Using agriculture wastes and sulfur obtained from the residues of the desulfurization of natural gas and oil as fertilizer for productive purposes.

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This study started in cooperation with SBS an engineering and production company specialized in the design and manufacturing of steel belt systems for continuous industrial processes, pioneers in developing flaking and pastillating units for a wide range of products.

- **Elemental Sulfur (99% S)** obtained from the residues of the desulfurization of natural gas and oil **is a pollutant for the environment with serious impact on human health.** It is, nowadays in a small percentage used in the industrial process to produce sulfuric acid.

- **Olive wastes and orange residues** are recalcitrant biomass, pollutant for the environment.

- **S is insoluble in water, and to be used for agriculture purpose needs to be mixed with** bentonite an inhert clay to form pellet (or pastille). When the clay becomes wet in the soil, it swells and breaks the pellet into many small pieces with a very large reactive surface area releasing sulfur.

- **Released sulfur** requires microbial oxidation to sulfate before plants can take it up. The rate of oxidation is largely governed by the properties of soil and environmental conditions.

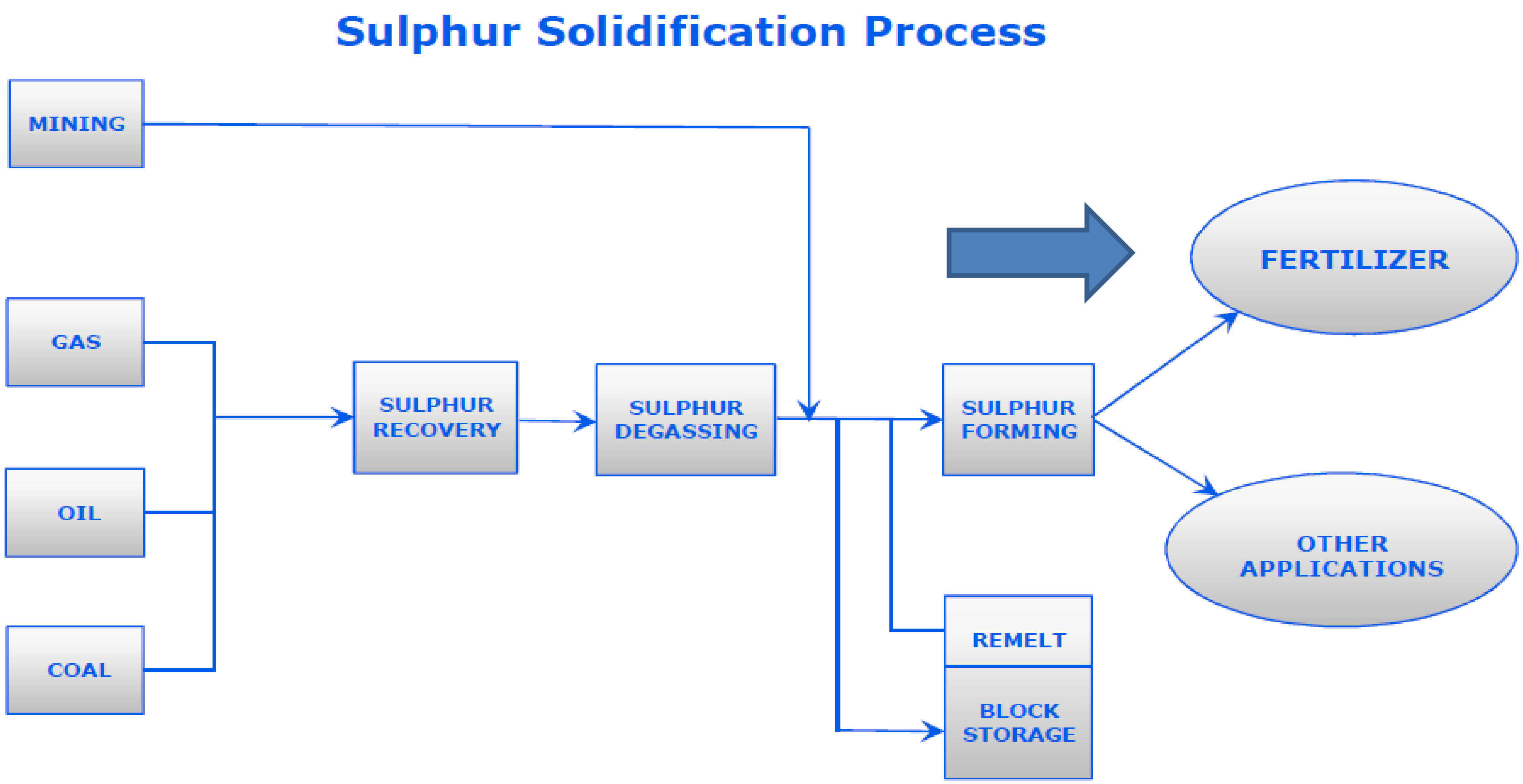
The novelty of this study was

to use **sulfur-bentonite** linked to **recalcitrant organic matrices**

DUAL AIM

1. improving the quality and fertility of alkaline soils in a sustainable way.
2. increasing plant productivity.

