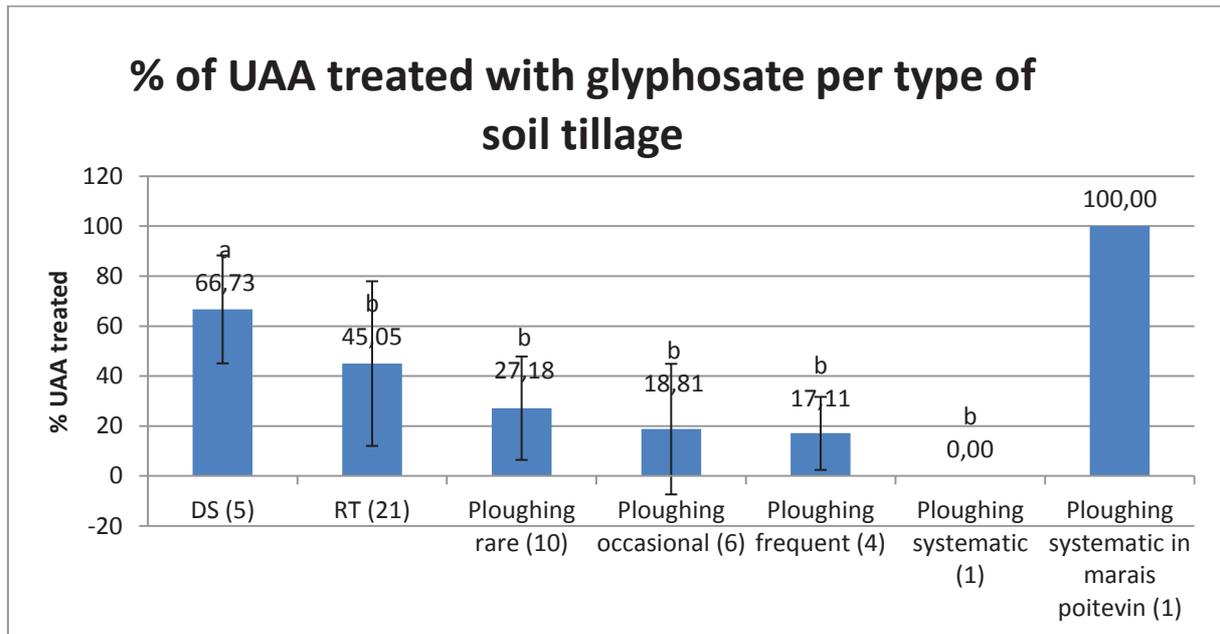


Figure 26: Percentage of UAA treated with glyphosate per type of soil tillage

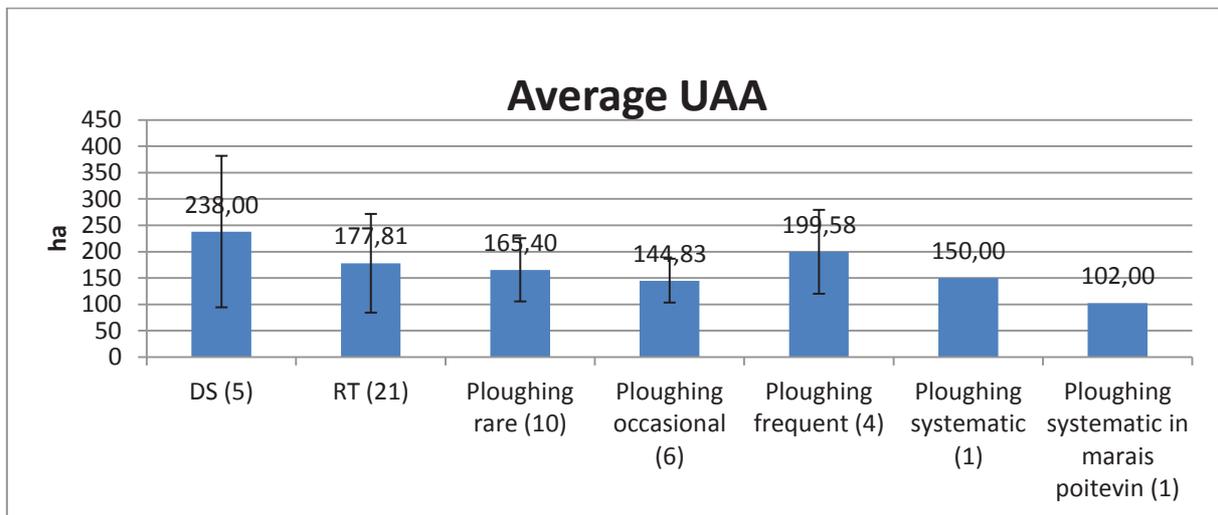


Figure 27: Average UAA per type of soil tillage

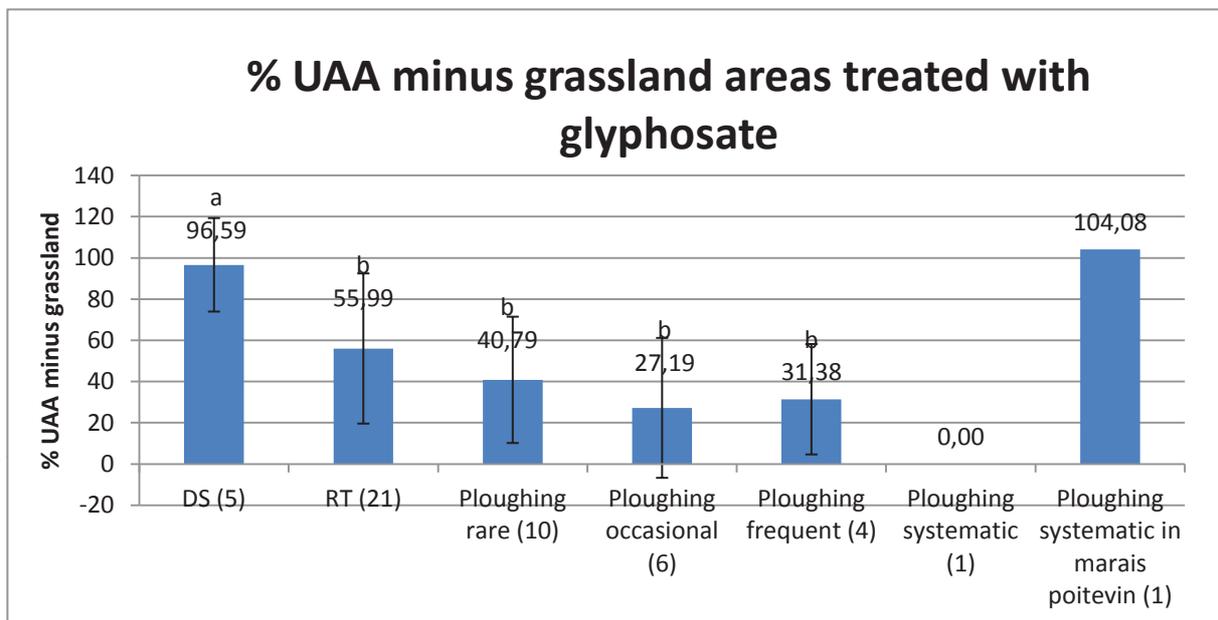


Figure 28: Percentage of UAA minus grassland areas treated with glyphosate per type of soil tillage

treated areas in the spring before planting corn is higher than that in the fall before planting wheat (figure 25). We observe that it is the opposite between rapeseed and barley.

III.2.2 Analysis of glyphosate uses by type of tillage system

III.2.2.1 Part of the area treated by glyphosate

- % UAA=Utilised Agricultural Area treated

Of the 48 farmers, 6 do not use glyphosate. 2 of them are certified organic or in conversion. 3 are in RT, 1 in rare ploughing, 1 in occasional ploughing, and 1 in systematic ploughing.

The frequency of glyphosate use is highly dependent on the type of tillage (figure 26). The smaller the tillage, the greater the percentage of area treated, with the exception of the farmer in Poitevin marshes.

In direct seeding, the percentage of UAA reached 66.73% in Pays de la Loire, 45.05 % for RT and 20.83% for the ploughing systems on average (without systematic ploughing in poitevin marsh)(figure 26).

The sample takes into account only one farmer in systematic ploughing, whereas more than 70 % of the sowing were conducted with a plough in Pays de la Loire in 2011 ((Heddadj et al, 2014). Knowing that the percentage of surface treated for the crops of the list 1 is according to mes parcelles of 10.61% in pays de la Loire, the area treated with glyphosate by those who practice systematic ploughing is less than 10%.

- % UAA without grassland treated

Since grasslands often represent a small part of the area treated because returned every 5 or 6 years on average, permanent and temporary grasslands have been removed from the calculation of the percentage of area treated by type of tillage.

Almost all (96.6%) of the cultivated areas of which the only tillage is sowing (DS) receive glyphosate treatment (figure 28). The gap between no-till and RT farmers is growing. In the absence of temporary and permanent grassland, farmers in regular or occasional ploughing treat on average weighted by the number of farmers in each category, 28.86% of their cultivated area. This figure is higher than reality because grassland treatments are taken into account but not the grassland area. The 104% for systematic ploughing in the Poitevin marsh means that the meadows are also treated (the% of treated surface is thus greater than 100%).

