EFFECT OF THE APPLICATION OF THE SEDIMENTS FROM THE CAT WITH DIFFERENT SOURCES OF FERITLIZERS ON RICE CULTIVATION AND GHG

EBRO ADMICLIM

Deliverable corresponding to Actions B5 and C2

Martínez-Eixarch, Maite
Català, Maria del Mar
Viñas, Marc
Ibáñez, Carles

EFFECT OF THE APPLICATION OF THE SEDIMENTS FROM THE CAT WITH DIFFERENT SOURCES OF FERITLIZERS ON RICE CULTIVATION AND GHG EMISSIONS

Deliverable B5 (deadline 01/04/2017; accomplished 28/09/18)

Introduction

The main objective of this action was to test the effect of organic fertilization (chicken slurry) and addition of sediments in the rice fields (coming from CAT water treatment plant) on both GHG emissions and agronomic pattern of rice crop.

The addition of sediments attempted to simulate the cumulative effect of 100 years of sediment injection of irrigation canals, according to action B2 of this project. The implementation of a permanent system of continuous sediment injection from the water purificacions plant of the CAT, as originally planned, represented a short increment of sediment concentrations in the network of irrigation canals. Therefore, doses of sediment arriving to the fields were expected to be very low and thus, the impact on the crop, if any, difficult to detect. Hence, the continuously injection was shifted to a unique injection of sediment at a rate of 0.5 kg/m^2 (which represents the estimated amount of sediment accumulated over a 100-year period). Thus, sediment was applied and mixed into soil of experimental plots.

The sediments from the water treatment plant resulting from the process of water purification can be rich of iron. Iron is usually found in its ferric and precipitated form in surface water, often in combination with suspended solids. During the clarification stage in the plant water treatment, iron is removed from the water and retained in the sediments. The presence of iron in the sediments can promote competition within the community of decomposers in favor of iron reducing microorganisms, i.e. those using iron as an electron acceptor, in detriment of methanogenic bacteria. Considering this, in 2016 we wanted to test the hypothesis that iron-rich sediments can reduce CH_4 emissions.

Material and methods

The studied strategies are detailed in table 1:

Strategy	Application mode and fertilizer
Organic fertilization with chicken manure	Basal fertilization
Organic fertilization with chicken manure with sediments	Basal fertilization
Mineral fertilization	2/3 Basal fertilization (Urea) 1/3 Split application(Ammonium Sulfate)
Mineral fertilization with sediments	2/3 basal fertilization (Urea) 1/3 Split application(Ammonium Sulfate)

Table 1 Studied strategies and moment of nitrogen application.

A randomized complete block design with 4 replications was used, with elementary plots of 48m^2 in 2015 an 56m2 in 2016. Each plot was sown at dose 500 seeds/m^2 of Gleva cultivar, as it is the most representative in the area.

The amount of sediment applied was equivalent to a natural accumulation within 100 years (5000 kg/ha). The total dose of nitrogen applied was 170Kg/ha in all the strategies.

Soil analysis was performed prior to the implementation of the crop, the two-year trial (Table 2).

Parameter	2015	2016
OM*(% o.d.m.*)	0,94	2,7
Clay (%)	24,7	30,6
Fine lime (%)	29	48,5
Big lime(%)	29,7	13,9
Sand(%)	16,6	7,0
Texture	Silt-loam	Loam-silty-clay
C*(%)	5,59	6,1
Sulphates(mgkg-1 o.d.m.*)	840	2141
Nelemental*(% o.d.m.*)	0,09	0,1
Nkjeldahl*(% o.d.m.*)	0,078	0,1
COT*(% o.d.m.*)	<1	1,8

Table 2 Soil analysis. OM*: organic matter, C*: elemental carbon, Nelemental*: elemental nitrogen, Nkjeldahl*: total nitrogen, COT*: total organic carbon, o.d.m*: on dry matter

The nutrient content (Nitrogen, ammonia, phosphate) of the chicken manure was analyzed, to properly calculate the required dose of chicken manure which was based on the nitrogen demand of the crop of 170 Kg/ha (Table 3).

