Photosynthetic responses of plants exposed to CeO_2 nano-powder

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INTRODUCTION

Nanotechnology is not a chemical novelty but the advances in the chemical field have allowed to handle and give specific features to these particles spreading its use by almost all industry of goods (Ju-Nam & Lead 2008). In this context Cerium oxide (CeO_2) has become ecologically relevant as an air pollutant, as forming prominent nanoparticles (CeO_2-NP) upon use in diesel fuel (Park *et al*. 2008). In the atmosphere, CeO_2-NP can have toxic effects when in contact with biological structures such as plant leaves. Despite that, the research has been concentrated on its belowground toxic effects on plants, after being washed out into soil (Dietz & Herth 2011). Its phytotoxicity is associated with the induction of reactive oxygen species (ROS), either by direct physical impact (PI) or defence-related metabolism (DRM). Direct physical impact of CeO_2-NP results in lowered maximum photosynthetic efficiency ($max\varphi_{PSII}$) and Quinone A oxidation rates (qL) and increased energy loss through non-photosynthetic quenching (NPQ) (Gao *et al.* 2013) . In contrast, DFM enhances $max\varphi_{PSII}$ or qL (Stael *et al.* 2015, see table 1).

HYPOTHESIS

We hypothesize that CeO_2-NP injury is related to physical impact on tissue structures reducing the photosynthetic activity through ROS production at the surface of CeO_2-NP.

MATERIAL AND METHODS

One leaf from seven plants of different species received CeO_2-NP on leaf surface through of a fine brush. Despite of the amount of CeO_2-NP powder attached on leaf be dependent from leaf surface characteristics, the brush with nanopowder was swept five times on adaxial leaf surface to minimize the variance of quantity applied in each species. Due to their economic relevance were chosen the species *Zea mays*, *Ocimum basilicum*, *Brassica oleracea, Rudbeckia hirta, Salvia officinalis, Quercus robur and Helianthus annuus* as models in this study. Induction curves (Baker 2008) with actinic light intensity of 320 µmol photons m^{-2} s^{-1} were taken before and after the use of CeO_2-NP and weekly repeated during one month. The plants were maintained in growth chamber under temperature of 25 °C, RH of 70 % and light intensity around 300 µmol photons m^{-2} s^{-1}

Figure 1: Species selected to receive CeO_2-NP in the growth chamber and during the application in the fume hood.

The concentration of CeO_2 in the leaves was determined after one month by inductively coupled plasma analysis (ICP, n=4).

	DRM		PI
	PTI	ETI	
φmax_{PSII}	↑	↓	↓
NPQ	↓	↑	↑
qL	-	↑	↓

Table 1: Profiles of photosynthetic metabolism. The arrows point the sense of increase or decrease of variables in agree with defence-related metabolism (DRM) or physical impact (PI). Abbrivations: PTI, pathogen-triggered immunity; ETI, effector-triggered immunity. Modified from Stael *et al.* (2015).

RESULTS AND DISCUSSION

	CeO_2-NP Treated
Brassica oleracea	0.40
Helianthus annuus	0.23
Ocimum basilicum	0.15
Quercus robur	0.25
Rudbeckia hirta	0.53
Salvia officinalis	0.20
Zea mays	0.29

Table 2: Coefficient of variation of CeO_2 concentration present in the CeO_2-Nanoparticles groups by species. The coefficient of variation was in mean 0.2 showing homogeneity in the treated groups except by *Rudbeckia sp.* and *Brassica sp.*