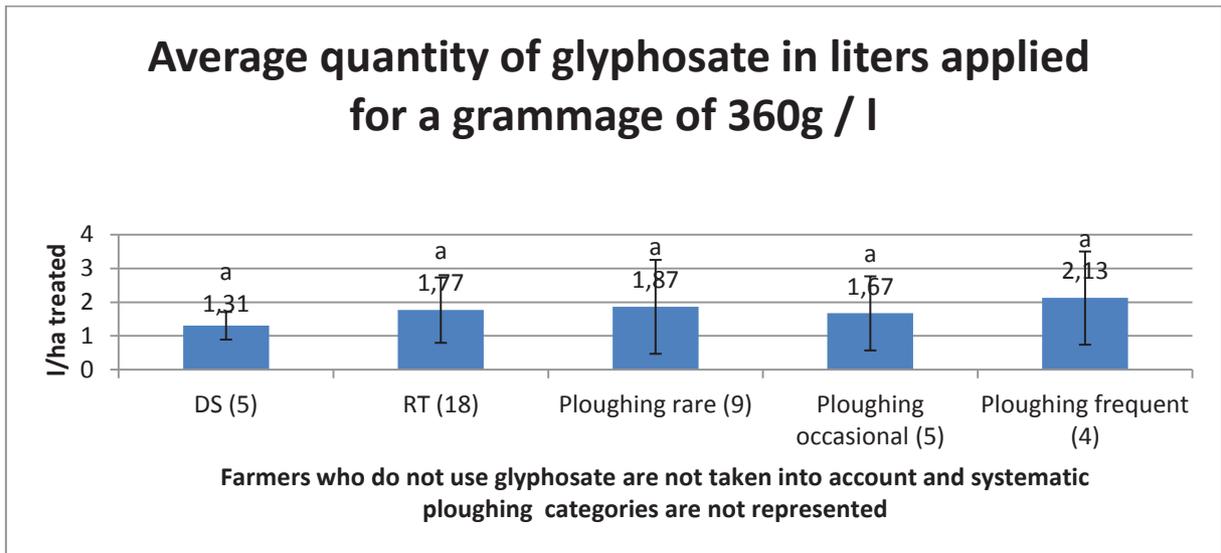


Figure 29: Average quantity of glyphosate applied per type of soil tillage

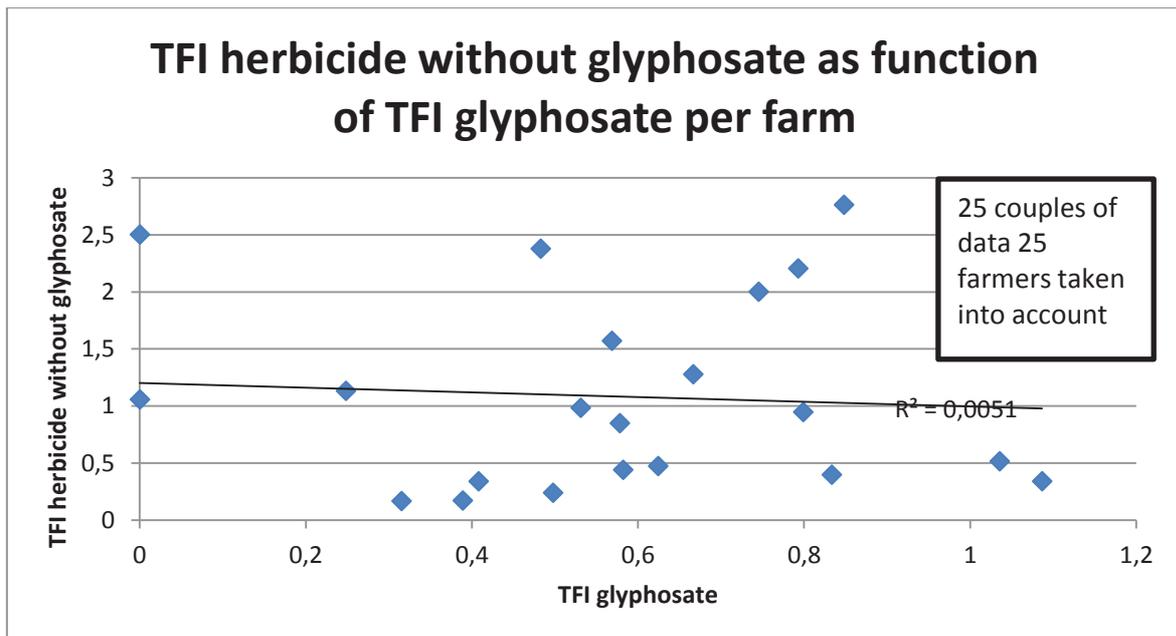


Figure 30: TFI herbicide without glyphosate as function of TFI glyphosate per farm

III.2.1.2 Intensity of the use of glyphosate

The average dose in l / ha treated does not depend on the type of tillage (figure 29). However, a lower dose and a lower standard deviation can be observed for DS farmers. Although the standard deviations are high and the sample small, the average of the DS, RT, ploughing rare and ploughing occasional categories are lower than the regional average.

The average of the sample is 1.76 l / ha, which is below the regional average of 2.12 l/ha. This lower average could be due to the over-representation of the types of tillage without ploughing in the sample. However, no statistical link has been shown between the amount of active ingredient applied and the type of tillage adopted.

For most plots, planting is based on ploughing before sowing. The average dose of farmers in systematic or frequent ploughing is therefore closer to the regional average dose. It is the case for ploughing frequent in the sample (2,13l/ha, figure 29).

III.2.1.3 Link between the use of herbicides in crops and the use of glyphosate

The use of herbicides in crops (TFI herbicide without glyphosate per farm) does not depend on the use of glyphosate (TFI glyphosate) (figure 30), as it is the case for corn and soft wheat (figure 19 and 20).

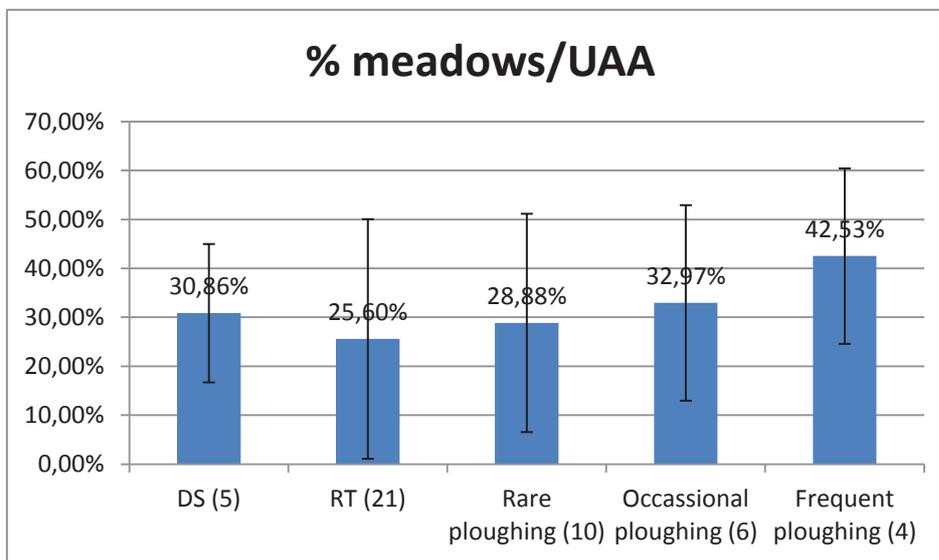


Figure 31: Percentage of meadows on the UAA per type of soil tillage

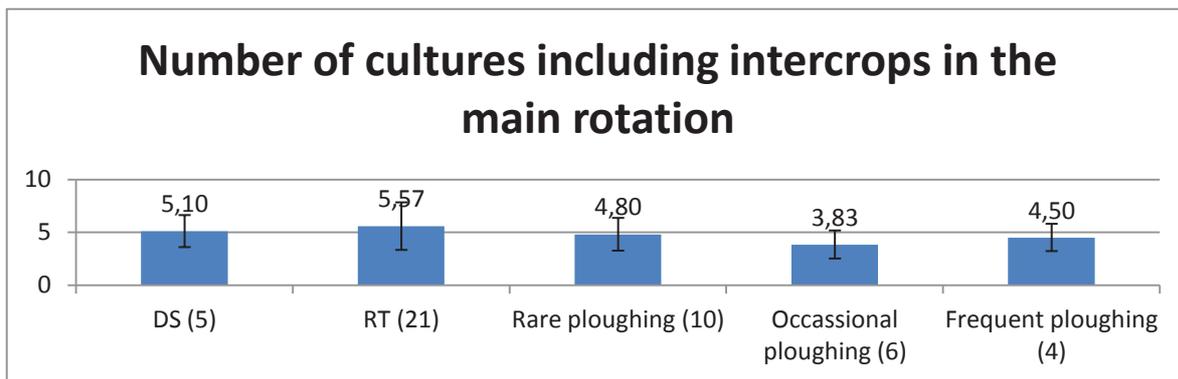


Figure 32 : Number of cultures including intercrops in the main rotation per type of soil tillage