Parameter		2015	2016
Dry matter 105ºC		28,7 % o.w.m*	64,1 % o.w.m*
N Kjeldahl (N)		4,16 % o.d.m *	4,63 % o.d.m *
Ammonia (N)		3,45 % o.w.m *	1,15 % o.w.m*
Phosphate (P)		1,87 % o.d.m *	2,41 % o.d.m *
Potassium (K)		3,09 % o.d.m *	2,99 % o.d.m *
Chicken manure content	**Nitrogen**	21,84 Kg/tone of chicken manure	37,05 Kg/tone of chicken manure
	P_2O_5	12,29 Kg/tone of chicken manure	20,69 Kg/tone of chicken manure
	K_2O	10,64 Kg/tone of chicken manure	23 Kg/tone of chicken manure

Table 3 Chicken manure analysis. o.w.m*: on wet matter, o.d.m*: on dry matter

The low content of organic matter found in the experimental plots in 2015 (Table 2) forced us to change the location of the second year as it could have interfered in the dynamics of GHG emissions.

The field works conducted are detailed in Table 5.

Work	2015	2016
Basal fertilization and sediment application	April 14th	April 19th
Seeding	April 30th	May 2nd
Split application of fertilizer	June 7th	July 7th
Herbicide treatment	June 23rd	June 3rd
Herbicide treatment	-	July 4th
Fungicide treatment	July 24th	August 8th
Fungicide treatment	August 13rd	August 16th
Harvest	October 9th	October 10th

Table 4 *Crop management.*

The agronomic measurements are detailed below:

- Plant density: the assessment was performed on the phenologic stage of early tillering (BBCH code 21). 5 frames of 0,25m^2 were sampled randomly. It was performed in May 22nd, 2015 and June 8th, 2016.
- Panicle density was performed in the phenologic stage of grain soft dough (BBCH code 85). Five frames of 0,25m^2 were randomly sampled. It was performed on August 17th, 2015 and July 30th, 2016.
- Plant height was measured at the same time as the panicle density by measuring the height from the base of the plant to the apex of the panicle.
- Plant disease was surveyed at the same time as the panicle density. It was evaluated on a 1-9 scale (1: no damage, 3: low 5: medium 7: high, 9: very high) of Blast (*Magnaporthe grisea)* and Brown spot (*Bipolaris oryzae).*
- Yield components, which are the number of grains per panicle, panicle fertility (% full grains) and weight of one thousand grains. At maturity (BBCH code 89), two frames of 0.25 m^2 each were randomly harvested, of which 40 panicles were separated at random. These are shelled by hand and full and empty grains were separated by a densitometry column to determinate the percentage of fertility of the panicle.
- Harvest index: three circles of 0.08m^2 were harvested manually and at random, obtaining a total of 0,24m^2 harvested in each plot, from which the straw and the grain were separated and weighed. Straw and grain oven-dried at 72 ° C for 3 days. The index is calculated formulas follows: Dry grain weight /Dry total biomass weight.

GHG samples were monthly taken in both campaigns from May (June in 2016) to September:

2015: 20/05/2015; 17/06/2015; 22/07/2015; 25/08/2015; 23/09/2015; 21/10/2015; 18/11/2015 and 16/12/2015

2016: 19/5/2016, 15/6/2016, 21/7/2016, 4/8/2016, 1/9/2016 and 29/9/2016. Simultaneously, soil and water physic-chemical parameters were also recorded.

Results and conclusions

GHG emission and GWP

The overall CH_4 emissions in 2015 were very low (0.28 ± 0.96 mg C-CH_4 m^{-2} h^{-1}) likely because of the low organic matter content in soil (0.94%, Table 2). Accordingly, the experimental site was changed in 2016 (see Material and Methods) what allowed to obtain mean CH_4 emission rates close to the average rate (7.37 ± 0.93 mg C-CH_4 m^{-2} h^{-1}). Because of this change in the experimental site, results are presented separately by years (Table 5).

