PHORWater

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for Phosphorus recovery
and reuse from Urban Wastewater

LIFE12 ENV/ES/000441

Results obtained in the struvite agricultural applications

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1. Background

Modern agriculture is dependent on continual inputs of P fertilisers to sustain high crop yields and replace the soil with nutrients lost in each harvest. Around 80% of phosphates produced are used today in fertilisers industry, with a further 5% being used as animal feed supplement. These phosphates are manufactured from phosphate-rock mined from deposits in several countries (140 million tons of phosphate rock are extracted each year).

The World's reserves of mineral phosphate rock commercially viable are estimated to deplete at somewhere between 50 – 250 years, under increasing pressure because of the growing world's population, increasing meat in the global diet and the production of bio-energy crops. The EU food system is "highly vulnerable to future P scarcity"; nearly 90% of P is used in agriculture thus the EU is highly dependent on imported phosphates. Moreover, there are serious environmental impacts of phosphate fertiliser production and use, including the production of toxics and wastes, cadmium pollution to soils, greenhouse gases emissions, and the eutrophication of the rivers and shores.

A 'Copenhagen Resource Institute' report (Fischer et al., 2012) on "Recycling and Sustainable Materials Management" looking particularly at P scarcity, estimates that today, around 37% of P in municipal wastewater is recycled back to agriculture in Europe. A long term solution for P management would require a 70% reduction in demand, therefore the remaining 30% being supplied by P recycling. Around 1.9 Mt of P per year is consumed in agriculture. Less than 0.4 Mt/year of it reaches the consumer (household), showing that the P-chain is characterized by low efficiency and large losses such as accumulation of P in soils and landfills, losses to the hydrosphere by erosion, leaching, and wastewater discharges.

Therefore, there is significant potential to optimize P management by the implementation of new technologies and enhanced management practices in agriculture and waste management. One of the possible ways to achieve this goal is the optimization of the integral management of wastewater treatment plants (WWTPs), in terms of P, coupled to a crystallization process to recover P as struvite ($MgNH_4PO_4 \cdot 6H_2O$).

Struvite is a potentially marketable product for the P fertiliser industry. It has the advantage of containing N as a nutrient needed for the crops and plants growth. There are significant economic and environmental advantages in developing this product in a wide range of fertilisers. Its inherent slow release property prevents the burning of roots, despite the application of excess quantities. Moreover, the insoluble nature of struvite in neutral water prevents eutrophication in surrounding surface waters and restricts leaching into water reserves, providing efficient and economical use of fertiliser (Schuling and Andrade, 1999). In addition to these results, pilot trials show that struvite production results in reductions of over 50% in sulphur dioxide, carbon monoxide and nitrous oxide emissions and 80% lower greenhouse gas emissions on a carbon dioxide equivalent basis, when replacing traditional fertilisers.

Conventional fertiliser manufacturing processes are energy intensive, involving mining, long transport distances, thermal processes, and in some cases direct combustion of fossil fuels for product manufacture (e.g. ureas production). In contrast, struvite recovery facility operates on a total installed electrical capacity of approximately 25 horsepower.

2. Objective

The purpose of the struvite obtained in the crystallization reactor is to be used in agriculture application assays for its validation as a fertiliser. Two crops with different growing cycles will be assayed. After fertiliser application (before planting) and at the end of the growing season, the soil will be analysed for each treatment. At the end of cycle biomass, the plant phosphorus, nitrogen and magnesium availability will be assessed by comparing total plant phosphorus, nitrogen and magnesium content (leaves and roots) of the crops studied.

The aim of this report is to assess the feasibility of using struvite from Calahorra WWTP as fertiliser in two different crops: wheat and potato.

In order to evaluate the improvement in quality and yield of wheat and potato crops due to the struvite's fertilisation programme, two specific objectives will be addressed:

1. Comparison between struvite and conventional fertilisation.
2. Check which strategy is better: struvite background application with conventional top dressing or struvite alone.