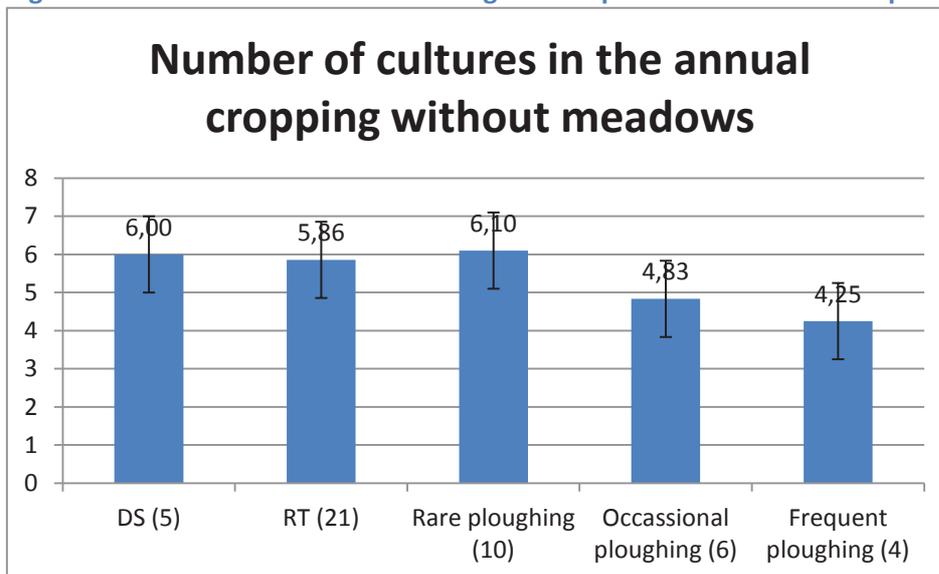


Figure 33 : Number of cultures in the annual cropping without meadows per type of soil tillage

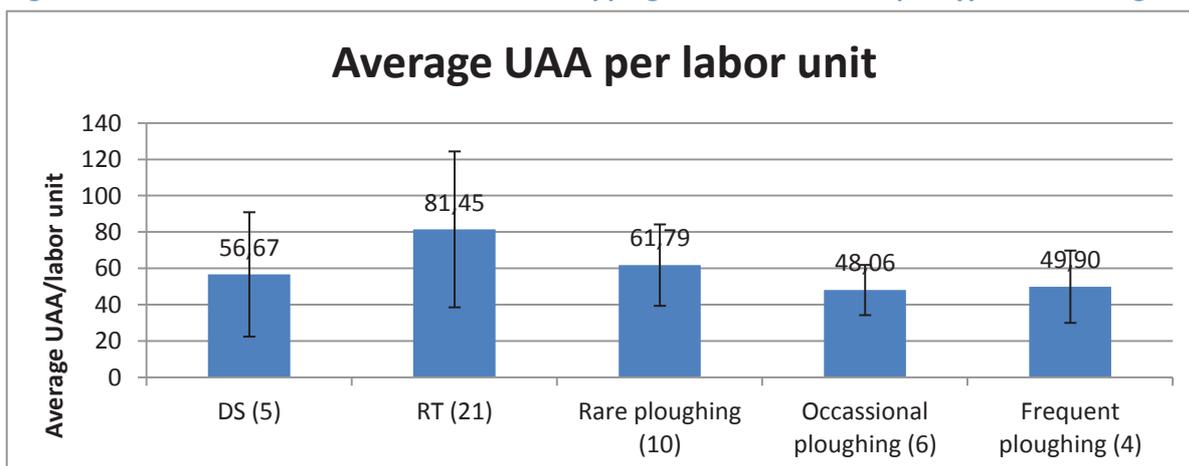


Figure 34 : Average UAA per labor unit per type of soil tillage

III.2.1.4 Linear regression

• Observations

The percentage of grassland in the UAA of farms is trending higher for farmers in ploughing (figure 31). The number of crops including intercrops varies little between types of soil tillage (figure 32). The number of crops in the crop rotation is in a higher trend of 1 crop or more between frequent and occasional ploughing and rare ploughing, RT and DS. The number of hectares of UAA per labor unit* is on average higher for RT than for other categories (figure 34).

• Factors

In order to analyze whether these observations by factors can explain the levels of use observed between types of soil tillage, linear regressions were carried out to explain the factors: % UAA treated with glyphosate and quantity of glyphosate per treatment.

The explanatory factors taken into account are: UAA, grassland shares on the UAA, number of cultures including intercrops in the main rotation, number of cultures in the annual cropping without meadows, rotation duration in the year of the main rotation, the presence (yes or no) of multiannual (> 3 years) meadow in the main rotation, labor unit, department, ETO.

• Results

For the sample of 48 farmers:

The linear regression for % UAA treated with glyphosate shows a significant effect at 95% significance level of the type of tillage and grassland component of UAA for the sample of 48 farmers. 3 categories of tillage are significantly different for the factor to explain percentage of treated surface: DS, systematic ploughing in poitevin marsh, other categories.

The linear regression for quantity of glyphosate per treatment shows any significant effect at 95% significance level. The types of soil tillage are not significantly different in relation to the quantity of glyphosate applied.

For each category of soil tillage:

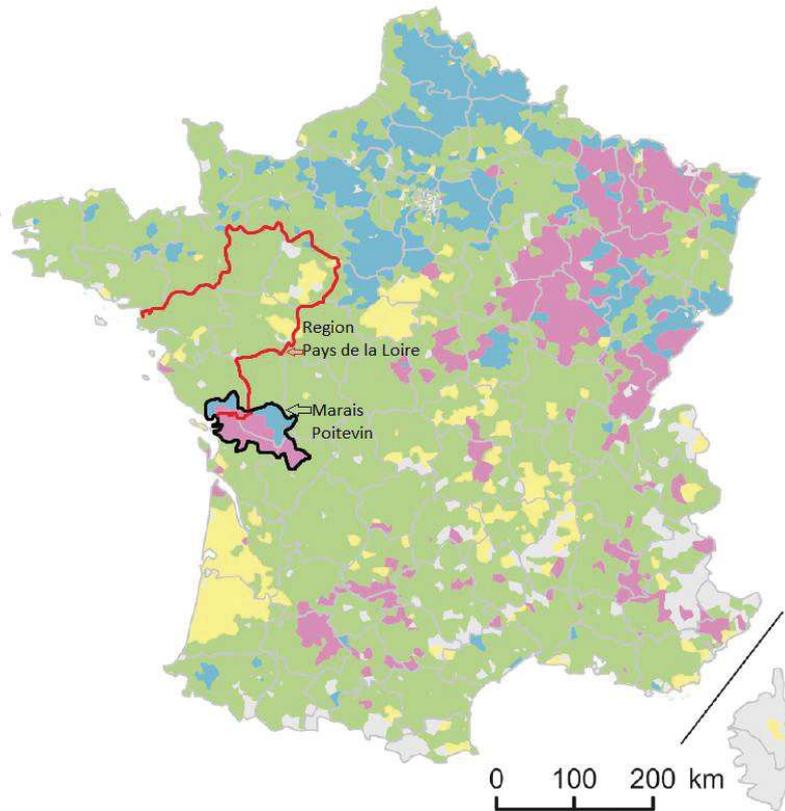
The same explanatory factors and factors to explain % UAA have been used to analyze the uses within the tillage categories.

For the DS category, statistical analysis is not possible due to the sample too small (5).

For the RT category, linear regression shows a significant effect from grassland ($p < 0.05$), UTA factor ($p < 0.1$) and UAA ($p < 0.1$). As for the sample of 48 farmers, the grassland share in the UAA has a significant effect at the 5% threshold and distinguishes within the RTs from the low use of glyphosate users in terms of area. The numbers of labor units as well as the useful agricultural area have a significant effect at the 10% threshold. The RT category is made up of 21 farms, which vary in their use of glyphosate and differ in their own characteristics (% grassland in rotation and area per unit of work have high standard deviations).

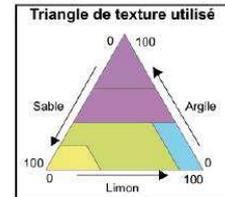
For the ploughing, the analysis was conducted for the types of soil ploughing tillage system gathered. Any significant effects have been identified.

La texture dominante de l'horizon supérieur des sols agricoles par canton



Texture dominante

- sableuse
- équilibrée
- limoneuse
- argileuse
- pas de données



Source : Gis Sol, BDAT, 2011.

Figure 35: The dominant texture of the top horizon of agricultural soils by township Source Gis Sol, BDAT, 2011

NUMERO	1359	1360	1361
Sables grossiers %	0.4	0.4	0.1
Sables fins %	0.5	0.6	0.4
Sables très fins %	3	3	3
Limons %	27	45	55
Argile %	64	51	41
pH	7.4	7.9	7.9
Calcaire total %	3 moyen	13.5 a. Riche	14 a. Riche
Matière organique %	4.6 normal	0.90	0/72
Résistivité (Ω cm)	8830	2830	250
Conductivité en $\mu S/cm$	0.1 T. Faible	0.35 moyen	4 T. Elevé
BASES SOLUBLES + ECHANGEABLES (en ppm)			
MgO Magnésium	2595	2235	2195
K ₂ O Potasse	805	715	810
Na ₂ O Soude	860	2070	1895
SELS SOLUBLES (en meq / 100 g)			
Mg ⁺⁺ Magnésium	1.92	2.31	5.23
K ⁺ Potassium	0.18	0.15	0.28
Na ⁺ Sodium	0.24	1.41	4.69
Ca ⁺⁺	8.44	35.34	27.23
BASES ECHANGEABLES (en meq / 100 g)			
Mg ⁺⁺	11.76	7.87	5.74
K ⁺	1.54	1.36	1.45
Na ⁺	2.53	5.26	7.41
Ca ⁺⁺	21.96	14.68	12.63

Figure 36: Soil analysis of 3 clay plots cultivated from the Poitevin marsh

Special case of the Poitevin marsh: Clay texture and uses of glyphosate

The marsh Poitevin is a regional natural park whose northern part is located in Vendée. Part of the marsh poitevin was cropped following drainage operations that helped to dry the marsh and make it stable (characterized by low sodicity and high percentage of limestone). The nutrient richness of these stable marsh soils makes them soil with strong agronomic potential.