Year			Mean	Standard Error
2015	MFE	NSE	0.06	0.19
		SED	0.05	0.17
		Total	*0.06 B*	*0.19*
	OFE	NSE	1.15	1.36
		SED	2.75	4.01
		Total	*1.95 A*	*1.92*
2016	MFE	NSE	16.89	14.27
		SED	16.97	10.17
		Total	*16.93 B*	*12.05*
	OFE	NSE	33.49	15.75
		SED	15.50	10.87
		Total	*24.49 A*	*7.62*

Table 5 *Mean cumulative C-CH_4 emissions over the growing season in 2015 and 2016 in the four treatments studied resulting from the factorial combination of factors Type of fertilizer (OFE, Organic; MFE, Mineral) and Addition of Sediments (SED, addition of sediments; NSE, no sediments added). Different capital letters means significant differences (P<0.05) between Fertilizer treatments, whereas lower case letters means significant differences (P<0.05) between Sediment treatments. Analyses of variance were conducted separately for each year.*

Organic fertilization (OFE) significantly increased cumulative C-CH_4 emissions in relation to mineral fertilization (MFE) over the growing season by 34 times in 2015 and 1.5 times in 2016 (Table 5). Despite the large differences between treatments in 2015, in absolute values were 0.06 and 1.95 g C-CH_4 m^{-2} (in MFE and OFE, respectively). The effect of the sediments differed between years, so that CH_4 emissions increased with the addition of sediments in 2015 (0.61 vs 1.40 g C-CH_4 m^{-2} in NSE and SED, respectively) whereas the opposite effect was detected in 2016 (33.49 vs 15.50 g C-CH_4 m^{-2} in NSE and SED, respectively). In addition, in 2016 the addition of sediments combined with organic manure significantly reduced CH_4 emissions by 50% in relation to organic manure without sediments (33.5 ± 4.6 vs 15.5 ± 2.0 g C-CH_4 m^{-2}) and so leveling to the same rates as with mineral fertilization (mean across sediment treatments: 16.9 ± 2.0 g C-CH_4 m^{-2}). Contrarily, such reductions in CH_4 in sediment treatments were not detected in 2015 yet they were higher in fields with organic fertilization and addition of sediments (Fig. 1). Interestingly, such potential mitigation effect of the sediments coincides with the year when iron-rich sediments (>20%) were used. Despite these results are not conclusive, they open a promising option for the use of sediments as mitigation measures for greenhouse gas emissions that should be further studied.

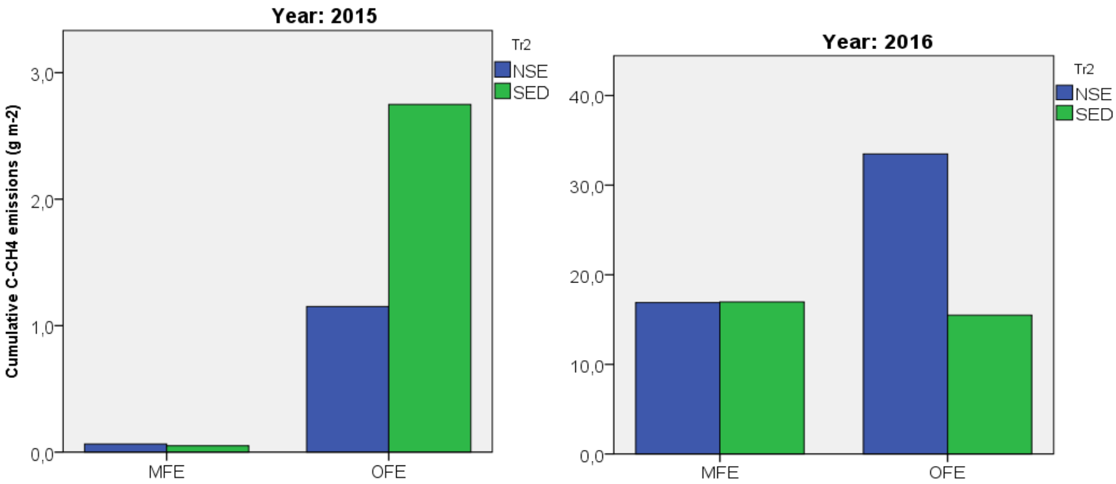

Figure 1 *Effect of organic fertilization (OFE) relative to mineral fertilization (MFE) (A) and addition of sediments (SED) relative to no sediments (NSE) (B) on C-CH_4 cumulative emissions in years 2015 and 2016. Note the different range of emission in 2015 (0 to 3 g C-CH_4 m-2) relative to 2016 (0 to 40 g C-CH_4 m-2)*

N_2O emissions remained very low or even negligible in the two years of the study, with no significant differences across the treatments and with cumulative emissions ranging from -0.01 to 0.08 g N-N_2O m^{-2}. Consequently, differences in GWP across the treatments performed similarly to CH_4 emissions (Table 6).