3. Materials and methods

3.1. Struvite specifications

The composition (%) of the struvite produced at Calahorra WWTP, the one used for the agriculture application assays, was N = 5.7%, P = 12.1%, K = 0.17%, Ca = 6.8%, Mg = 9.0%. These fractions represent the percentage of active ingredient in the formulated product on a weight/weight basis.

3.2. Trial treatments

SynTech Research Spain S.L., for each kind of crop, wheat and potato, carried out three different trials. The conventional fertilisers used, in addition to struvite, were:

- SOLUCROS (granular, content in K_2O = 51%)
- UREA (granular, content in urea = 46%)
- LIKI-K (soluble concentrate, N_{Total} = 3%, K_2O = 32%)
- HEROGRA ABOSOL (liquid, N_{Total} = 11%, P_2O_5 = 11%, K_2O = 11%, CaO = 0%, MgO = 0%)

The fractions represent the percentage of active ingredient in formulated product on a weight/weight basis. Only the amount of each active compound is shown.

Table 1 shows the six trials carried out, three of them with each crop, specifying the treatment and the dosage applied. The methodology followed for the application of the fertilisers is detailed in Table 2.

Table 1. Trials done for wheat and potato crops

Crop	Trial number	Treatment name	Dosage (kg/ha)	Application code
wheat	1w	STRUVITE	921	AB
	2w	STRUVITE	631.6	A
		UREA	150	B
		LIKI-K	2	C
	3w	HEROGRA ABOSOL	300	A
		UREA	150	B
		LIKI-K	2	C
potato	1p	STRUVITE	1170	DEF
	2p	STRUVITE	1100	D
		SOLUCROS	140	D
		UREA	150	EF
		LIKI-K	10	EF
	3p	HEROGRA ABOSOL	1000	D
		UREA	150	EF
		LIKI-K	10	EF

Table 2. Application description for wheat (A, B and C) and potato (D, E, F) crops

	A	B	C	D	E	F
Application Date:	30/12/2015	4/3/2016	28/3/2016	25/1/2016	3/2/2016	28/3/2016
Appl. Start Time:	10:00	13:30	17:00	10:00	10:30	17:00
Application Method:	SPDINC	SPREAD	SPREAD	SPDINC	SPREAD	SPRAY
Application Timing:	PRSECR	POEMCR	POEMCR	PRSECR	POEMCR	POEMCR
Application Placement:	BROSOI	BROSOI	BROSOI	BROSOI	BROSOI	BROSOI
Air Temperature, Unit:	16,4 C	15 C	16 C	17 C	18 C	17 C
% Relative Humidity:	65	67	43	65	70	0
Dew Presence (Y/N):		N no	N no		N no	N no
Soil Temperature, Unit:	12,5 C	14,0 C	14,7 C	10,2 C	12,9 C	13,2 C
Soil Moisture:	SLIWET	WET	SLIWET	SLIWET	WET	SLIWET
% Cloud Cover:	10	0	20	10	80	0

SPDINC: spreading and incorporation
SPREAD: spreading
SPRAY: spraying
PRSECR: pre seed
POEMCR: post emergence
BROSOI: broadcast soil
SLIWET: slightly wet

3.3. Site description and fertiliser application

For wheat trials, an experimental plot in Chiclana de la Frontera (Cádiz) was selected, which was sowed with wheat crops on December 30th, 2015. A randomized complete block design was done, with 4 replications per treatment and elemental plots of 30 square metres (sqm). First two applications were basal (A and B, see Tables 1 and 2), by means of spreading and incorporation, and third top application (C, see tables 1 and 2) using a knapsack sprayer (Maruyama) with field boom, flat fan nozzle, at 4 bar of pressure and using a water volume of 500 l/ha, except for struvite, which was always applied by means of soil incorporation.

For potato trials, the experimental plot selected was in Conil de la Frontera (Cádiz). This plot was sowed with potato crops on January 25th, 2016. A randomized complete block design was done, with 4 replications per treatment and elemental plots of 24 sqm and 128 plants per plot. First application (D, see Tables 1 and 2) was basal by means of spreading and incorporation to the soil, the rest of applications (E and F, see Tables 1 and 2) were top applications at different crop development using a knapsack sprayer (Maruyama) with field boom, as in the case of wheat.