BRIEF INTRODUCTION TO THE SULFUR PROCESS



- Pastilles were developed from mixtures of 10% sodium

Pastilles

Granules

The pastilles of sulfur bentonite were linked with agriculture wastes

Elemental S

Bentonite

Dried orange residues

Dried olive residues

Experiment with soil

• Alkaline sandy-loam soils, in pots, have been amended with sulfur-bentonite + orange waste “A”; sulfur-bentonite + olive waste “B”, sulfur - bentonite “C” at the concentration of 0.88 g l^{-1}. Not amended soil was used as control.

• Soil in pots was regularly watered to maintain 70% of field capacity and 2 months after treament, soil chemical and biological parameters were detected.

Soil chemical and biochemical parameters

2 months after treatment

RESULTS

Treatment	Tex						FDA	MBC
Control	SL	8.4^{a}	200	11	1.49^{c}	0.28^{d}	42^{b}	842^{d}
A	SL	6.8^{d}	437	10	1.68^{a}	0.50^{a}	46^{a}	1245^{a}
B	SL	7.2^{c}	419	10	1.63^{ab}	0.33^{b}	44^{a}	1007^{b}
C	SL	7.6^{b}	485	10	1.58^{a}	0.30^{c}	43^{b}	890^{c}

Experiments with plants:

In Vitro experiments

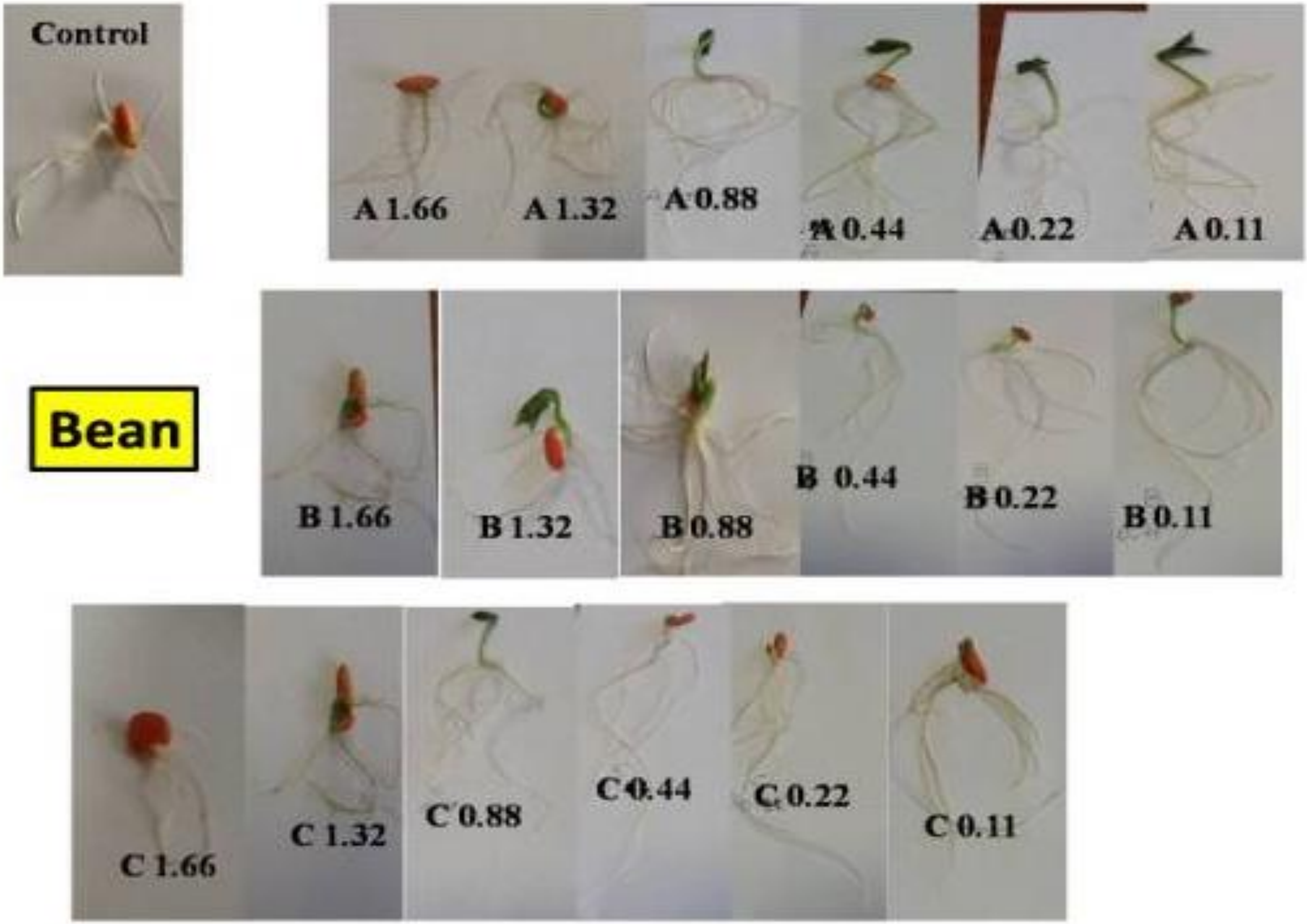
Germination in petri dishes in growth chamber at 25°C and 70% humidity (red onion and bean) with sulfur-bentonite + orange waste "A"; sulfur-bentonite + olive waste "B"; sulfur -bentonite "C" at the concentrations of 1.66; 1.32; 0.88; 0.44; 0.22; 0.11 g l^{-1} and control "distilled water."

