Development of a controlled release NPK fertilizer – coating optimization and LED modules system for smart gardening

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The aim of this work is to optimize the efficiency of a Nitrogen enriched coating previously employed on a Potassium-Phosphorous ceramic aggregate, derived by leftovers, in order to develop a new controlled release NPK fertilizer with a core-shell structure. An important add value of this study derives by the valorization of waste in a circular economy perspective. To improve the agronomical results, among the parameters considered in this study also the effect of light on crops growth has been considered, by developing a prototype based on a system of LED modules with adjustable emitted intensity and wavelengths (Figure 1). Design of Experiment (DoE) methodology was used to analyze data and minimize empirical tests.

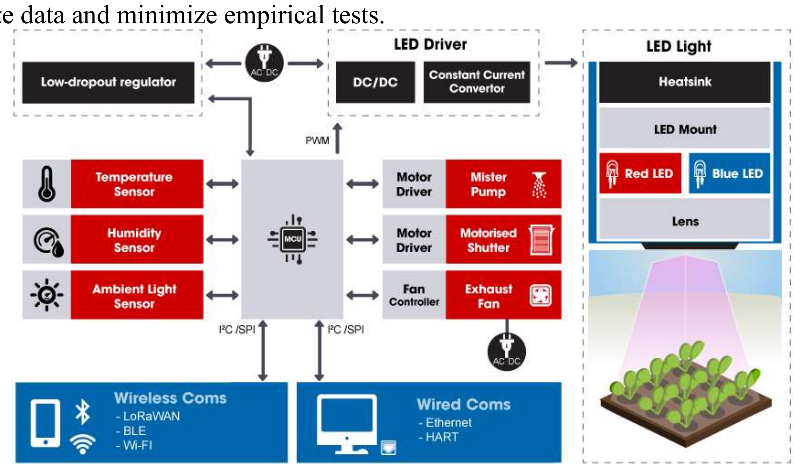

Figure 1: explanatory diagram of the system of led modules for plants growth

A ceramic light-weight aggregate (LWA) rich in phosphorus and potassium (Table 1) obtained from biological leftovers was employed as fertilizer's core. Black soldier fly (BSF) prepupae (Figure 2) defatted, therefore, N-enriched (7.90 wt %) biomass was considered as base materials for the fertilizer coating (Caligiani *et al.*, 2018). BSF prepupae were derived from the treatment of organic wastes as reported by Barbi et al (2018).

Table 1:Chemical analysis of LWA in wt%

	Oxide (wt%)	LWA (%)
Macronutrients	K_2O	8.40
	P_2O_5	5.63
Secondary	SiO_2	47.35
	CaO	8.85
	MgO	2.77
	Na_2O	0.75
Micronutrients	Fe_2O_3	5.70
Others	Al_2O_3 , TiO_2	19.81
Toxic	PbO	<0.05
	LoI	0.70


Figure 2: Black Soldier Fly (BSF) prepupae

Through Doe methodology, coating compositions that optimize mechanical resistance and macro-nutrients release were identified by modifying coating plasticizer and thickness, and therefore application methods. LED modules were developed and then optimized through DoE methodology. Finally, plant species suitable for growth tests in a controlled environment, with temperature and humidity measurement, were identified as basil, tomato, bell pepper (Groher *et al.*, 2019; Joshi *et al.*, 2019). The growth of plants in different tests (Figure 3) has been evaluated with dry mass and size measurements. Fertilizer and LED modules separate effects have been evaluated, as well as their interaction effects through DOE methodology.

Use of defatted N-enriched BSF prepupae biomass for potassium and phosphorous ceramic LWAs ensures controlled nutrient release, as highlighted in previous studies, considering the coating barrier effect (Chen *et al.*, 2018)(Azeem *et al.*, 2014). Coating's thickness and mechanical resistance in water (Figure 4) have been measured for different compositions highlighting that their optimization represent a key point in a scale up perspective, ensuring also a well-tailored nitrogen release over time. LED modules, already studied for horticulture (Parma and Baxant, 2018; Dieleman *et al.*, 2019), have been used in addition to sunlight to enhance growth of plants through emission of different wavelengths (blue= 446 nm, green= 530 nm, red= 663 nm, amber= 627 nm). The modification of the wavelengths emitted by the module both during the single day, and during the entire life cycle of the plants has led to different effects on their growth.

Figure 3: growth tests on different plants using LED modules

Figure 4: low mechanical resistance of fertilizer coating in water

In this study the combined use of a controlled-release NPK, whose coating has been optimized, and LED modules for horticulture, lead to the development of a promising and versatile system for the growth of plants in a controlled environment. This system designed using synergies between circular economy and agronomical requirements is potentially adaptable to any type of plant, if the needs of nutrients and light are known the system can be optimized through the Doe methodology.

Azeem, B. *et al.* (2014) 'Review on materials & methods to produce controlled release coated urea fertilizer', *Journal of Controlled Release*. Elsevier, 181, pp. 11–21. doi: 10.1016/J.JCONREL.2014.02.020.

Barbi, S. *et al.* (2018) 'Rational design and characterization of bioplastics from Hermetia illucens prepupae proteins', *Biopolymers*, (November 2018). doi: 10.1002/bip.23250.

Barbi, S. *et al.* (2020) 'Valorization of seasonal agri-food leftovers through insects', *Science of the Total Environment*. Elsevier B.V., 709, p. 136209. doi: 10.1016/j.scitotenv.2019.136209.

Caligiani, A. *et al.* (2018) 'Composition of black soldier fly prepupae and systematic approaches for extraction and fractionation of proteins, lipids and chitin', *Food Research International*. Elsevier, 105(December 2017), pp. 812–820. doi: 10.1016/j.foodres.2017.12.012.

Chen, J. *et al.* (2018) 'Environmentally friendly fertilizers: A review of materials used and their effects on the environment', *Science of the Total Environment*. Elsevier B.V., 613–614, pp. 829–839. doi: 10.1016/j.scitotenv.2017.09.186.

Dieleman, J. A. *et al.* (2019) 'Integrating morphological and physiological responses of tomato plants to light quality to the crop level by 3D modeling', *Frontiers in Plant Science*, 10(July), pp. 1–12. doi: 10.3389/fpls.2019.00839.

Groher, T. *et al.* (2019) 'Influence of supplementary LED lighting on physiological and biochemical parameters of tomato (Solanum lycopersicum L.) leaves', *Scientia Horticulturae*. Elsevier, 250(June 2018), pp. 154–158. doi: 10.1016/j.scienta.2019.02.046.

Joshi, N. C. *et al.* (2019) 'Effects of daytime intra-canopy LED illumination on photosynthesis and productivity of bell pepper grown in protected cultivation', *Scientia Horticulturae*. Elsevier, 250(September 2018), pp. 81–88. doi: 10.1016/j.scienta.2019.02.039.

Parma, M. and Baxant, P. (2018) 'Experimental LED Luminaire and Its Usage at Study of Plant Physiology', *7th Lighting Conference of the Visegrad Countries, LUMEN V4 2018 - Proceedings*, pp. 0–2. doi: 10.1109/LUMENV.2018.8521002.