	Fertilizer	**Sediment**	**Mean**	**Standard Error**
2015	MFE	NSE	2.07	2.97
		SED	-3.59	3.59
		Total	*-0.76 B*	*2.44*
	OFE	NSE	55.25	25.69
		SED	72.10	6.93
		Total	*63.68A*	*12.48*
2016	MFE	NSE	467.63b	20.10
		SED	473.74b	45.01
		Total	*470.68B*	*22.09*
	OFE	NSE	935.90a	74.78
		SED	431.95b	32.52
		Total	*683.92A*	*118.44*

Table 6 *Mean cumulative global warming potential (GWP) of rice plot experiments in 2015 and 2016 across the four treatments studied resulting from the factorial combination of factors Type*

of fertilizer (OFE, Organic; MFE, Mineral) and Addition of Sediments (SED, addition of sediments; NSE, no sediments added). Different capital letters mean significant differences (P<0.05) between Fertilizer treatments, whereas lower case letters mean significant differences (P<0.05) between Sediment treatments. Analyses of variance were conducted separately for each year.

Agronomic response

In regard of the agronomic performance of the crop, seedling establishment (i.e., the ratio of established seedlings over sown seeds) was, in average, 53%, which is higher than the mean rate in the Ebro Delta rice fields (estimated at 30%). Concerning the agronomic effect of the tested treatments, it was observed that the mineral x CAT sediment (M-S) treatment showed the largest number of panicles/m2 (448 ± 47 panicles/m2) while the lowest value was found in the manure x no- CAT sediment (M-NS; 389±30 panicles/m2) although the difference was not statistically significant.

Plants under M-S treatment were highly infested by blast, as opposed to the other treatments, which showed low infestation. Referring to *Helmintosporium oryzae* disease, no differences were obtained between treatments. Overall, plants were low affected by *Helmintosporium oryzae* fungus. Rice yield across all treatments was higher than the mean production in the Ebro delta (mean value 6550 kg/ha). Highest yield, with 8782±629 kg/ha was obtained in M-S whereas the lowest in O-S, with 7493±1061 kg/ha although the differences did not reach the 5% level of statistical significance. Despite the lack of significant differences among treatments it was noticed that the yield average in plots with mineral fertilization was higher (8533±711 kg/ha) than in plots fertilized with organic manure (7503±1099 kg/ha).

In summary, the results indicated that the addition of sediment did not affect grain yield whereas fertilization with organic manure may reduce it. However, it is worthwhile to mention that a number of studies on organic manure on rice yield show slight declines in rice production during the early years but tends to increase up to average yield thereafter.

Conclusions

The following are the main outcomes derived from sediment injection and different sources of fertilization in rice fields:

1) Sediments derived from CAT water treatment plant can be safely implemented in terms of rice production since no effect on grain yield was observed.
2) Under mineral fertilization, sediments did not influence total GWP of rice fields.
3) Organic fertilization without sediments can increase GWP rice cultivation, although such a patter needs to be confirmed at a longer period.
4) Iron-rich sediments in combination with organic manure (chicken slurry) can be used as a mitigation measure to enhance soil organic carbon content in soil (carbon sequestration) without increasing of CH_4 emissions. Iron-rich sediments (> 20%) from CAT water treatment plant could compensate the increase of CH_4 emissions resulting from chicken slurry levelling off the emissions to those obtained with mineral fertilizers (Fig. 1). It is worthwhile to note that this result is not conclusive but it opens a promising option for the use of sediments as mitigation measures for greenhouse gas emissions that should be further studied.