The texture of these cultivated soils of the marsh is predominantly clayey, with clay% up to 65%.

The swamp material is impervious due to the presence of illite-type swelling clays, which reduce porosity and soil cracks. For this reason, marsh farmers routinely plow before winter to improve soil structure and minimize soil disturbance. They then let the action of the winter restructure this clay texture sensitive to desiccation / humification and freeze / thaw during the winter.

Any pressure by mechanical work on the ground after winter is not recommended in order not to destructure the clay. The islands of the Poitevin marsh, whose clay contents are superior to 40%, have for this reason a waiver of non-obligation to cover soils in long interculture.

The soil characteristics of the marsh have led farmers in these clay-rich islands to use glyphosate to manage intercropped soil.

A group of farmers from the marsh and the plain led by Sebastien Clavée and Delphine Molenat from the Vendée south Chamber of Agriculture was formed to reflect on the "après glypho" (name of this group of farmers). The two facilitators provided me with farmer fact sheets on their use of glyphosate (what is the use of glyphosate, for what targets, at which doses) and one farmer of the Poitevin marsh was surveyed. Figure 36 is an extract of soil analysis from 3 clays plots cultivated in the Poitevin marsh, it illustrates in yellow the high level of clay in the soil.

For the implantation of a spring crop (corn or sorghum in general), 3 farmers out of 5 make 3 passages of glyphosate at doses varying between 2.5 and 3l / ha. One pass is made before winter, two more before spring sowing. The other 2 farmers make one or two fewer trips. Whoever makes only one passage does it before the winter and increases the dose to 4l / ha.

For winter crops, a glyphosate treatment is made at a dose varying between 2.5 and 3l / ha. 3 of these 5 farmers make seed alfalfa, treatment between 0.75 and 1.1l / ha is done.

These figures show that farmers in the Poitevin marsh have an intensive and frequent use of glyphosate.

These farmers are dependent on glyphosate for the management of the dirtying of their crops.

The « L'après glypho » group allows farmers in the lowlands and swamps to talk to each other about their practices and glyphosate use. It allows to think about the possibilities of reduction and change of crop systems possible but for the moment, the stopping of the glyphosate would probably be a technical impasse to the continuation of the arable crops in these zones of swamps with high rate of clay.

III.2.2 Qualitative analysis of farmer surveys Alt'R'Glypho

III.2.2.1 Cover crop choice

Out of 46 farmer surveys, the average number of crops in the long-term cover or meslin or back cover is 3.5.

11 farmers on 48 make short crop cover crops with an average crop number of 2.4.

The choice of cover crop depends little on the mode of destruction; it appears that the composition of the cover is rather made for the input of organic matter or structuring of the soil.

III.2.2.2 Link between the organic fertilization and the weed management

The farmers surveyed generally do not identify a link between their fertilization with fresh organic matter (manure, green waste, digestate ...) and the management of soil contamination.

Some observe, however, a mess when manure or digestations are not sufficiently decomposed. The origin of the straws and the waste for the methanization units is one of the points of vigilance to avoid a dirtying of the plots, by rye resistant grass in particular.

Only one farmer observed a positive effect on weed management of these plots when he brought woodchip (BRF) around a meslin field. His woodchip had been used as litter for cattle and had already started to be broken down biologically. He spreads it in mulch at 30T / ha in late May, the time to let the meslin develop before. He observed that the perimeter of the plots in which he had spread the BRF was cleaner than the interior of the plot.

III.2.2.3 The conditions of application

28 farmers on 42 users of glyphosate (67%) adds one or more adjuvants (oil and / or ammonium sulfate and / or hormone) when dealing with glyphosate. The use of adjuvants with a product containing glyphosate is not automatic or systematic for all farmers.

Few farmers have ever been trained on adjuvants for plant protection products.

Very few plays (2/46) on all possible dose reduction parameters at the same time (adjuvant oil, ammonium sulfate adjuvant, volume of boils, hormones if cruciferous or thistle).

The conditions of wetness and wind applications are well known to farmers.

The use of low-pressure nozzles seems to be known but not very widespread, particularly because of their cost.

Obstacles to the stop of glyphosate cited by farmers

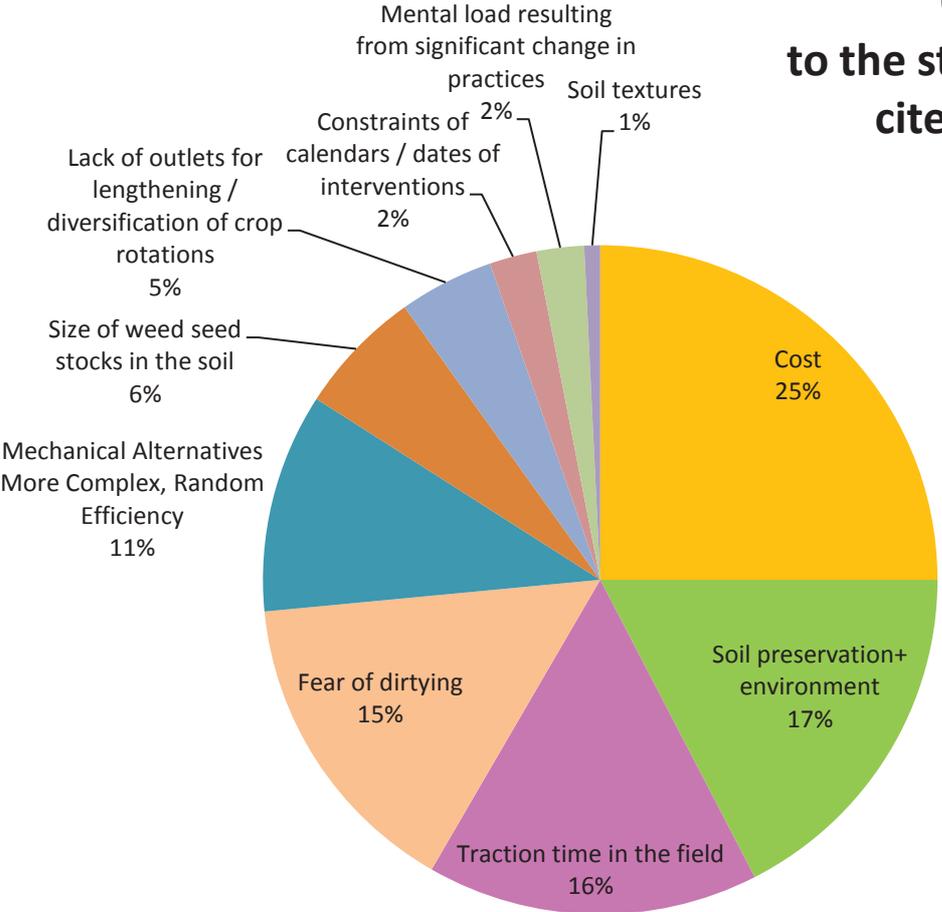


Figure 37 : Obstacles to the stop of glyphosate cited by farmers

III.2.2.4 Obstacles at the stop of the glyphosate

Supplementation cost with glyphosate cessation induced by changes in practices through the use of other more costly herbicides or through increased mechanization loads is the most frequently cited obstacle by farmers. The soil and environmental protection brake arrive in the second position followed by the traction time in the field (figure 37).

Among the types of tillage, the prevention of soil and environmental activity is the first thing that comes down to RT and DS groups.

For all plowing (rare + occasional + frequent), the number 1 brake is the cost, followed by the time of traction in the field, followed equally by the size of the weed stocks in the field, the fear of the dirtying by weeds, mechanical alternatives more complex/random efficiency.

III.2.2.5 Opinion on the levers considered and possible

The analysis of the levers takes into account only 25 farmers, because of the late modification of the evaluation mode of the levers envisaged by the farmers. Only 75 reliable answers, ie 25 farmers are taken into account. In addition, some farmers have already put in place some levers.

The levers below are those envisaged or will be increased by farmers if glyphosate is discontinued. They are classified in 2 categories: substitution and redesign of the cropping system.

- Substitution

The use of other herbicides lever (15) is the lever that returns the most times, followed by the tillage lever (14) and the lever combinations of crops (11) equal to that of permanent cover (11).

Several farmers in DS or RT do not want to resort to a return of work from ploughing tillage to manage weeds.

- Redesign of the cropping system

Crop associations are for many farmers a lever of management of weeds to develop, some deplore however the lack of sorters, sorting center proposed by the collection centers.

One farmer wants to test seedling on the fly of clover in the wheat., a clumping low clover that does not rise.

The levers for redesigning the cropping system are more difficult for farmers to consider. Their effectiveness in reducing glyphosate is not as obvious and quick as the substitution levers.

Many farmers believe that precision farming through the use of nozzles (low pressure), cut-offs, RTK * system will improve glyphosate dose efficiency but regrets the current high cost of these technologies, which are not very accessible for many.

Table 9: % area treated with glyphosate per type of soil tillage according to Alt'R'Glypho survey and 2011 SPP source

% treated area per type of soil tillage	Alt'R'glypho survey % (number of farm surveyed)	SSP 2011
DS	66.73%(5)	≈62%
RT	45.05%(21)	≈36%
Ploughing rare	27.18%((10)	
Ploughing occasional	18.81%(6)	≈16%
Ploughing frequent	17.11%(4)	≈10%
Ploughing systematic	0 %(1)	≈6%
Average	Pays de la Loire	France
	10,61%	14%

III.2.2.6 Farmers opinion on the discontinuation of glyphosate

To the question, what do you think of the possible stopping of the glyphosate for the French agriculture in general, opportunity / risks?