In VITRO RESULTS

Red Onion	Treatment	Germination %	Radicle cm	Shoot cm
Control	water	100	1.5^{f}	3.0^{e}
A	0.11	100	3.2^{b}	4.2^{b}
	0.22	100	4.5^{a}	4.3^{b}
	0.44	100	4.6^{a}	4.4^{b}
	[illegible]	[illegible]	[illegible]	…7^{a}
	[illegible]	[illegible]	[illegible]	…9^{d}
	[illegible]	[illegible]	[illegible]	…9^{d}
B	[illegible]	[illegible]	[illegible]	…7^{c}
	[illegible]	[illegible]	[illegible]	…7^{c}
	[illegible]	[illegible]	[illegible]	…7^{c}
	[illegible]	[illegible]	[illegible]	…8^{c}
	[illegible]	[illegible]	[illegible]	…5^{d}
	[illegible]	[illegible]	[illegible]	…0^{e}
C	0.11	100	0.9	1.6^{f}
	0.22	100	1.2^{g}	1.6^{f}
	0.44	100	0.8^{i}	1.6^{f}
	0.88	100	0.8^{i}	1.6^{f}
	1.32	50	0.8^{i}	1.2^{g}
	1.66	35	0.8^{i}	1.0^{h}


A 1.66
A 1.32
A 0.88
A 0.44
A 0.22
A 0.11
Control
B 1.66
B 1.32
B 0.88
B 0.44
B 0.22
B 0.11
Control
Red Onion
C 1.66
C 1.32
C 0.88
C 0.44
C 0.22
C 0.11
Control

Bean	Treatment	Germination %	Radicle cm	Shoot cm
Control	water	80	8.5^{i}	2.5^{g}
	0.11	100	16°	3.8^{e}
	0.22	100	19^{c}	7^{b}
	0.44	100	22^{b}	7^{b}
A	0.88	100	24^{a}	9^{a}
	1.32	90	22^{b}	0.8
	1.66	85	18^{d}	0
	0.11	100	19^{c}	2.0^{h}
	0.22	100	19^{c}	2.5^{g}
	0.44	100	19^{c}	2.5^{g}
B	0.88	100	24^{a}	4.5^{d}
	1.32	95	24^{a}	4.0^{e}
	1.66	90	22^{b}	3.8^{e}
	0.11	100	14^{f}	3.5^{f}
	0.22	100	18^{d}	4.0^{e}
	0.44	100	18^{d}	4.5^{d}
C	0.88	100	21^{b}	6.5^{c}
	1.32	70	11^{g}	2.5^{g}
	1.66	62	9.5^{h}	0



Control
A 1.66
A 1.32
A 0.88
A 0.44
A 0.22
A 0.11
Bean
B 1.66
B 1.32
B 0.88
B 0.44
B 0.22
B 0.11
C 1.66
C 1.32
C 0.88
C 0.44
C 0.22
C 0.11

