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Effect of an organo-mineral fertilizer produced by recovered sulphur & orange wastes on winter wheat growth as a sustainable mitigation of soil desertification

Konstantinos Zoukidis[1*], Christos Vasilikiotis[1], Athanasios Gertsis[1], Antonio Scialletti[2], Georgios Strouthopoulos[1] and Evangelos Vergos[1]

[1] Department of Sustainable Agriculture and Management, Perrotis College, Division of the American Farm School, Thessaloniki, Greece.
[2] Strategy & Business Development Advisor, Project Leader for LIFE Project "RecOrgFert PLUS", SBS Steel Belt Systems Srl, Milano, Italy.
**Corresponding author: kzouki@afs.edu.gr*

European Environment Agency reports that 8% of the European territory (~14 million hectares) already shows some degrees of desertification. The uses of chemical fertilizers are causing substantial loss of soil fertility and especially in arid and semi-arid regions where desertification is a major problem. Intensive tillage and excessive fertilization practices affecting nutrient chemical properties, nutrient availability and cycle and crop productivity. In addition, aims of European Union's (EU) Green Deal program are to reduce the reliance on agrochemicals and chemical fertilizers for a more sustainable agriculture, by utilization of organic fertilizers to preserve soil fertility. One European Commission's goal is achieving a 30% reduction in non-renewable resource usage by recycling them into fertilizers (Marra et al., 2023). The reuse of organic waste materials for agricultural purposes (i.e. citrus waste) enhances soil quality by enriching soils with improving soil biodiversity, soil organic carbon and nutrients (Corti et al. 2012). Organic and industrial wastes can represent a great opportunity to produce organic-mineral fertilizers by using principles of circular economy with a great number of advantages for agriculture and environment (Muscolo et al., 2022). Sulphur is the fourth most critical plant nutrient after nitrogen, tends to be deficient primarily in high-yield, arid, semiarid, and desertified soils (Yesmin et al. 2021). The fertilizer was tested for pathogens and heavy metals and the results evidenced absence of pathogens and heavy metals (Muscolo et al. 2021). The new fertilizer mix of Sulphur, Bentonite and Pastazzo (orange waste dried in powder), which improve the growth and the productivity of plants, is rich in sulphur, nitrogen, potassium, phosphorous and micronutrients, contains more carbohydrates simple and complex, amino acids, organic acids, increased microbial soil activity to produce enzymes that need to release nutrients and increase the soil fertility improving soil biodiversity and soil ecosystems. Main results and environmental benefits that expected at the end of the experiment was waste reduction, reduction of greenhouse gas (GHG) emissions, create a new organic-mineral fertilizers that can replace chemical fertilizers, improve soil properties and soil protection (decreasing soil pH, increase organic carbon, nitrogen, Cation Exchange Capacity (CEC), nutrients, microbial biomass, improving soil biodiversity and improving soil quality) and soil surface with desertification effect mitigated (Marra et al., 2023). The new fertilizer type aims to contribute to the following European environmental policies and legislations with a focus on soil and land degradation: EU Thematic Strategy for Soil Protection, European Green Deal and aligns with the missions of FAO and United Nations Sustainable Development Goals, on eradicating hunger through sustainable soil management.

The objective of this study was to turn orange (citrus) waste and recovered sulphur into a high-quality innovative organo- mineral fertiliser and soil improving product (named as **RegOrgFert**),, which can be used in alkaline and degraded lands to improve soil fertility and productivity. The research / experimental cultivation of durum wheat took place at Perrotis College, a division of American Farm School (AFS), Thessaloniki, Greece, on a field with an area of approximately 12 ha (~ 3 ha per treatment) (Fig. 1). The fertilization mixing of sulphur, bentonite and agricultural wastes (pastazzo) to obtain a new organic-mineral fertilizer was applied before seeding the durum wheat (variety Giulio at 250 kg/ha rate), and at the middle of vegetative cycle and will be compared to other fertilizers currently used in agriculture such as chemical fertilizer [winter fertilization (200 kg/ha) 16-20-0 + SO_3 and spring fertilization (150 kg/ha) 40-0-0 + 14% SO_3] and compost cow manure (20 m^3/ha), and an unfertilized soil plot will be used as the control treatment. Fertilization with the new organic-mineral fertilizer ¨RegOrgFert¨ (476Kg/ha) will be twice per year (cultivation period 2022-2023 and 2023-2024). In the end of every year's cultivation period, measurements were conducted for field products parameters [yellow index or vitreous (kernels) (%), protein

content, gluten index, total yield per treatment], soil parameters [soil texture, soil moisture (VWC%), soil electrical conductivity (dS/m), soil pH, CEC (meq/100g), total N, phosphorus and exchange K, C/N ratio] and evaluate total yield. Moreover, more analysis has been done, such as: agronomic traits [root, stem & seed head (fresh and dry weight, length) and number of tillers], analyze nutrient content in plant tissues and measuring soil respiration (CO_2 flux). More specifically the study aims to compare the effectiveness of the new organic-mineral fertilizer (Sulfur-Bentonite-Pastazzo) on soils and crops with the soils treated with chemical fertilizers and composted cow manure.

The results varied between the two years due to very low rainfall (about 40 % less) during the rowing season during the second year. Overall the results (Table 1) indicated that yield and other agronomic traits highly increased in the RegOrgFert fertilizer vs. Chemical fertilizer and the other treatments applied. The last year, the total yield and test field products and soil parameters were the best in the RegOrgFert treatment from all the others treatments (manure, chemical fertilizer and control). During these 2 years, soil pH decreased, and soil carbon (SOC) and soil Cation Exchange Capacity (CEC) increased and soil respiration [CO_2 flux ($\mu mol\ m^{-2}\ s^{-1}$)] was the maximum measurement. In conclusion, the use of the new mix RegOrgFert is proven on wheat production and recommended as a means to improve soil properties responsible for reducing desertification effects.

Table 1. Agronomic traits and soil parameters, for the 2 year study

	Weights (g/plant)				Soil parameters measured			
Treatments	**Dry seed**	**Dry stem**	**Dry root**	**Yield (kg/ha)**	**CO_2 Flux ($\mu mol\ m^{-2}\ s^{-1}$)**	**Soil pH**	**SOC (%)**	**Year**
Control	0,7	0,8	0,3	1.770	5	8	2,32	2023
Cow Manure	1,0	1,4	0,6	1.569	7	7,9	3,44	2023
Reg Org Fert	2,2	2,1	0,9	1.747	10	7,9	2,34	2023
Chemical Fertilizer	1,1	1,5	0,5	1.976	10	7,9	4	2023
Control	0,5	0,4	0,1	649	4	8	2,546	2024
Cow Manure	0,4	0,9	0,2	522	6	7,7	3,04	2024
Reg Org Fert	1,1	0,7	0,2	1.387	6	7,6	3,19	2024
Chemical Fertilizer	0,6	0,9	0,1	751	4	7,9	4,1	2024

Key words: organo-mineral fertilizer, sulphur - bentonite and orange waste, pastazzo, winter durum wheat and soil desertification.

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