3.4. Wheat crop description

The main characteristics of the wheat crop are listed below.

Crop: TRZAW Triticum aestivum (winter), Winter wheat
Variety: Don Ricardo
Description: Industry
Planting Rate, Unit: 220 kg/ha
BBCH Scale: BCER
Planting Date: 30/12/2015
Planting Method: DRILLE drilled
Planting Equipment: SR Drilling Machine
Harvest Date: 10/6/2016

Maintenance treatment:
Tebuconazol (1 L/ha) and Chlorothalonil (0.3 %

v/v) were foliar applied 47 days after the planting date. Azoxystrobin (1 L/ha) was similarly applied 58 days after the planting date.

3.5. Potato crop description

Characteristics of potato crop are listed below.

Crop: SOLTU Solanum tuberosum potato
Variety: Spunta
BBCH Scale: BPOT
Row Spacing, Unit: 0.75 m
Spacing Within Row, Unit: 0.25 m
Planting Density, Unit: 53333 P/ha
Planting Date: 25/1/2016
Planting Method: SEEDHA seeded by hand
Planting Equipment: HA By Hand
Harvest Date: 27/5/2016

The maintenance treatment of the potato crop is summarised in Table 3. All products were applied by foliar application.

Table 3. Maintenance of potato crop.

No.	Date	Maintenance product name	Concentration (%)	Rate	Rate unit
1	10/02/2016	Linuron	45	1	L/ha
2	23/02/2016	Chlorothalonil	50	0.3	% v/v
3	23/02/2016	Chlorpyrifos	48	0.2	% v/v
4	06/03/2016	Mancozeb	75	1.5	kg/ha
5	06/03/2016	Dimethomorph + Pyraclostrobin	7.2+4	0.2	% v/v
6	06/03/2016	Lambda Cyhalothrin	10	0.1	L/ha
7	19/03/2016	Cymoxanil	45	0.3	% v/v
8	19/03/2016	Chlorothalonil	50	0.3	% w/v
9	19/03/2016	Metalaxyl	25	0.1	% w/v
10	26/03/2016	Cymoxanil + Mancozeb		0.3	% w/v
11	26/03/2016	Fluopicolide + Propamocarb	6.25+52.5	1	L/ha

Table 3 cont. Maintenance of potato crop.

No.	Date	Maintenance product name	Concentration (%)	Rate	Rate unit
12	02/04/2016	Dimethomorph + Pyraclostrobin	7.2+4	0.2	% v/v
13	02/04/2016	Chlorothalonil	50	0.3	% v/v

3.6. Soil description

In the wheat crop trial, the soil was composed of sand (55 %), silt (22 %) and clay (23 %). The percentage of organic matter was 1.94%, with a cation exchange capacity (CEC) of 236. The texture was silty clay loam, showing a pH of 8.06 and a good fertilisation level. The soil drainage was good.

For the potato crop trial, the soil composition was sand (48 %), silt (47 %) and clay (5 %). The percentage of organic mater was 1.74%, with a CEC of 237 and a pH of 8.01. The soil presented a sandy loam texture. The fertilisation level and the soil drainage were both good.

3.7. Analytical methods

The trial was performed in accordance with Good Experimental Practices (GEP), following whenever possible the Guidelines: EPPO bulletin No PP 1/135(3), 1/152(4), 1/181(4), and 1/54(3).

3.8. Statistics

The software used for the analysis of the results was ARM Revision 9.2014.7 from Gylling Data Management. Data were analysed using analysis of variance (ANOVA) on untransformed data and on transformed ones when the Bartlett's test indicated so. If transformation did not improve the distribution, original values were used and therefore significant differences reported should be interpreted with carefully.