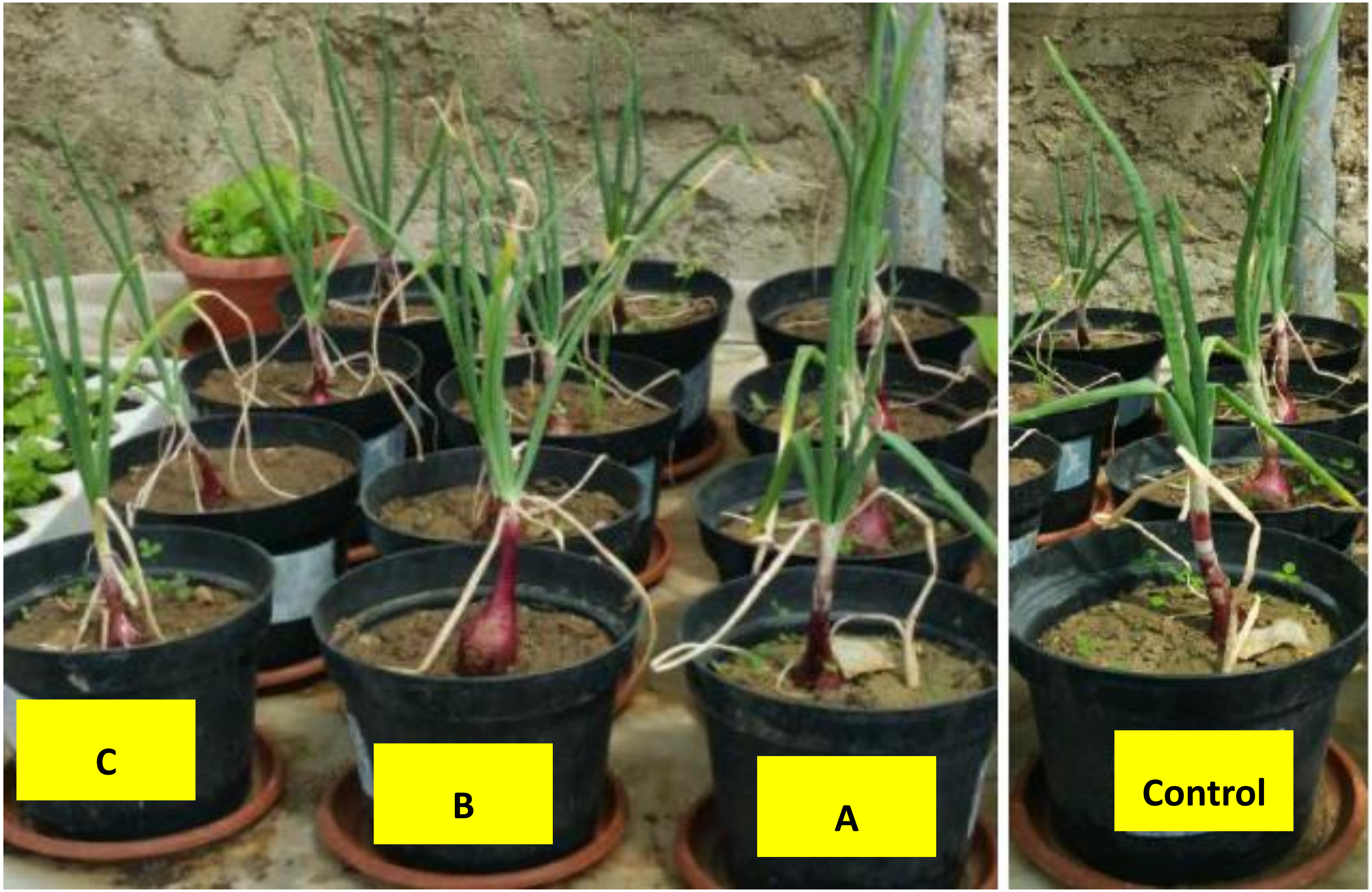
Pot experiments

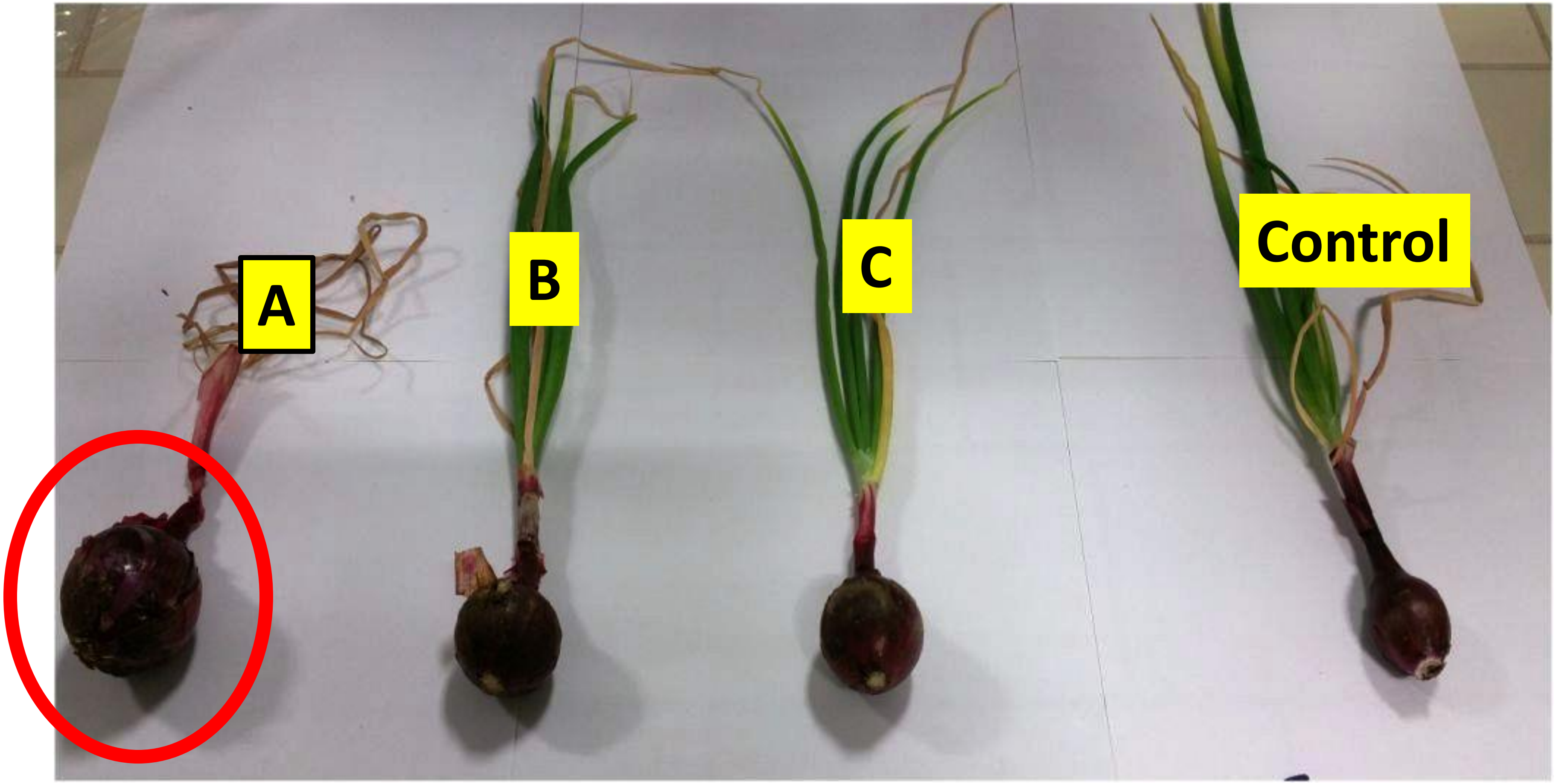
Phenotypic and growth measurements, in pots with alkaline soil, fertilized with sulfur-bentonite + orange waste “A”; sulfur-bentonite + olive waste “B”; sulfur -bentonite “C” at the concentrations of 0.88 g l^{-1} and control “not ammended” (red onion, bean and chili pepper). The plants were regularly watered to maintain 70% of field capacity.

Phenotypic and growth parameters of **red onion** 3 months after treatment (A, B, C) with respect to control (not treated) number in the same column followed by different letters are statistically different p ≤0.05