There is a risk of unfair competition from imports of products whose technical route includes uses of glyphosate.

They do not believe in an added value for products without glyphosate. The extra cost of stopping glyphosate to manage weeds in the cropping system would not be offset by an additional cost to producers. They do not believe in creating a chain without glyphosate.

In addition, some note that there is a risk of a decrease in some crops where there are few herbicides in crops, which is contrary to crops diversification.

They are for the development of decision rules which might allow an optimum allocation of glyphosate use.

Out of 45 responses, 32 are for a dose limitation per hectare, 11 are not for. 3 are for the ban of glyphosate in bare soil (those who do not do cover crop).

III.3 Discussion

The sample of 48 farmers is not representative of the DS and / or RT in Pays de la Loire region but has allowed taking into account the peculiarities of these farmers who manage weeds without the tillage lever. Management of intercropping differs between these types of tillage system.

They cultivate more crops, practice long and short intercrops with often more than 3 species in the way to alternative type of crops, dates of sowing and always cover the soil.

Despite the small sample, the percentages of surface treated by type of tillage by farm are of the same order of magnitude as the percentages of areas treated by farm according to SSP 2011(table 9).

The farmer interview survey is a special exercise, especially when the questions are open. The investigator must remain neutral so as not to guide the survey while collecting information to understand their management of weeds and analyze the responses between surveys. The duration of the interviews (from 50 minutes for the shortest to more than 2:15 for the longest) illustrates the variability of the exchanges). The subject of the glyphosate is all the more favorable to the debate that it is a media subject, which arouses the interest of all. .

The exchanges with the farmers make it possible to identify the features of each one, for example the use of some alternatives is not possible for every farm. For clay soils, the use of mechanical tools is not possible to mitigate the possible stopping of glyphosate. And even if it is possible, in landscapes with high risk of erosion, the shift from one to the other can increase erosion.

Exemple d'un itinéraire technique en Semis direct

Quelle combinaison de leviers pour la gestion des adventices avec un faible usage du glyphosate

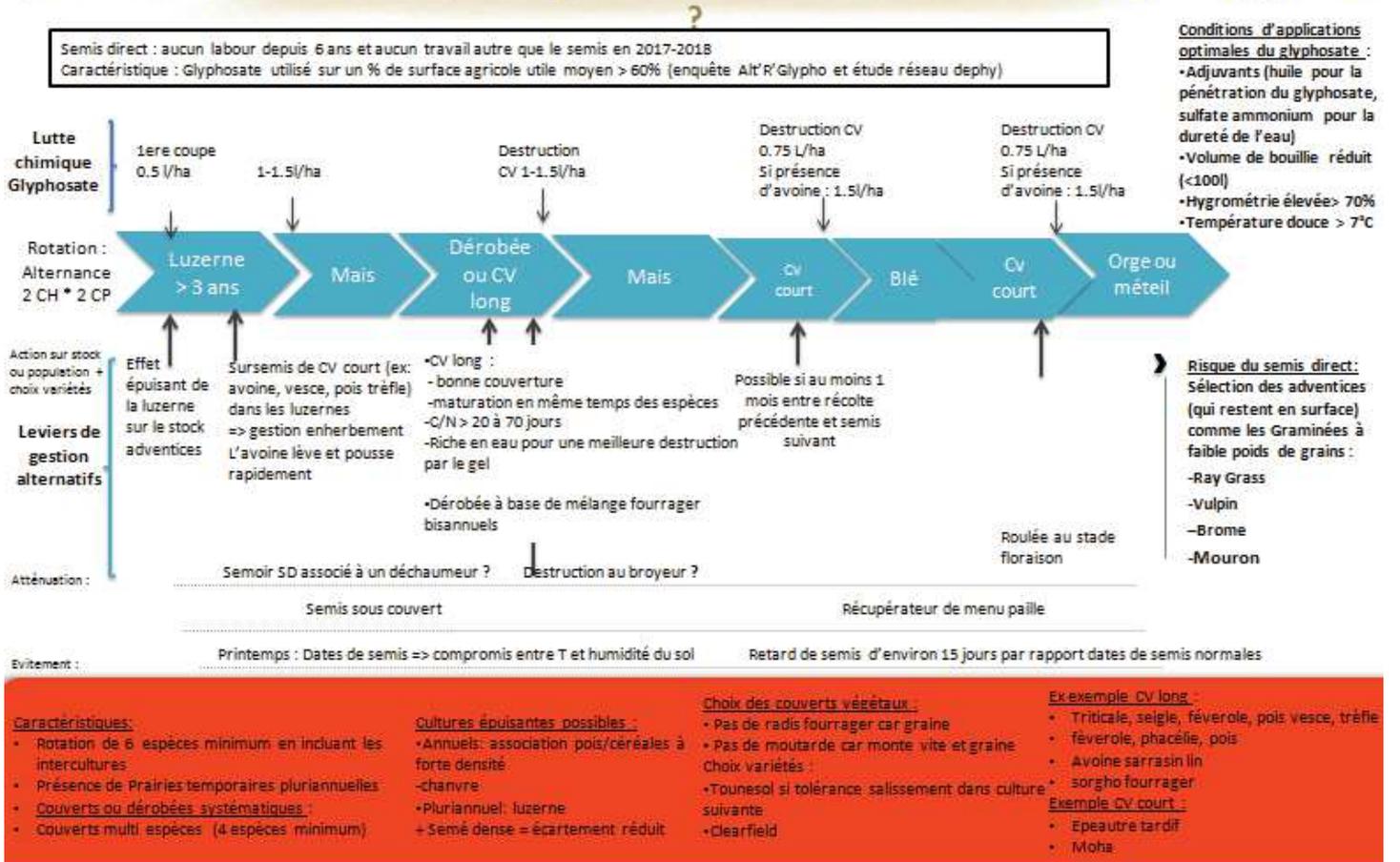


Figure 38: Example of a low-use glyphosate technical itinerary for tillage: Direct Seeding

Exemple d'un itinéraire technique en Technique Culturelle Simplifiée

Quelle combinaison de leviers pour la gestion des adventices avec un faible usage du glyphosate

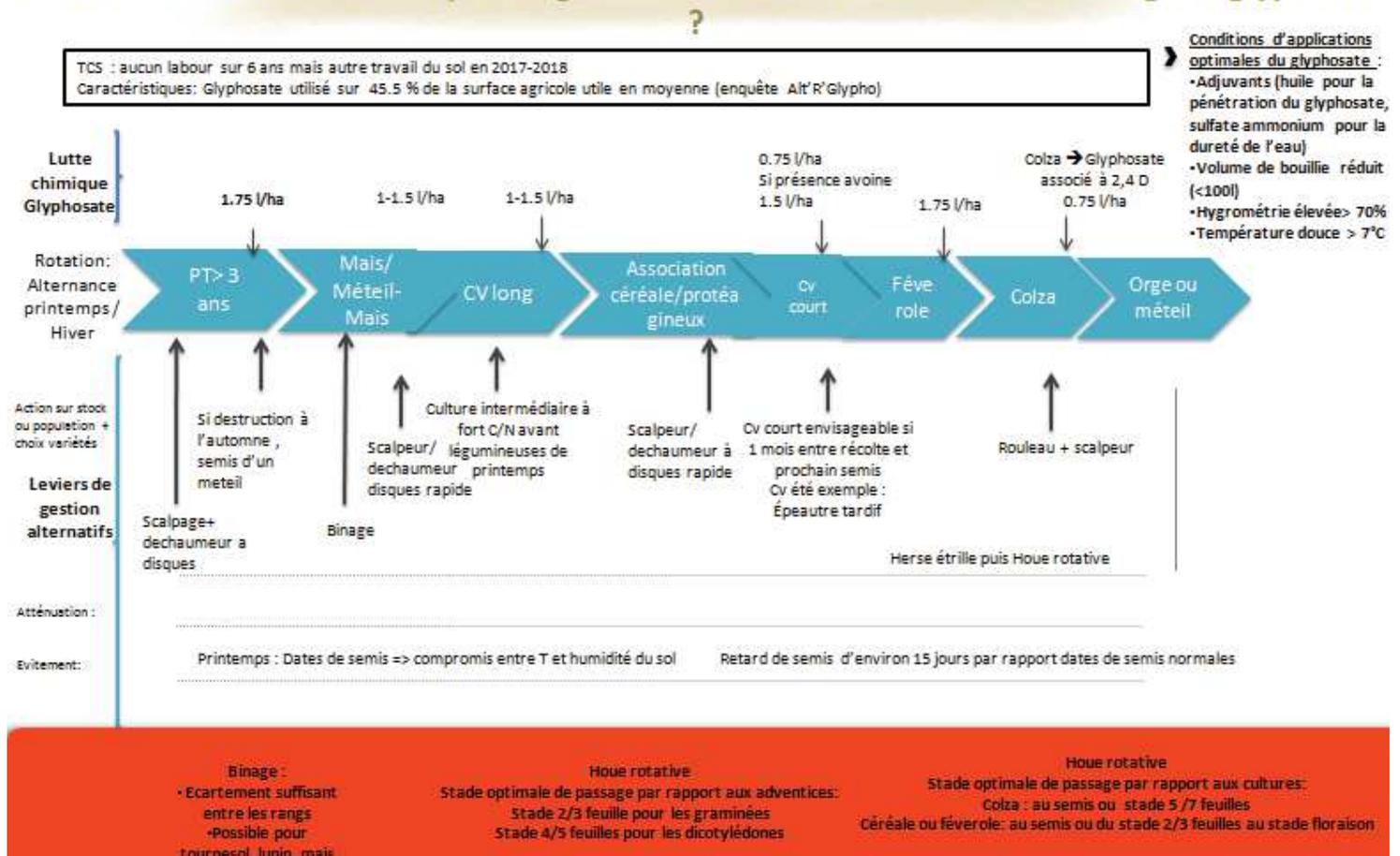


Figure 39: Example of a low-use glyphosate technical itinerary for tillage: Reduced tillage

Case study : decision-making framework of the crop system/ technical itineraries for low use of glyphosate according to types of tillage.