The probability of no significant differences occurring between treatment means was calculated as the F-probability value (Treatment Prob(F)). Student-Newman-Keuls (S-N-K) test was applied when treatment differences were identified on the basis of the ANOVA (AOV) test. Mean comparison performed only when AOV Treatment P(F) is significant at the observed significance level (OSL) selected. Results obtained were indicated by a letter (a, b) - treatment means with no letters in common are significantly different in accordance with a S-N-K conducted at a 95% confidence level. Where data have been transformed, letters are included in the transformed data.

4. Results

4.1. Wheat crop

The experimental fertiliser STRUVITE from Calahorra WWTP was tested alone, applied at 921 kg/ha and combined applied at 631.6 kg/ha with UREA + LIKI-K at 150 kg/ha and 2 kg/ha, respectively. The combination supplied enough nitrogen according to wheat demand at the early stages and avoided the supply later on to prevent crop lodging. This meant duplicate phosphorous dose which resulted in good yield results and neither negative effects on development nor yield.

Both treatments were compared to that of standard fertilisation program which included HEROGRA ABOSOL at 300 kg/ha + UREA at 150 kg/ha + LIKI-K at 2 kg/ha.

Crop development, quality parameters and yields were compared between treatments with similar results at the trial completion.

4.1.1 Crop development

Number of plants emerged in a sample size of 1 sqm at 15 DA-A (days after A) was 308.5 for Struvite, 296.5 for combination of Struvite with other standard fertilisers and 314.8 plants for standard fertilisation program, with no statistical differences from one to another (Table 4).

Table 4. Emergence.

	Emergence (No. plants)
	After-A
Struvite	308.5 a
Struvite + conventional	296.5 a
Conventional	314.8 a

Means followed by the same letter do not significantly differ
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

4.1.2 Yield

Results on yield at harvest (70 DA-C) were slightly higher in plots with Struvite (5060.5 kg/ha and 4639.2 kg/ha) than in the standard fertilisation program (4764.4 kg/ha) with no statistical differences within the trials. Only yield increase respect to standard fertilisation program was recorded and resulted in 5.8% higher for struvite alone (Table 5).

Table 5. Yield of wheat crop.

	Yield (kg/ha)	**Yield (% increase)**
	harvest	harvest
Struvite	5060.5 a	105.8 a
Struvite + conventional	4639.2 a	97.4 a
Conventional	4764.4 a	100.0 a

Means followed by the same letter do not significantly differ
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

4.1.3 Quality parameters

Quality control was also assessed recording the specific weight, the quantity of protein in grain, the wet gluten, the grain humidity and the suitability for baking process. Regarding the specific weight of 1 hL results were very similar for treatments #1, #2 and #3 (8331.8 g, 8359.3 g and 8572.8 g, respectively) with no statistical differences among the trials (Table 6). The quantity of protein in grain does not show differences among the treatments (14.3, 14.8 and 14.6, respectively). The same tendency is observed for wet gluten and humidity in grain with no significant difference among the results (35.2%, 36.6% and 35.8% for wet gluten and 12.6%, 12.7% and 12.7% for the humidity in grain).

Regarding suitability for baking process there were no differences observed for the parameters analysed, and flour balance (P/L) was 3.95 for treatments #1 and #2 and 3.55 for conventional treatment #3. Baking strength was 0.0254 J, 0.0267J and 0.0302J respectively with no statistical differences to be mentioned (Table 7).

Table 6. Quality parameters. Grain quality.

	Specific weight (g)	**% Grain protein**	**% Wet gluten**	**% Grain humidity**	**1000 grains weight**
#1 Struvite	8331.8 a	14.3 a	35.2 a	12.6 a	50.9 a
#2 Struvite + conventional	8359.3 a	14.8 a	36.6 a	12.7 a	50.5 a
#3 Conventional	8572.8 a	14.6 a	35.8 a	12.7 a	51.8 a

Means followed by the same letter do not significantly differ
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison observed significant level.

Table 7. Quality parameters. Suitability for baking process.