POT RESULTS

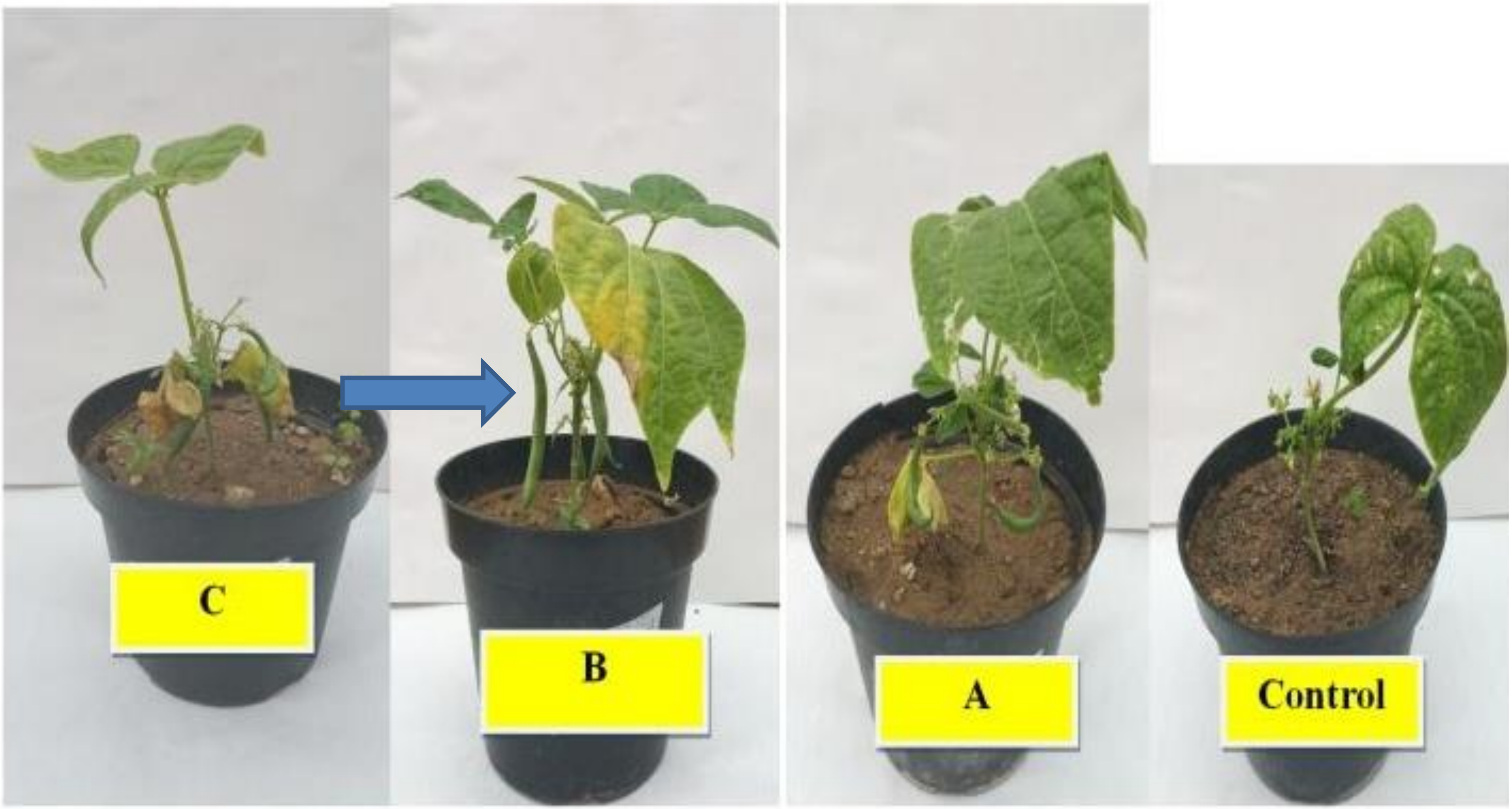
Treatment				**ruit diameter cm**
Control	38^{c}	5^{b}	4.6^{d}	3.1^{c}
A	**46^{a}**	**6^{a}**	**6.3^{a}**	**4.4^{a}**
B	38^{c}	5^{b}	5.6^{b}	3.5^{b}
C	41^{b}	5^{b}	5.0^{c}	3.4^{b}


C
B
A
Control


A
B
C
Control

Phenotypic and growth parameters of **bean** 3 months after treatment (A,B, C) with respect to control (not treated) number in the same column followed by different letters are statistically different $p \leq 0.05$

