Annex 6a:

Field evaluation of the short-term P effect of recycling-derived fertilisers (RDF) on spring barley

Arvalis Protocol

Spring 2019 and spring 2020

Authors: BOUTHIER Alain, LAGRANGE Hélène
Arvalis Institut du végétal

Table of contents

1. Context, State of art

Phosphorus from mineral fertilizers is mainly a mined resource. Even if the timeframe of its non-availability remains uncertain it requires to be managed from the point of view of its scarcity. In this context, it is desirable to develop RDF use as an alternative resource. To develop them efficiently, it is necessary to quantify the biodisponibility of the phosphorus of these products. The references on P availability of RDF are less numerous than for N availability. Speciation of P in RDF can be very variable.

The phosphorus of RDFs can be of mineral or organic forms. In most cases the mineral form is predominant. The chemical form depends on the origin of the product (animal species and way of feeding them…), as well as possible treatments applied (composting, liming, heat treatments…). The origin and the treatments before spreading can influence the short-term availability of phosphorus. For example, in ashes, part of phosphorus can be phosphate-calcic which is insoluble.

Measurements of short-term or mid or long term availability is a challenge in fertilization planning. This different times availability answer different issues:

- The evaluation of short-term availability is useful to predict the ability of the RDF to provide sufficient phosphorus to the current crop in a field with low availability of P in soil.
- The evaluation of mid or long-term RDF P availability in the soil is relevant for soils where P bioavailability is correct.

In all cases, it is necessary to quantify a fertilizing value in reference to a P mineral fertilizer with a high solubility in water (ie: triple superphosphate, or TSP).

This protocol refers to the short-term effect measured under real field conditions.

2. Trial objectives

2.1. Main objective

The objective of this protocol is to evaluate the phosphorus short-term effect of several RDF applied to a crop.
This effect is expressed through 2 coefficients: the apparent P recovery (APR) and P fertilizer replacement value PFRV (coefficient of equivalence with TSP). These coefficients are calculated from measurements of yield and P absorbed by aerial parts of the crop.

- PFRV in reference to TSP, represents the ratio between the supplement of production with P_2O_5 of the RDF compared to the non-fertilized and the same supplement with TSP. This coefficient can be calculated from yield and P absorbed by aerial parts at maturity of the crop. It can also be calculated with biomass and P absorbed by aerial parts at several vegetation stages.

$$PFRV = [Pabs\ RDF - Pabs\ T0]/[Pabs\ TSP - Pabs\ T0]$$

(Pabs = P absorbed by aerial parts)

- APR is obtained by calculating the ratio between the phosphorus supplement absorbed by a crop fertilized with the RDF compared to a non-fertilized reference, and total phosphorus brought by this RDF.

  APR = [(P absorbed (by crop having received the RDF) – P absorbed by the non-fertilized crop)]/ [total P amount brought by the RDF].

  APR can also be calculated for TSP. The ratio between APR_{RDF} and APR_{TSP} gives an estimation of P fertilizing value.

2.2. Additional Objectives

- In 2019: Soil sample will be taken and send to Ireland for Microbiome and Nematode Analysis.

- In 2019: Product samples will be send to a lab for P pot trials (see protocol for P pot trial in France). This will aim to compare both methods for short-term P availability.

- This protocol could be use to assess short-term P effect depending on different methods of application (period, incorporation or not…). This is not the objective for ReNu2farm project.

3. Studied factors

This protocol is used for 3 field trials:

- 1 field trial in 2019, on spring barley, in region Champagne Ardennes
- 1 field trial in 2020, on spring barley, in region Champagne Ardennes
- 1 field trial in 2020, on spring barley, in region Ile de France

Treatments necessary to calculate APR and PFRV:

The calculation of PFRV requires a response curve to the P reference mineral fertilizer including a treatment without fertilization and 4 rates of reference mineral P fertilizer and two treatments (2 rates) for each RDF with the same method of application.

The P absorbed response curve to TSP , is used to check the dose of fertilizer for which yield or P absorbed are maximum. It is also used to check if the doses of RDF applied fit or not with the objectives of the protocol. APR and PFRV can be estimated with the slope of the linear part of the response curve.

3.1. List of treatments

Treatment number	Product	Dose P_2O_5 (kg/ha)	Comments	
1		0	**blank**	
2	TSP (= super 45)	X/3(*) : 50	>30kg P_2O_5/ha	**TSP response curve**
3	TSP (= super 45)	2X/3 :75		
4	TSP (= super 45)	X: 100	X: P_2O_5 dose calculated by the French Comifer method	
5	TSP (= super 45)	2X : 200		
6	Product 1	Dose 1	Low dose (at which P is very limiting according to P response curve). Dose between X/3 and X/2	
7	Product 1	Dose 2	Suboptimal dose (at which yield or P absorbed is a little lower than rate which maximize yield or P absorption). Dose between 2X/3 and X	
8	Product 2	Dose 1		
9	Product 2	Dose 2		
	Etc…			

3.2. Products in French trial

Product tested	2019 (Champagne Ardennes)	2020 (Champagne Ardennes)	2020 (Ile de France)
Poultry litter ash	X		
Sewage sludge ash		X	X
Struvite from sewage sludge	X		
Compost: solid fraction of pig slurry (30%) and hen droppings (70%) - from Belgium, imported to France	X	X	X
Compost: solid fraction of pig slurry (70%) and hen droppings (30%) - from Belgium, imported to France	X	X	X
Compost: from solid fraction of pig slurry after methanation	X	X	X
Sugar beet scum	X		
Solid fraction of digestate (farm inputs)		X	X

Doses are calculated in reference to the French Comifer method: these doses depend on the soil type, POlsen in soil, crop needs.