	P (mm)	G (mm)	L (mm)	P/L (mm/mm)	W (J)
#1 Struvite	158	14.1	40	3.95	0.0254
#2 Struvite + conventional	162	14.3	41	3.95	0.0267
#3 Conventional	167	15.3	47	3.55	0.0302

Methodology PEQ302. P: baker Cs tenacity. L: baker's extensibility. W: baker strength. P/L: flavour balance

4.1.4 Soil and leaves analysis

The soil analysis revealed that experimental plots selected had a good fertilisation level similar for the three treatments (Table 8). Physic, nutritional fertility was similar for all treatments at trial completion as well as the nutrients available at the soil.

When focus on leaves analysis performed at pre harvest, macronutrients and micronutrients content were similar in all experimental plots (Table 9).

No symptom suggests any kind of phytotoxicity were observed in any of the plots treated at the rates proposed in wheat plants. No problems when handling the experimental product.

Table 8. Soil analysis for wheat crop.

SOIL ANALYSIS	Struvite				Struvite + conventional				Conventional			
Soil texture	Sandy clay loam				Sandy loam				Sandy clay loam			
Soil compaction	Low		Low		Low		Low		Low		Low	
	Before application		After applications		Before applications		After applications		Before applications		After applications	
Active lime (%CaCO3)	6.0	H	4.1	H	5.7	H	4.9	H	5.8	H	5.3	H
C/N	11.2	N	8.84	L	9.77	L	8.39	L	10.4	N	7.5	L
CE (µS/cm)	236	N	187	L	284	N	178	L	288	N	184	L

SOIL ANALYSIS	Struvite				Struvite + conventional				Conventional			
Soil texture	Sandy clay loam				Sandy loam				Sandy clay loam			
Soil compaction	Low		Low		Low		Low		Low		Low	
	Before application		After applications		Before applications		After applications		Before applications		After applications	
P available (mg/kg)	51.6	H	97.4	H	41.3	H	67.7	H	50.7	H	43.4	H
Organic matter (%)	1.94	N	1.64	N	2.0	H	1.64	N	2.10	H	1.4	N
N (mg/kg)	1.00	N	1.07	N	1.19	N	1.13	H	1.17	N	1.08	N
pH	8.06	H	8.07	H	7.93	H	8.13	H	8.01	H	8.09	H
Na available meq/100g)	0.22	L	0.2	L	0.22	L	0.14	L	0.21	L	0.31	N
Ca available(meq/100g)	12.7	N	9.03	N	13.0	N	9.40	N	13.8	N	9.18	N
Mg available(meq/100g)	0.54	L	0.63	L	0.73	L	0.27	L	0.73	L	0.08	L
K available (meq/100g)	0.42	L	0.3	L	0.62	N	0.43	L	0.54	N	0.3	L
Fe available (mg/kg)	6.88	N	11.0	H	6.06	N	10.2	H	8.08	N	10.8	H
Mn available (mg/kg)	8.53	H	13.8	H	7.42	H	12.8	H	9.31	H	10.5	H
Cu available (mg/kg)	11.4	H	11.1	H	9.86	H	16.2	H	11.9	H	10.9	H
Zn available (mg/kg)	7.87	H	6.92	H	7.57	H	7.12	H	8.42	H	7.2	H

L: low; N: normal; H: high values. Quantification index for Cu available is 5.

Table 9. Leaves analysis for wheat crop.

	LEAVES ANALYSIS	Struvite		Struvite + conventional		Conventional	
MACRONUTRIENTS (%)	N Dumas	4.59	H	4.28	H	4.43	H
	K	1.61	N	1.48	L	1.64	N
	P	0.28	N	0.28	N	0.27	N
	Ca	1.06	H	1.25	H	1.02	H
	Mg	0.24	H	0.27	H	0.24	N
	S	0.46	N	0.47	L	0.45	N
MICRONUTRIENTS (mg/kg)	B	13.0	H	9.10	N	9.934	N
	Cu	12.0	N	<5	N	<5	N
	Fe	99.8	N	99.5	N	97.7	N
	Mn	20.4	N	22.0	N	18.7	N
	Zn	45.7	N	42.1	N	38.3	N
	Mo	<10	L	<10	L	<10	L

	Na	350	L	326	L	322	L
	Clorures	1.972	L	1.15	L	1.617	L

L: low; N: normal; H: high values. Quantification index for Mo available is 10.