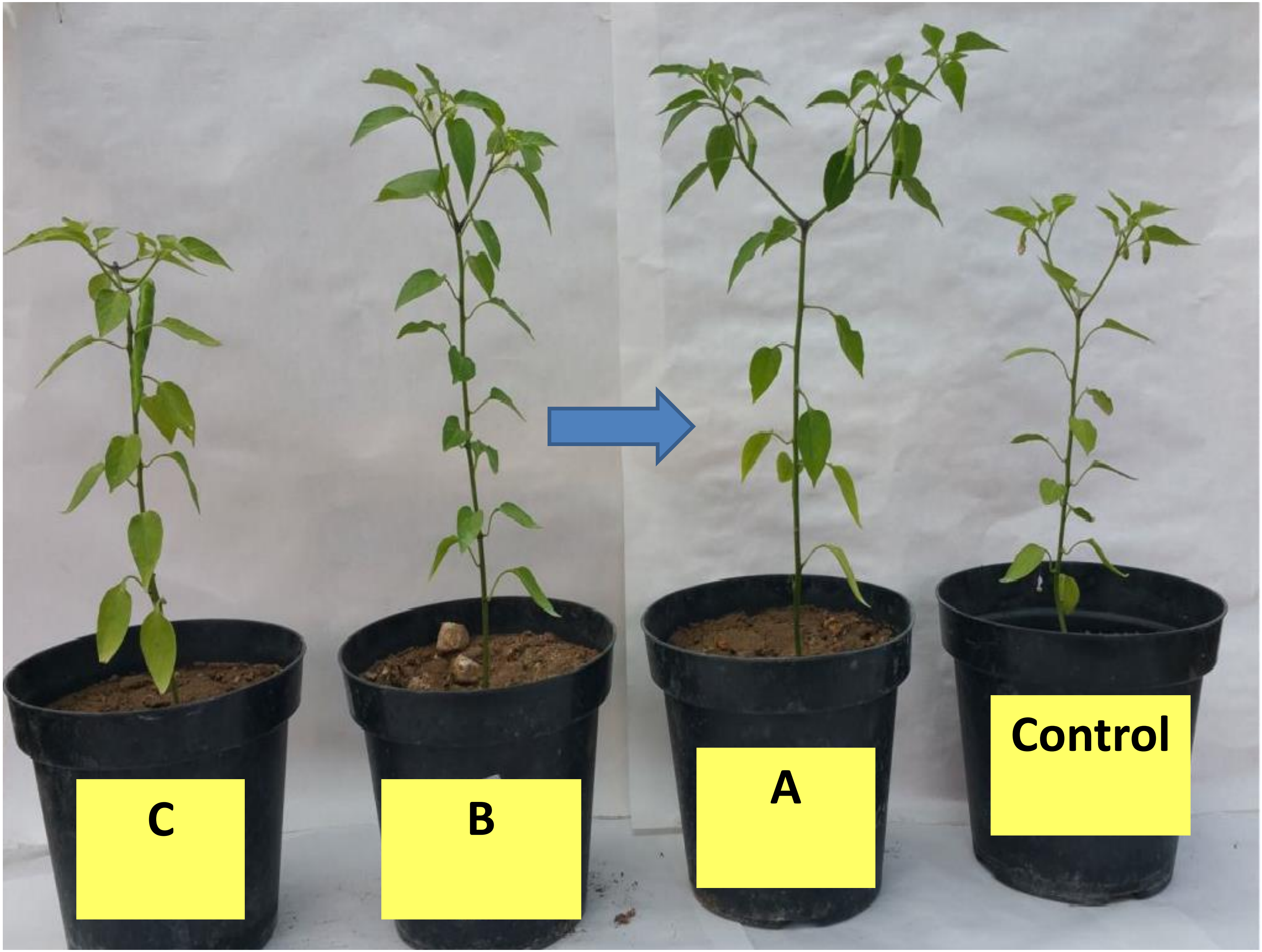
Treatment	**Plant height cm**	**Leaf number**	**Flower number**	**Fruit number**
Control	15^{c}	5^{d}	1^{c}	2^{c}
A	18^{b}	10^{b}	3^{b}	5^{b}
B	**20^{a}**	**14^{a}**	**8^{a}**	**10^{a}**
C	16^{c}	7^{c}	2^{c}	5^{b}



Bean

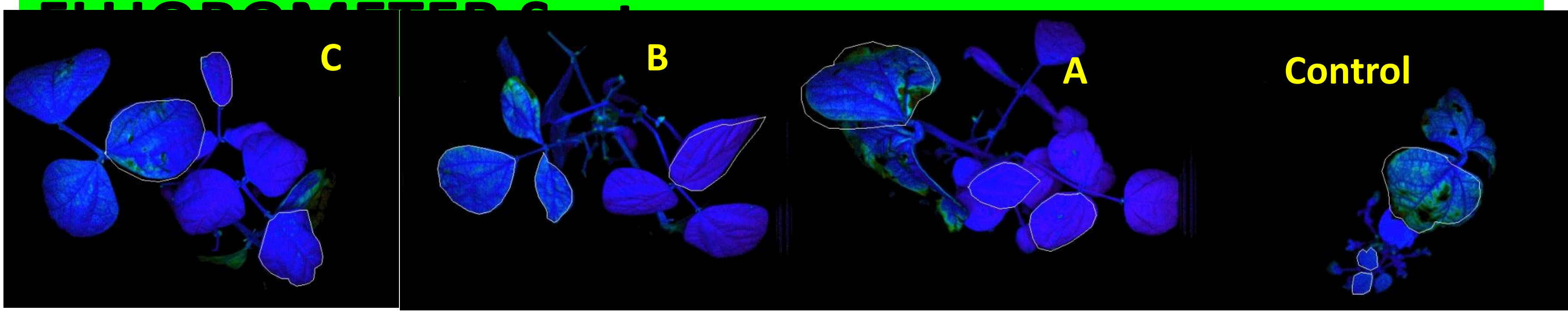
Phenotypic and growth parameters of **<u>cayenna red pepper</u>** 3 months after treatment (A, B, C) with respect to control (not treated). Number in the same column followed by different letters are statistically different $p \leq 0.05$

