PhD School on Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XXXVII cycle, 2021-24)

Project draft

1.Field of interest

AGR/04 - VEGETABLE AND ORNAMENTAL CROPS

2.Project title: Basic and applied research approaches for improving light use efficiency in vegetable crops

3.Tutor Giacomo Cocetta (Website: https://www.unimi.it/en/ugov/person/giacomo-cocetta; Scopus Author ID: 37664557800; Orcid Author ID: 0000-0002-8796-4245)

Co-tutor: Antonio Ferrante (Website: https://www.unimi.it/en/ugov/person/antonio-ferrante; Scopus Author ID: 35145567000; Orcid Author ID: https://orcid.org/0000-0001-7781-9784)

4.Relevance of the topic and state of the art: mezza pagina

The interest toward the possibility of growing vegetables in indoor and protected systems is increasing. New forms of vegetables production are now available and includes greenhouse, indoor cultivation, and vertical farms. The main problem of greenhouses and indoor crop cultivation systems is the correct choice of artificial light source and the quality of light spectrum. In greenhouse and indoor cultivations, plant density is higher compared to open field and plants must compete for light and nutrients. Nowadays, advanced systems for indoor horticulture are based on light emitting diodes (LED) for improving crop growth, enhancing the plant productivity, and promoting higher nutritional quality. In closed environments, as indoor growing modules, the lighting system represents the only source of light and its characteristics in terms of light intensity, spectrum composition and photoperiod are fundamental for obtaining the best performances and the higher efficiency in the use of light, water, and nutrients. The lighting distribution and the digital controls are fundamental for tailoring the spectral distribution on each plant in specific moments of its growth and play an important role for optimizing growth and produce high-quality vegetables. LED lights can increase plant growth and yield, while promoting higher nutritional quality, since some light intensities increase the biosynthesis of important secondary metabolites and enhance the antioxidants content of leaves and fruits. By using LED light, it is possible to set up different “light recipes” and to modify them to maximize the positive effects for a specific crop at a specific phenological stage. The light spectra regulation includes mainly the regions of blue and red, which are known to be the key regulators of plants growth and physiological responses related to crop quality. Moreover, applying ultraviolet radiation (UVR) to vegetables and fruits, has been shown to be a simple and effective technology to biofortify plant tissue with secondary metabolites. Current literature on the mechanisms and effects of UVA and UVB radiation on the accumulation of different bioactive phytochemicals are showing the effectiveness of this light regions and their possible application during cultivation as well as in postharvest. However, some of the mechanisms and modes of action by which specific light radiations and intensities affects crops yield and quality are still unknown. To promote the use of light as a tool for improving vegetables crop systems efficiency and quality, it is important to further study these aspects and to investigate the plants physiological, biochemical, and genetic traits, that could be linked to a higher attitude for indoor cultivation and artificial lighting.

5.Layout of the project (draft)

The research activities will be focused on the optimization of light management for some important vegetable crops, including leafy vegetables (spinach, lettuce, rocket, swiss chard) and tomato. These activities will be carried out indoor, using artificial light as unique source of light (indoor) or in experimental greenhouse, where artificial light will be administered, as a complement to natural light.
Moreover, UVB light treatments will be performed during cultivation and storage, to characterize the plants specific responses and the effect on crops quality and yield.
Part of the project will be focusing on the molecular responses induced by the different lighting regimes, as well as on the use of mutants, that will be studied to individuate some traits potentially linked to a higher adaptability of the crops to the indoor cultivation systems.

5.1.Materials & Methods: da mezza pagina ad una pagina massimo

Plant material

Plants for the selected species will be grown in greenhouse or in a LED-equipped growth chamber. Comparisons will be made with other common sources of artificial light, including HPS and fluorescence lamps. Infra-red (IR) supplementation will be also tested, to evaluate the possibility to control temperature together with light. The cultivation system will be selected based on the specific experimental needs, among hydroponic floating system or substrate pot cultivation. For leafy vegetables the cultivars studied will be selected among those mainly used for baby leaf production, while for tomato, some widespread cultivars, used for industrial and/or fresh consumption purposes, will be selected.
The evaluation of crops performance will be carried out *in vivo* by measuring non-destructive parameters including chlorophyll fluorescence, chlorophyll content, nitrogen balance index and flavonoids.
Analytical determinations will be carried out to estimate the changes in quality parameters and physiological responses in leafy vegetables (sugars, nitrate, carotenoids, phenolic compounds, glucosinolates) and fruits (total soluble content, titratable acidity, pigments content, colour). Different analyses will be carried out to estimate the oxidative/tissue stress potentially induced by non-optimal light recipes and will include the analysis of lipid peroxidation (TBARS), electrolyte leakage, and oxidative stress (superoxide anion).
Gene expression analyses and transcriptome analyses will be carried out to study the molecular responses induced by specific light treatments in different crops.
Mutants will be generated for selecting new genotypes adapted to different light conditions especially for indoor cultivation. The spinach seeds will be treated with four Ethyl methanesulfonate (EMS) concentration doses (0.0%, 0.5%, 1.0%, and 2.0%), and four EMS exposure periods (6, 12, 24, and 48 hours). Seeds will be screened under different light conditions and the best genotypes will be studied and characterised.

5.2. Schedule and major steps (3 years): mezza pagina max

WP1 (year 1): Light optimization. The activity will be focused on the individuation of the best light management for at least two representative crops. The protocol of optimization will include spectrum composition, light intensity, and photoperiod.
WP2 (year 2-3): Molecular approaches for understanding the mechanisms and modes of action behind the beneficial effects of light-mediated plants quality enhancement. Gene expression analyses and transcriptome RNAseq analyses.

WP3 (2-3): Study of plant mutants, for the individuation of genetic traits possibly linked to a better attitude to indoor cultivation/artificial lighting. A possible candidate for this experiment will be spinach.

6. Available funds (source and amount)
Private research funds 20000 €

7. Literature: max 10 citazioni

1. Cocetta, G., Casciani, D., Bulgari, R., Musante, F., Kołton, A., Rossi, M., & Ferrante, A. (2017). Light use efficiency for vegetables production in protected and indoor environments. The European Physical Journal Plus, 132(1), 1-15.
2. Jacobo-Velázquez, D. A., Moreira-Rodríguez, M., & Benavides, J. (2022). UVA and UVB Radiation as Innovative Tools to Biofortify Horticultural Crops with Nutraceuticals. Horticulturae, 8(5), 387.
3. Loconsole, D., Cocetta, G., Santoro, P., & Ferrante, A. (2019). Optimization of LED lighting and quality evaluation of romaine lettuce grown in an innovative indoor cultivation system. Sustainability, 11(3), 841.
4. Mitchell, C. A., & Sheibani, F. (2020). LED advancements for plant-factory artificial lighting. In Plant Factory (pp. 167-184). Academic Press.
5. Sipos, L., Boros, I. F., Csambalik, L., Székely, G., Jung, A., & Balázs, L. (2020). Horticultural lighting system optimalization: A review. Scientia Horticulturae, 273, 109631.
6. Folta, K. M. (2019). Breeding new varieties for controlled environments. Plant Biology, 21, 6-12.
7. Kreuger, M., Meeuws, L., & Meeuws, G. (2018). Total indoor farming concepts for large-scale production. In Smart Plant Factory (pp. 125-135). Springer, Singapore.