4.2. Potato crop

Crop development, quality parameters and yield were compared between treatments with similar results at the trial completion.

4.2.1. Crop development

Number of plants emerged in a sample size of 8 sqm at 23 DA-E was 29.4 for Stuvite, 29.6 for combination of Struvite with other standard fertilisers and 27 plants for standard fertilisation program, with no statistical differences among the observed results (Table 10).

Regarding to vigour assessment, according to a scale (1-10 with average reference value of 5), the plants vigour was similar for all treatments at 23 DA-E, 54 DA-E and 25 DA-F with 5 as average value and no statistical differences between them.

Table 10. Emergence and crop development. In potato crop trials.

	Emergence (No. plants)	Vigour (%)		
	After-E	After-D	After-E	After-F
Struvite	29.4 a	5.0 a	5.0 a	5.0 a
Struvite + conventional	29.6 a	5.3 a	5.3 a	5.0 a
Conventional	27.0 a	5.3 a	5.3 a	5.0 a

Means followed by the same letter do not significantly differ
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

4.2.2. Yield

Results on yield at harvest (60 DA-F) were slightly higher in plots with Struvite (46822 kg/ha and 47216.7 kg/ha) than in the standard fertilisation program (44377.8 kg/ha) even with statistical differences between them. In fact, yield increase respect to standard fertilisation program was recorded and resulted in 5.5% higher for struvite alone and 6.2% higher for struvite in combination with standard fertilisers (Table 11).

Table 11. Yield of potato crop.

	TOTAL WEIGHT (Kg)		YIELD (Kg/ha)		YIELD % increase	
	harvest		harvest		harvest	
Struvite	7.9	a	46822.2	a	105.5	a
Struvite+ conventional	9.4	a	47216.7	a	106.2	a
Conventional	7.2	a	44377.8	b	100.0	b

Means followed by same letter do not significantly differ.
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

4.2.3. Quality parameters

The highest number and weight of tubers from 1st category (>12 cm) was that of plots fertilized with Struvite with almost 130 tubers, higher than Struvite applied in combination with 125.5 tubers and also with standard fertilisation program with 126.3 tubers from 1st category. The weight of tubers from 1st category was also high for Struvite applied alone with 34.2 kg higher than Struvite in combination with standard fertilisers (33.1 kg) and the conventional strategy (32.7 kg).

The best potatoes starch content was that of plots fertilized with Struvite 17.3% compared to a 13.2% of the standard fertilisation program (Table 12).

Table 12. Quality parameters of potato crop

	NUMBER TUBERS						WEIGHT TUBERS (Kg)						STARCH CONTENT
	1st category		2nd category		3rd category		1st category		2nd category		3rd category		
Struvite	129.8	a	60.5	a	44.3	a	34.2	a	7.9	a	2.0	a	17.3
Struvite+ conventional	125.5	a	82.8	a	33.3	a	33.1	a	9.4	a	1.5	a	12.3
Conventional	126.3	a	58.8	a	32.0	a	32.7	a	7.2	a	1.6	a	13.2

Means followed by same letter do not significantly differ
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.
Tubers 1° Category (Tubers >12 cm)
Tubers 2° Category (Tubers 3-12 cm)
Tubers 3° Category (Tubers <3 cm)

4.2.4. Soil and leaves analysis

The soil analysis revealed that experimental plots selected had a good fertilisation level similar for the three treatments (Table 13). Physic, nutritional fertility was similar for all treatments at trial completion as well as available soil nutrients.

When focus on leaves analysis performed at pre harvest, macronutrients and micronutrients content was similar in all experimental plots (Table 14).

No symptoms suggesting any kind of phytotoxicity were observed in any of the plots treated at the rates proposed in potato plants. No problems when handling the experimental product.