A diagram illustrates a cropping system combining different levers and parameters for managing weeds with low glyphosate use. Many other cropping systems are possible. The decision-making schemes (figure 38, 39) are based on the farmers surveys and the information below.

Cultivation systems in no till (RT and DS) have advantages for the soil (better structural stability, less erosion, concentration of organic matter on the surface) but 2 negative effects can be observed: less regulation of micromammals and increase in weeds (Chauvel et al, 2009). The systems in no till (20% to 30% of surfaces were cultivated without tillage in the country of the Loire in 2011 (Heddadj et al, 2014)) must therefore play on more levers agronomic not avoid too much development of weeds, and pay more attention to perennial weeds that are more difficult to remove when they are installed and can infest crops..

One of the levers is to diversify and lengthen crop rotations. Alternating spring crops with winter crops allows for a diversification of crop succession that breaks the rate of weeds and allows the natural death of seeds in the soil over time (Gautellier et al, 2017). According to Anderson (Anderson 2015), a rotation of at least 4 years with 2 winter crops and 2 spring crops seems to be the best compromise to reduce the amount of weeds. The choice of crops, and in particular of intercropping, can be done in an objective of covering and managing weeds, for example, and spelled out, have a known inhibitory effect on weed growth in the next crop. (Munier Jolain et al, 2005). Playing on sowing dates is another lever that avoids exposure to a crop at a time when it is most sensitive to weed competition (Munier -Jolain et al, 2008). Seeding delays can reduce the risk of aphids in the fall and may also reduce the density of some weeds. The average efficiency of late seeding on weed density is more effective for ray grass (-68%), sterile brome (-72%) foxtail (-56%), than for dicotyledonous (-32%) (Mishler, Lheureux.2008). During early planting (to stifle weeds with equivalent emergence periods), nitrogen management is very important. The lack of nitrogen on early sowing (little time of mineralization or insufficient intake) can damage the leaf area which is not sufficient to stifle weeds. Crop / legume combinations can improve plant growth factors by 25-38% (Hauggaard-Nielsen et al., 2001) and increase the association's association with weeds. These levers of re-design of the cropping system are interesting agronomically but an increased and regular monitoring of the plots is necessary for plots in no-till because the in crop rotations are less effective than the plowing for certain weeds like the couch grass and other perennials (Wielse et al, 2016). On the other hand, systematic plowing may have the opposite effect of infestation of plots by raising seed buried in previous years but still viable, more occasional plowing, every 3-4 years avoids this too early recovery (Gautellier and Bonin, 2017).

Whatever the type of tillage, the agronomic levers can be interesting to manage weeds with a view to reducing chemical herbicides and / or the passage of mechanical tools. Thus, weed management is part of an integrated crop, plot and environmental protection approach.

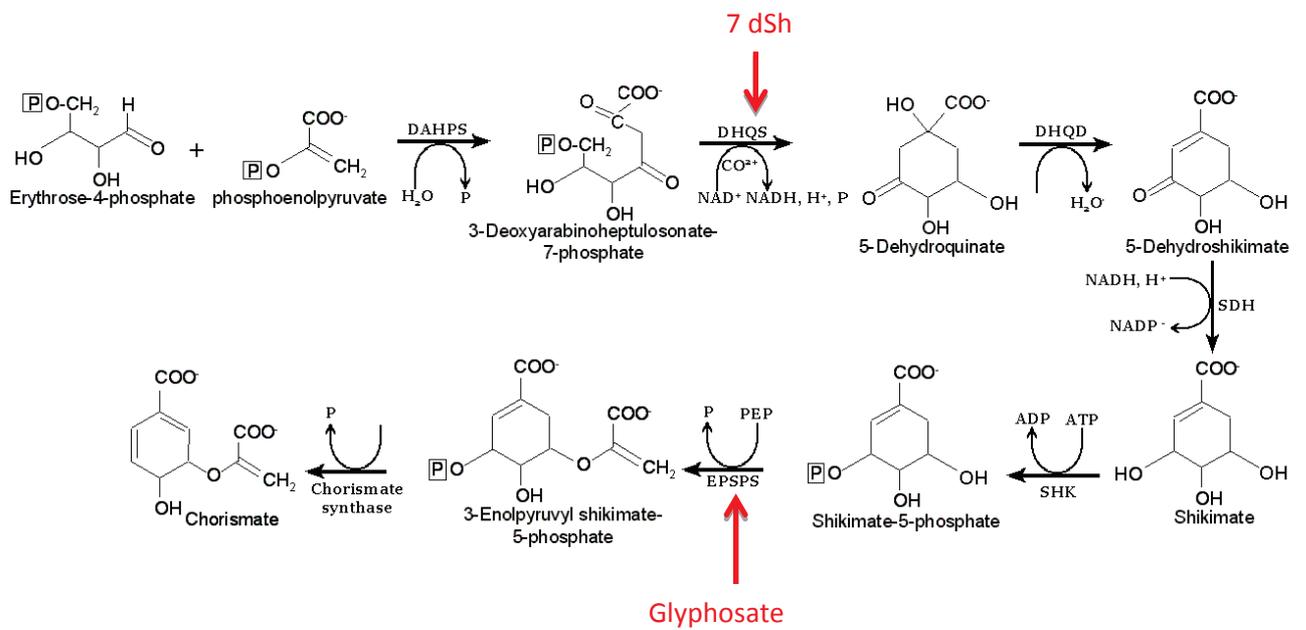


Figure 40: Localisation of the 7 deoxy sedoheptulose action in the shikimate pathway, adapted from Dosselaere et Vanderleyden 2001

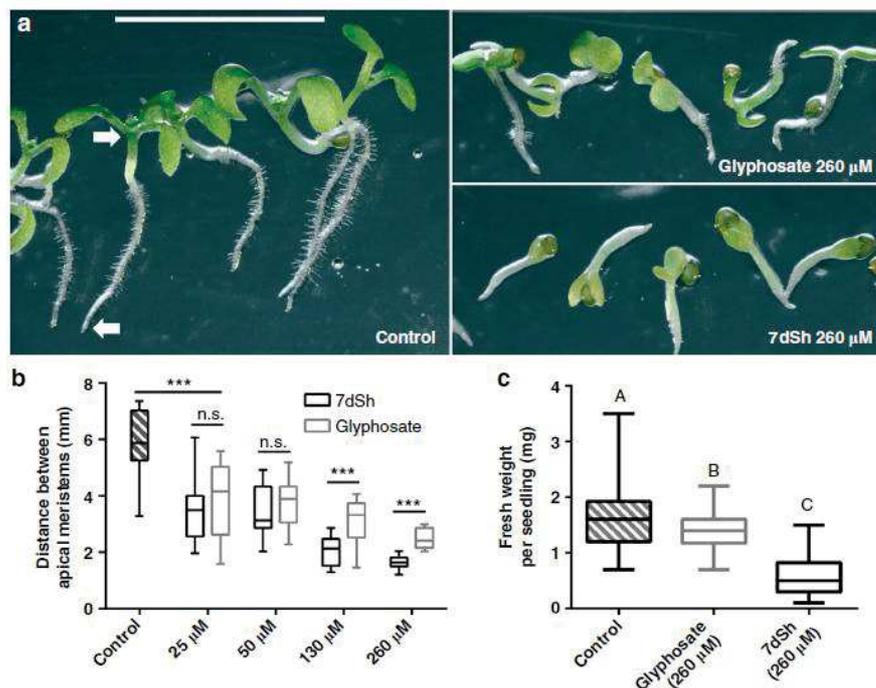


Fig. 6 7dSh (1) reduces the growth of *A. thaliana* seedlings. **a** Morphological appearance of autotrophically grown *Arabidopsis thaliana* seedlings 7 days after induction of germination. Seedlings were grown in constant light on agar plates without an antimetabolite (control) or in the presence of 7dSh or glyphosate. Plates were mounted vertically and illuminated from above. White arrows mark the root and shoot apical meristem. Scale bar (5 mm) applies to all images. **b** Measurement of the distance between root and shoot apical meristem. Significant differences between seedling sizes were analyzed in an unpaired *t*-test (**p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.001; n.s., not significant). Box-and-whisker plots represent the values of at least 16 seedlings. **c** Effect of 7dSh and glyphosate (each 260 µM) on the growth of *A. thaliana* on soil after 18 days in a day/night cycle. Statistical analysis was performed by using a one-way ANOVA. Tukey's multiple comparison test was used as the post-hoc test. Means that were significantly different (*p*-value < 0.05) are marked with different capital letters in the diagram. Box-and-whisker plots represent the values of at least 58 *A. thaliana* seedlings. For **b**, **c**: Error bars indicate range, box bounds indicate second and third quartiles, center lines indicate median. Source data are provided as a Source Data file

Figure 41: Effects of 7 dSh on A Thaliana seedlings compare to glyphosate Source: Brilisauer et al, 2017 licence CC

IV. Update on Innovative Alternatives to the Use of Glyphosate

V.1. Chemical alternatives

V.1.1 7 deoxy sedoheptulose=7 dSh

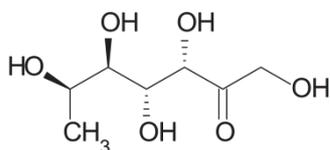


Figure 42: 7-deoxy-sedoheptulose =7 dSh developed formula

<https://de.wikipedia.org/wiki/7-Desoxy-sedoheptulose>

Researchers at the University of Tübingen (Germany) have discovered the existence of an antimetabolite that acts on the same biosynthetic pathway as glyphosate, the shikimate pathway. This antimetabolite is a sugar; 7-deoxy-sedoheptulose = 7dSh (figure 42). It acts at the second stage of the shikimate biosynthetic pathway (figure 40). It inhibits the synthesis of DHQ by fixing instead of the substrate on the enzyme DHQS. 7-dSh was discovered and isolated from *S. elongatus* cyanobacteria cultures. *S. elongatus*.