Treatment	**Plant height cm**	**Leaf number**	**Flower number**	**Fruit number**	**Fruit length cm**
Control	26^{c*}	30^{b}	2^{c}	1^{d}	0.3^{d}
A	**32^{a}**	**43^{a}**	**4^{a}**	**4^{a}**	**8^{a}**
B	30^{b}	33^{b}	3^{b}	3^{b}	6^{b}
C	27^{c}	33^{b}	3^{b}	2^{c}	3^{c}


C
B
A
Control

The performance of the fertilized plants was evaluated by assessing the photosynthetic effi[…]ed plants) by using IMAGING-PAM CHLOROPHYLL

FV/FM = reaction centre acivity in the PSII



Species	Treatment	F	Fm	F0	YII	Y(NPQ)	NPQ	YNO	qN	qP	qL	ETR	Inh	Fv/Fm
Red pepper	Control	0.147	0.222	0.153	0.310	0.314	0.219	0.364	0.859	0.94	0.91	10	0.15	0.310
	A	0.142	0.289	0.150	0.592	0.204	0.204	0.271	0.698	1.000	0.95	15	0.17	0.680
	B	0.127	0.226	0.120	0.546	0.180	0.219	0.321	0.769	0.94	0.93	13	0.13	0.470
	C	0.182	0.301	0.199	0.394	0.311	0.242	0.265	0.816	0.94	0.83	12	0.14	0.338
bean	Control	0.107	0.157	0.081	0.391	0.318	0.289	0.222	0.380	0.89	0.76	15	-0.28	0.484
	A	0.129	0.263	0.094	0.532	0.272	0.196	0.196	0.659	0.95	0.87	16	-0.22	0.640
	B	0.078	0.190	0.067	0.553	0.298	0.182	0.149	0.804	0.91	0.85	17	-0.28	0.647
	C	0.082	0.180	0.078	0.566	0.214	0.194	0.220	0.675	0.92	0.86	15	-0.18	0.560
Red onion	Control	0.075	0.182	0.099	0.588	0.358	0.251	0.255	0.663	0.95	0.90	13	-0.02	0.456
	A	0.143	0.321	0.120	0.593	0.157	0.130	0.250	0.452	0.95	0.89	17	-0.05	0.626
	B	0.120	0.302	0.120	0.491	0.267	0.102	0.240	0.551	0.92	0.90	16	-0.05	0.602
	C	0.601	0.246	0.130	0.502	0.304	0.095	0.194	0.314	0.69	0.65	14	-0.05	0.471

Chemical characteristics of sulfur-bentonite + orange waste "A", sulfur-bentonite + olive waste "B" and sulfur-bentonite "C"

	pH	EC	WSP	Na^+	$NH4^+$	K^+	Mg^{++}	Ca^{++}
		µS cm^{-1}	µg tannic acid/l	mg/l	mg/l	mg/l	mg/l	mg/l
A	**6.5**	**95**	**1107**	**16**	**nd**	**3.2**	**4.6**	**nd**
B	**6.8**	**106**	**738**	**26**	**0.6**	**4.0**	**3.1**	**nd**
C	**7.5**	**148**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**

Conclusion

•Sulfur bentonite is a corrective-nutritional fe[illegible]se unique formulation in pastilles of 2-4-mm allows the [illegible]bution and quick disintegration in soil, either in open field or [illegible]lized form.

• The easy disintegration allows [illegible] correction of the soil pH improving the cultivability of alka[illegible] saline [illegible]rt time.

•The lowering of the pH value [illegible] the [illegible]ment facilitates mobility and absorption o[illegible]ther [illegible]gen, phosphorus and potassium.

•The addition of agricultural wastes to su[illegible]cularly of orange waste, improves the fertilizer effects o[illegible]ntonite.

WORK IN PROGRESS


R E C Y C L E


danke
thank you
gracias
obrigado
merci