Table 13. Soil analysis for potato crop.

SOIL ANALYSIS	Struvite				Struvite + conventional				Conventional			
Soil texture	Sandy loam				Sandy clay loam				Sandy loam			
Soil compaction	Low		Low		Low		Low		Low		Low	
	Before application		After applications		Before applications		After applications		Before applications		After applications	
Active lime (%CaCO3)	3.0	N	2.6	N	3.1	N	2.8	N	3.0	N	2.9	N
C/N	10.0	L	8.56	N	9.37	L	8.95	L	9.7	L	8.21	L
CE (µS/cm)	237	N	88.1	L	214	N	92.7	L	240	N	86.4	L
P available (mg/kg)	31.2	N	89.5	H	32.3	N	73.6	H	36.8	N	35.1	N
Organic matter (%)	1.74	N	1.82	N	1.77	N	2.0	H	1.78	N	1.75	N
N (mg/kg)	1.00	N	1.234	N	1.09	N	1.296	N	1.06	N	1.239	N
pH	8.1	N	8.34	H	7.99	H	8.30	H	8.04	H	8.32	H
Na available (meq/100g)	0.5	N	1.12	H	0.48	N	0.95	H	0.54	N	2.4	H
Ca available (meq/100g)	24.4	H	43.1	H	24.9	H	44.8	H	25.8	H	55.0	H
Mg available (meq/100g)	2.47	N	6.78	H	2.40	N	5.07	H	2.6	H	4.79	H
K available (meq/100g)	1.05	H	1.91	H	1.04	H	2.47	H	1.15	H	2.40	H
SOIL ANALYSIS	Struvite				Struvite + conventional				Conventional			
Soil texture	Sandy loam				Sandy clay loam				Sandy loam			
Soil compaction	Low		Low		Low		Low		Low		Low	
	Before application		After applications		Before applications		After applications		Before applications		After applications	
Fe available (mg/kg)	11.7	H	11.3	H	7.03	N	17.3	H	9.43	N	12.2	H
Mn available (mg/kg)	7.55	H	15.1	H	9.35	H	16.0	H	12.1	H	17.3	H
Cu available (mg/kg)	0.63	N	<5	H	0.62	N	<5	H	0.68	N	<5	H
Zn available (mg/kg)	0.85	L	0.83	L	0.82	L	1.05	N	8.42	L	2.46	H

L: low; N: normal; H: high values Quantification index for Cu available is 5.

Table 14. Leaves analysis for potato crop.

	LEAVES ANALYSIS	Struvite		Struvite + conventional		Conventional	
MACRONUTRIENTS (%)	N Dumas	3.1	N	3.04	N	3.24	N
	K	3.9	L	4.41	L	4.34	L
	P	0.25	L	0.23	L	0.21	L
	Ca (%)	4.96	H	5.33	H	4.52	H
	Mg	0.86	H	0.89	H	0.98	H
	S	0.44	H	0.46	H	0.33	N
MICRONUTRIENTS (mg/kg)	B	21.2	N	22.1	N	15.1	L
	Cu	79.2	H	70.6	H	88.4	H
	Fe	692	H	852	H	578	H
	Mn	156	N	152	N	150	N
	Zn	29.7	N	20.1	N	20.1	N
	Mo	<10	L	<10	L	<10	L
	Na	677	L	829	L	838	L
	Clorures	19.294	H	17.326	H	20.400	H

L: low; N: normal; H: high values. Quantification index for Mo available is 10.

5. Conclusions

Wheat crop:

Under the conditions of this trial, it might be indicated that the experimental fertiliser struvite applied alone or in combination with another standard fertilisers is able to obtain similar quality results and yield in wheat than a standard fertilisation program. All products are selective to wheat plants cv. Don Ricardo.

Potato crop:

As a global conclusion, under the conditions of this trial, it might be indicated that the experimental fertiliser struvite applied alone or in combination with another standard fertilisers is able to obtain similar quality results and yield in potato than a standard fertilisation program. All products are selective to potato plants cv. Spunta.

6. References

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