The production of 7dSh is relatively simple (compared to other anti-metabolites blocking the synthesis of DHQ) and could therefore be produced in high doses.

Within these cyanobacteria, the in vivo biosynthesis of 7dsh is not yet identified and the role of 7dsh is not yet clear. However, the 7dsh could be artificially produced, using the promiscuous capacity of the transketolase enzyme. The precursor of 7-dSh is a monosaccharide, 5-deoxy-D-ribose, a metabolite first extracted from these bacteria that binds to the transketolase enzyme to produce 7dSh. In vivo synthesis of this deoxy precursor is also not identified.

The synthetic route of shikimate is present in many bacteria, fungi and plants. 7-dSh was tested on the fungus *Saccharomyces Cerevisae*; the growth rate of the fungus in the presence of 7 dSh is inhibited only when the fungus is grown in a nutrient-poor medium (YNB minimal medium).

For plants, the test was performed on *Arabidopsis Thaliana*. The researchers tested different concentrations of 7dSh and their effects on the growth rate of *Arabidopsis Thaliana*. The first results show an effective inhibition of the shikimate biosynthetic pathway, which leads to a cessation of plant growth. At equivalent concentration, the effect of 7-dSh is similar to that of glyphosate on the growth rate of *A. Thaliana* (figure 41) (Brilisauer et al. 2019)

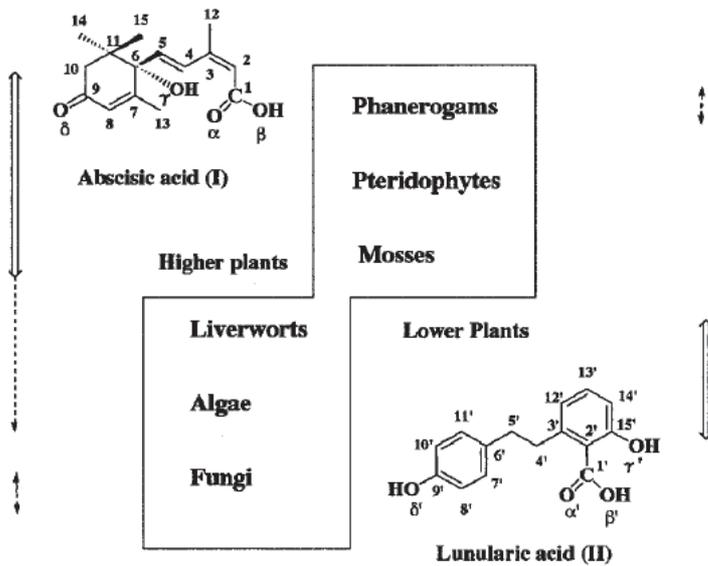


Figure 43: Structures of Abscisic Acid and Lunularic Acid and their distribution in the plant kingdom
Source Yoshikawa et al, 2002

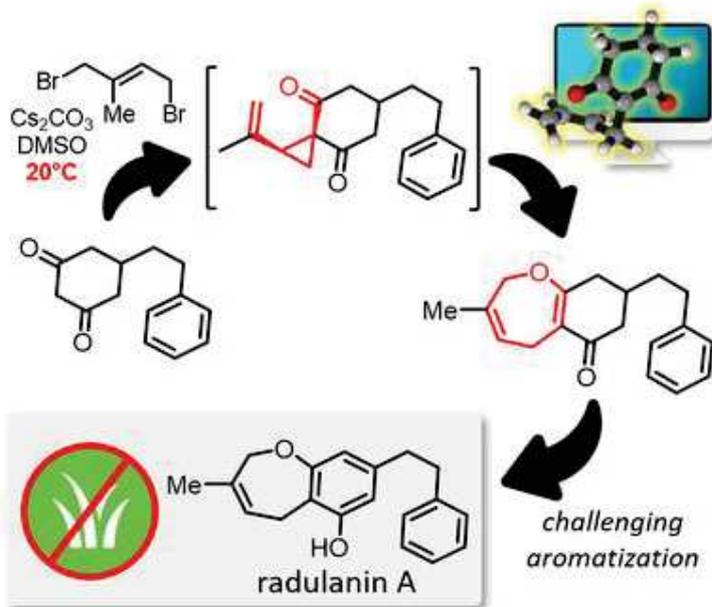


Figure 44: Chemical synthesis of radulanin A, obtained by researchers from the laboratory of organic synthesis of the Polytechnic School of France. Source: Bastien Nay Research Group



Figure 45: X power Zasso electric weeding , Mouchamps Vendée, 03/05/2019, ©Pierre Havard

V.1.2 Radulanin A

Researchers from the Laboratory of Organic Synthesis of the Polytechnic School of France have synthesized a natural molecule, Radulanine A (figure 44). This molecule is naturally present in some families of mosses. They observed that this molecule has structural similarities with Lunular Acid, a natural allelopathic product that interacts with abscisic acid (ABA). ABA is known to inhibit germination of seeds and growing plants.

The effect of the radulanine A molecule was evaluated on *Arabidopsis thaliana* at seeding. Remarkable phytotoxic effects at 50 mg/mL after 24 h, with a persistent effect after 120 h, compared to the similar effect of glyphosate at 25 mg mL were observed. The radulanine A possesses auxin activity making it an herbicidal potential.

Studies suggest that LA and ABA bind to the same receptor in higher plants (biological and structural activity) and a computational analysis revealed that the stable conformers of LA could be superimposed on the stable ABA conformers (figure 43). (Yoshikawa et al. 2002). The mechanism of action and toxicity of radulanine A remain to be evaluated (Zhang et al, 2019).

V.2 The electric weeding

The electric weeding consists in the application of an electric high voltage discharge on the aerial parts of the plants via applicators (pole +), the current spreads in the whole plant until the underground parts and an applicator behind the plants (pole -) closes the circuit. The electric current affects the cells.

Electric weeding and use of glyphosate are contradictory on their mode of action. Electric weeding interrupts the flow of sap by bursting the vessels while the diffusion of glyphosate into the cells is by the seve.

The concept of using electrical energy to kill weeds was developed in the late 1800s. This method has not been widespread in favor of herbicides, but new research and technologies are being developed. In Europe, the company Zasso develops an electric weeding device based on the model of the electroherb in Brazil, the Xpower. The effectiveness of weeding depends on the biomass present, its nature (cellulose), moisture and applied electrical energy, the duration of contact with the plant according to the speed and vegetation (0.01 to 1 s), the variable applied voltage between 3000 and 7000 V, the intensity (less than 0.5 A) and therefore the power.

Electric weeding is a hight energy technique which is best suited to low weed densities (Reed.2009). Experiments have been conducted with different voltages, mre than the power, it is the contact time that matters. (Sahin and Yalınkılıç 2017). With Xpower, the speed of advance can hardly exceed 2 m / s (7.2 km / h), for a width of 2.7 m ,that is maximum 1.9 ha / h (figure 45).

The question of the impact on the life of the soil remains posed. It is therefore a question of defining what are the levels of impacts on the actors of soil life and the plants according to the situations of use. Trials have been conducted in Germany and others are conducted in France (terre-net, 2019).

Conclusion

On average over the period 2016-2017-2018, 18.67% of farmers in fields crops or mixed crops/stock farming in Pays de la Loire use glyphosate between two crops.

Farmers using the cultural management tool mes parcelles representing over the period 2016-2017-2018 28,61% of the regional COP (cereals, oilseeds and proteaginous) treat on average 10,64% of their surfaces in these cultures. The average amount of glyphosate applied is 2.12 l / ha (360 g / l concentration). There is no difference in doses between applications before winter crops and those before spring crops. Many crops may be involved; A slightly higher proportion of spring crops area compared to winter crops area is treated with glyphosate. The surfaces in linen, sunflower, faba bean, beet, hemp are the most treated. There is ; excepted for rye which is treated at the highest dose (3.33l / ha); very little difference in average dose between crops.