Regarding the soil of the 3 trials and following the French Comifer method, the doses are the same in the 3 trials (same crop, low P soil):

X = 100 kg P_2O_5/ha
Dose1 = 50 kg P_2O_5/ha

Dose2 = 100 kg P_2O_5/ha

3.3. Product spreading

Mineral fertilizer (TSP) will be spread by hand, consistency on the soil surface. The amount for each plot will be weigh to bring the right doses (cf 3.1).

Solid organic fertilizers (RDF) will be spread by hand, consistency on the soil surface. The amount for each plot will be weigh to bring the right doses (cf 3.1). Because of difficulties to spread ashes in 2019, a handy lawn spreader is used to spread ashes in 2020.

Immediately after spreading the products on the soil surface and before any rain, they will be buried at 6-7cm depth maximum.

4. Experimental design

4.1. Trial duration

To study the short-term effect this trial will last a planting season on spring barley (from February or March (sowing period) to July (harvest period)).

To study the mid or long term effects the trial should last 3 years. This is not the option chosen for ReNu2Farm project in France.

4.2. Type of design

Statistic blocks with 3 replications on an homogeneous field.

NB: the first soil sampling before seeding will inform on the homogeneity (§6.1.2) . If needed, the trial should be done with 4 replications.

4.3. Size of elementary (individual) plots

Choose a minimal size of 3m X 10m for an elementary plot.

5. Initial characterization of the trial site

5.1. Soil type

This trial can be run on every kind of soil that has less than 20ppm of P2O5 Olsen. The amounts for the other nutrients have to be sufficient (K, Mg, …).

5.2. Farming history

This trial can be run in a conventional farming field (not organic farming because we need to bring mineral fertilizer in the field).

No organic or mineral P should have been brought in the previous 3 years.

5.3. Agricultural practices on the field

Tillage, crop protection products will be the same on every plots. Crop protection will be managed to avoid limiting factors (diseases, pests, weeds …).

To avoid any bias in the trial, a special attention will be given to the fertilization:

No application of products with P

In 2019: N fertilization is conducted at X+30kgN /ha on every plot to eliminate a potential N limiting factor. X is the dose calculated with the French balance method.

In 2020: because X+30kgN/ha was not sufficient to eliminate a potential N limiting factor in 2019, in 2020 the choice was made to spread the same amount of efficient N on each plot, taking into account the potential N effect of each RDFs. The complement was done with mineral N (Ammonitrate).

Every action will be registered.

6. Observations and measurements

6.1. Initial characterization of the trial site

6.1.1. Location

The field will be georeferenced (GPS, latitude, longitude, altitude).

The closest weather station will register daily rainfall, minimum and maximum temperature each day, and PET.

6.1.2. Initial Soil characterization

Sample soil at 0-20cm depth. 20cm being the depth of recent ploughing.
15 to 20 soil cores for each elementary plot* (a gouge will be better than an auger to control the depth).

- Measure POlsen for each plot.
- Soil physico-chemical analysis for each plot. (N Dumas ; Exchangeable Calcium (CaO) ; Carbonates ;CEC Metson ; Total Organic Carbon ; physical analisis 5 decarbonated fractions ; exchangeable Magnesium pH eau / PHH002* ; pH KCl ; Olsen Phosphorus; exchangeable potassium)

*if the field is homogeneous these measurement can be done for each bloc.

6.1.3. Measurements on the RDF products

Take 3 samples for each products:

- One sample is send to the lab for analysis. This is done 15 days before spreading to use data to calculate the amount of RDF to spread in each plot. (Dry matter, pH, organic C, N total, N-NH4, N-NO3, P, K, Ca, Mg)
- One sample is send to the lab for the P pot experiment (cf P pot protocol in lab). (only in 2019)
- One sample is kept until the end of the trial.

6.1.4. Measurements on the crops

This description is adapted to spring barley.

At late-tillering stage
- Grade plant vigour for each plot
- Take 57°pictures of each plot to compare leaves development
- Sample Response curve plots + blank plot to measure biomass

Option: **Between Z32 and Z39**: Sample Response curve plots + blank plot
- Biomass measurements for each plot
- P absorbed and N absorbed will be measured in lab.

At maturity stage:
- Ear number/m² for response curve plots and dose 2 plots.
- Grade lodging
- Take plant samples for each plot to measure N absorbed and P absorbed
- Grain/Straw ratio

At harvest:

- Yield for each plot
- Optional: grain/m²

6.1.5. Soil measurements at harvest

P Olsen for each plot (3 depths: 0-30cm; 30-60cm (only in 2019); 60-90cm(only in 2019))

N balance for each plot (NH4 extraction KCl ; NO3 - extraction KCl ; Dry matter) (3 depths: 0-30cm;30-60cm;60-90cm)

Heavy metals at 0-30cm on response curve, dose X of TSP, dose 2 for the RDF products . (Cadmium total - Chrome total - Cupper total - Mercury total - Nickel total - Lead total - Zinc total).

Take sample according to the Irish sampling protocol for Microbiome and Nematode Analysis (only in 2019)

7. Data analysis

Variance analysis on the yields, P absorption and N absorption to validate measurements

Calculation of APR and PFRV

Results from these trials and from the P pot trial will be compared to evaluate both tests.

Results from these trials and the P trials conducted by other ReNu2Farm partners will be compared.