The uses of glyphosate between two crops considered in the survey are cleaning plots before sowing, destruction of plant cover and / or grasslands when farmers do not use mechanical tools or that the action of the gel has not been sufficient and fights against perennial weeds. On average, farmers surveyed reported treating perennials at an average dose of 2,73 l/ha , destroying grasslands at an average dose of 2,12l/ha and destroying cover crop or clean up before sowing at an average dose of 1,47 l/ha. The use of glyphosate between farms is differentiated at the level of the treated surface. The lower the tillage, the higher the% of utilized agricultural area (UAA) treated. Direct seeding farms (5 farms) treat more than 60% of their AUU on average per year, reduce tillage farms (21 farms) treat on average 45,05 % of their UAA, ploughing farms (rare (10)+ occasional (6)+ frequent (4) treat around 25% of their UAA. Systematic ploughing; the most common category in Pays de la Loire; treat by inference less than 10% of their AUU on average per year. The proportions of grasslands in the UAA and the type of tillage by farm have a significant effect on the% of UAA treated. In the surveyed farmer sample (48), a lower applied rate per hectare was observed in the direct seeding category, but no significance or correlation between soil type and quantity per hectare was observed. The size of farms in terms of useful area and the number of labor unit per UAA do not have significant effects on the% of UAA treated for the whole sample of farms surveyed but are explanatory factors for within farms in reduce tillage category. The extra cost of stopping glyphosate at this time is the main obstacle cited by farmers. The dose applied per hectare can be reduced in particular by the use of adjuvants and a reduced volume of spray solution, Two practices that are not practiced by all farmers surveyed. New technologies such as low-pressure nozzles and the knowledge and recognition of weeds are two other ways to work on dose efficiency.

Stopping or reducing glyphosate may be an incentive to redesign cropping systems. According to a European regulation dating of July, 11, 2009, the withdrawal of a molecule authorized at European level must take into account the existence of credible alternatives, without environmental impact and without major economic impact. Alternatives for replacing glyphosate and re-designing the cropping system to reduce weed pressure are being identified. It would be interesting to know their current use, their effectiveness of management of weeds and their cost (monetary, working time, environmental) compared to the use of glyphosate, in the objective to integrate more agro ecological weeds management levers.

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Annexe 1 : Data on crops

Three-year sliding average over the years 2016-2017-2018	% area treated	grammage/ha treated	Liters/ha treated for 360g/L	Standard deviation	Numbers of parcel considered in Mes parcelles	Treated surface considered in Mes parcelles per year in ha	Surface considered in Mes parcelles per year in ha	Surface Pays de la Loire per year in ha (source Agreste 2016,2017 and 2018)	% (surface in mes parcelles/ total surface) for Pays de la Loire
Winter	9,91%	747,85	2,08		3472,67	17165,59	173277,95	621100	27,9 %
Spring	11,22%	789,79	2,19		2953	14264,68	127165,64	432100	29,4 %
Weighted Average	10,46%	766,33	2,13						
Cereals									
Corn	10,73%	788,96	2,19	1,31	2558,67	12665,51	118090,59	395300	29,87%
Sorghum	14,74%	817,91	2,27	1,46	112,33	202,01	1370,25	3133,33	43,73%
Soft wheat	9,60%	746,05	2,07	1,20	2063,33	10818,42	112660,83	394733,33	28,54%
Durum wheat	10,84%	947,79	2,63	1,58	153,33	777,42	7170,21	33633,33	21,32%
Triticale	6,03%	845,62	2,35	1,43	236,67	702,94	11653,55	35533,33	32,80%
Barley	11,66%	700,96	1,95	1,22	565	2371,78	20347,28	76533,33	26,59%
Rye	12,26%	1197,03	3,33	1,95	43,33	37,88	308,98	1166,67	26,48%
Oleaginous									
Sunflower	18,90%	799,99	2,22	1,4	281,67	1424,48	7537,16	28066,67	26,85%
Rapeseed	11,45%	661,68	1,84	1,12	466	2502,1	21854,73	82566,67	26,47%
Soya	4,19%	945,51	2,63	0,68	21	8,12	193,89	666,67	29,08%
Linen	25,02%	747,61	2,08	1,44	83	290,06	1159,29	3587,67	32,31%
Protein rich crop									
Faba Bean	18,10%	642,15	1,78	1,09	122,67	382,29	2112,7	6000	35,21%
Feed Pea	13,99%	786	2,18	1,42	79,67	223,86	1600,14	11300	14,16%
Lupin	6,67%	989,68	2,75	1,15	34,33	31,54	472,87	1645,33	28,74
Others									
Beet	17,99%	654,74	1,82	1,03	77	148	822,56	1000	82,26%
Textile hemp	17,10%	857,2	2,38	1,48	81,33	189,42	1107,49	1500	73,83%
Weighted Average for all the cultures	10,64%	765,80	2,12	1,27					28,61%
Sum over the 3 years					Sum : 6979,33	Sum : 32775,83	Sum : 308462,52	Sum 1076366,33	

Three-year sliding average over the years 2016-2017-2018	% area treated	grammage/ha treated	Liters/ha treated for 360g/L	Standart deviation	Numbers of parcel considered in Mes parcelles	Treated surface considered in Mes parcelles per year in ha	Surface considered in Mes parcelles per year in ha	Surface Pays de la Loire per year in ha ((source Agreste 2016,2017 and 2018)	% (surface in mes parcelles/ total surface) for Pays de la Loire
Alfalfa	4,88%	637,81	1,77		273	287,01			
Meadow (source Agreste 2010)	0,28%	764,66	2,12	1.25	815	731,53	265074,14	1000000000 >47 % UUA of Pays de la Loire	

Annexe 2 : Group of crops detailed

Legend : In bold the name of the crop group whose crop list is below			
Corn	Sunflower	Beet	Meadow
corn sweet	Rape	fodder beet	Brest 5 years old or less
corn silage	winter rape	non-fodder beet / chard	Cocksfoot 5 years old or less
Sorghum	spring rape	Hemp	Fescue 5 years old or less
Soft wheat	Soya	Alfalfa	Timothy 5 years or less
soft wheat winter	Faba bean	other alfalfa	legumes + grasses mixture
soft wheat spring	Faba peas	alfalfa	Long rotation meadow (6 years or more)
Durum wheat	winter forage peas	dehydrated alfalfa	Long rotation meadow (more than 5 years)
durum wheat winter	pea forage spring	alfalfa established for the 2016 campaign	permanent meadow
durum wheat spring	White Lupine + Blue Lupine	alfalfa new surface	meadow temp 5 years or less
triticale	sweet winter lupine	seed alfalfa	meadow temp <6a maj legumes
winter triticale	sweet lupine spring		Ryegrass 5 years old or less
spring triticale			pastoral surface predominant grass
Barley			X-Felium 5 years old or less
winter barley			
spring barley			
Rye			
winter rye			
Spring rye			



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Titre français : Typologie des usages et non usages du glyphosate dans les filières grandes cultures-polycultures élevages en Pays de la Loire.

Titre anglais : Typology of the uses and non uses of glyphosate in fields crops and mixed crops/stock farming in Pays de la Loire.

Résumé (1600 caractères maximum) :

Le glyphosate est un herbicide systémique total dont l'autorisation de mise sur le marché est actuellement remise en question, si des alternatives crédibles, sans impact environnemental et sans impact économique majeur sont identifiées. Les usages et non usages du glyphosate est l'objet de cette étude, basée sur deux sources de données ; l'outil de gestion culturale Mes parcelles et des enquêtes auprès d'agriculteurs. En pays de la Loire, 18,67% des agriculteurs en grandes cultures-polycultures élevages utilisent du glyphosate. Sur un échantillon représentant 28,61% des surfaces en COP (céréales, oléagineux protéagineux), 10,64% de ces surfaces reçoivent avant semis un traitement au glyphosate, à une dose moyenne de 2.22 l/ha (concentration de 360 g/l). Les doses entre types de cultures avant semis varient très peu. D'après les enquêtes agriculteurs, la dose de glyphosate varient en tendance entre type d'usages (lutte contre les adventices vivaces : moyenne de 2,73l/ha, destruction des prairies : moyenne de 2,12l/ha, destruction des couverts végétaux et nettoyages avant semis : moyenne de 1,47l/ha) toutefois les variabilités sont importantes entre exploitations. La part de prairies dans la SAU et le type de travail de sol sont les deux facteurs ayant un effet significatif sur le % de SAU traitée. Plus le travail du sol est réduit, plus les % de surfaces traités sont élevés. Bien que le cout de remplacement du glyphosate est le premier frein cité par les agriculteurs, combiner différents leviers agronomiques permet de réduire l'utilisation du glyphosate.

Abstract (1600 caractères maximum) :

Glyphosate is a total systemic herbicide whose marketing authorization is currently being questioned if credible alternatives with no environmental impact and no major economic impact are identified. The uses and non-uses of glyphosate is the subject of this study, based on two sources of data; the cultural management tool Mes Parcelles and surveys of farmers. In Pays de la Loire, 18.67% of farmers in fields crops/ mixed crops sectors use glyphosate. In a sample representing 28.61% of the COP (cereals, protein oilseeds) surfaces, 10.64% of these surfaces received before sowing a glyphosate treatment, at an average dose of 2.22 l / ha (concentration of 360 g / l). Doses between types of crops before sowing vary very little. According to farm surveys, the dose of glyphosate varies in trend between types of use (control of perennial weeds: average of 2.73l / ha, destruction of grasslands: average 2.12l / ha, destruction of plant cover and pre-plant cleanings: average of 1.47l / ha), however, variability is important between farms. The proportion of grassland in the UAA and the type of tillage are the two factors that have a significant effect on the% of UAA treated. The lower the tillage, the higher the% of treated surfaces. Although the cost of replacing glyphosate is the first obstacle cited by farmers, combining different agronomic levers can reduce the use of glyphosate.

Mots-clés : glyphosate, adventices, herbicide, travail du sol, semis-direct, labour, alternatives

Key Words: glyphosate, weeds, herbicide, soil, tillage, direct seeding, ploughing, alternatives