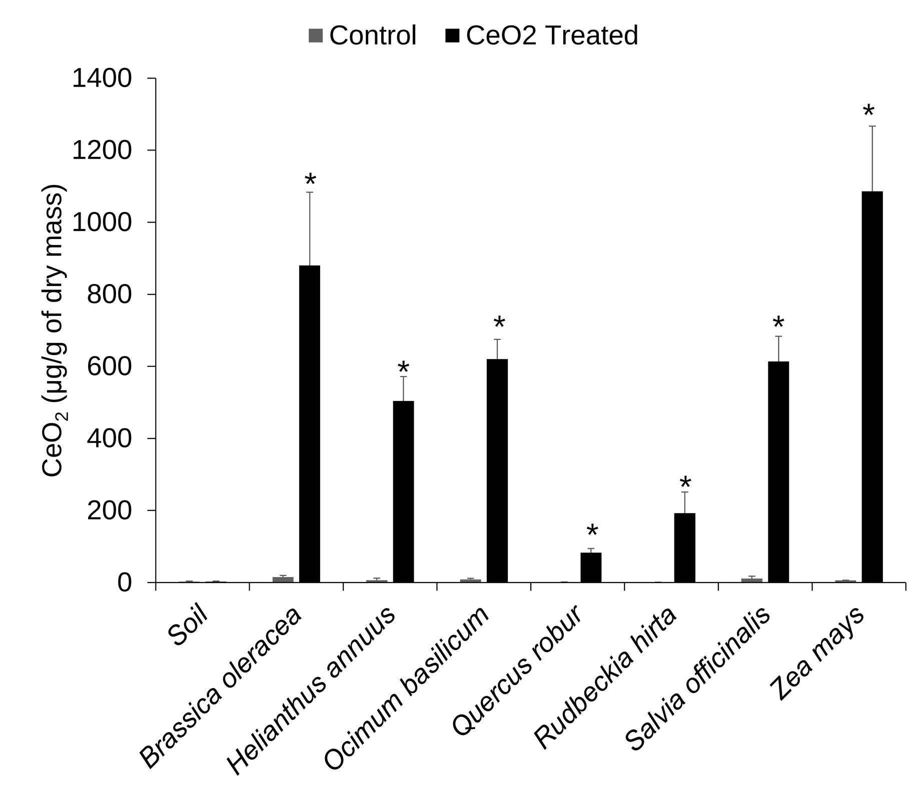

Figure 2: Mean CeO_2 concertation in soil, leaves of control groups and leaves treated with CeO_2-Nanoparticles. Error bars represent standard error to each group. (*) shows p<0.05 between control and treatment. CeO_2 natural presence was established in soil samples to avoid overestimation of leaf concentration.

- *Quercus sp* revealed an enhancement of NPQ and reduction in $max\varphi_{PSII}$ as immediate responses to actinic light.

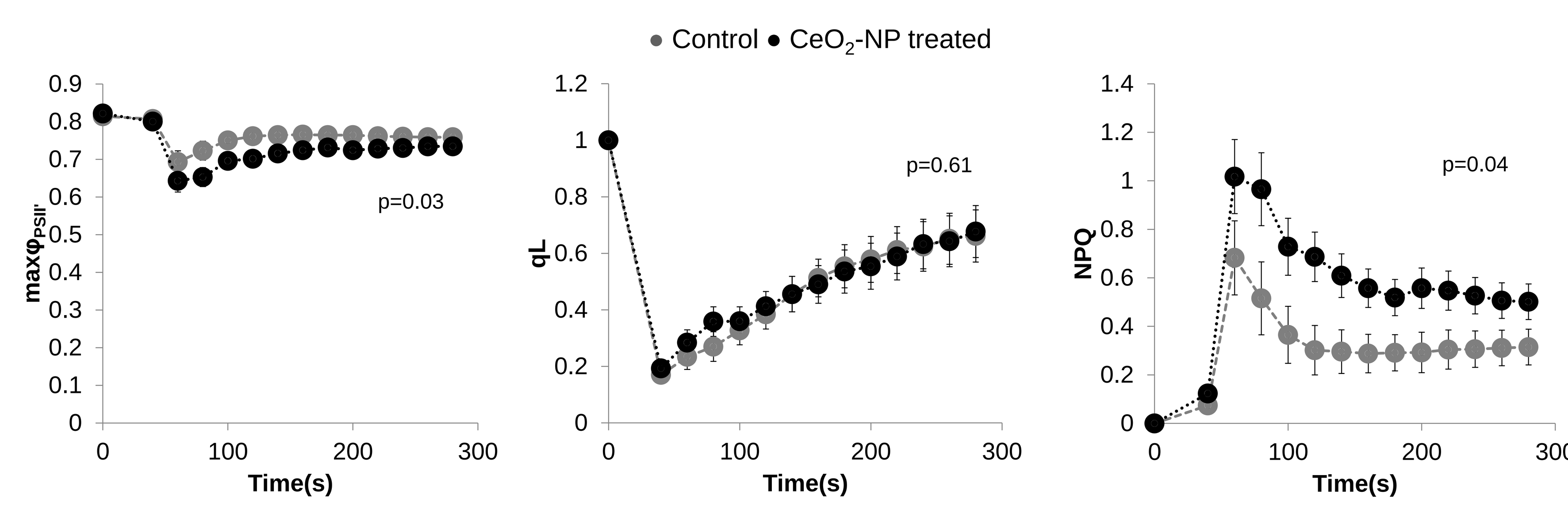

Figure 3: Mean of chlorophyll fluorescence profile of *Quercus robur* 21 days after the exposition to CeO2-Nanoparticles. Time equal 0 represents measure made in dark-adapted leaf. Error bars give standard error.

- *Ocimum sp.* and *Zea sp.* reflected characteristic patterns of pathogenic IT response, corroborated by reduced NPQ and increased $max\varphi_{PSII}$.

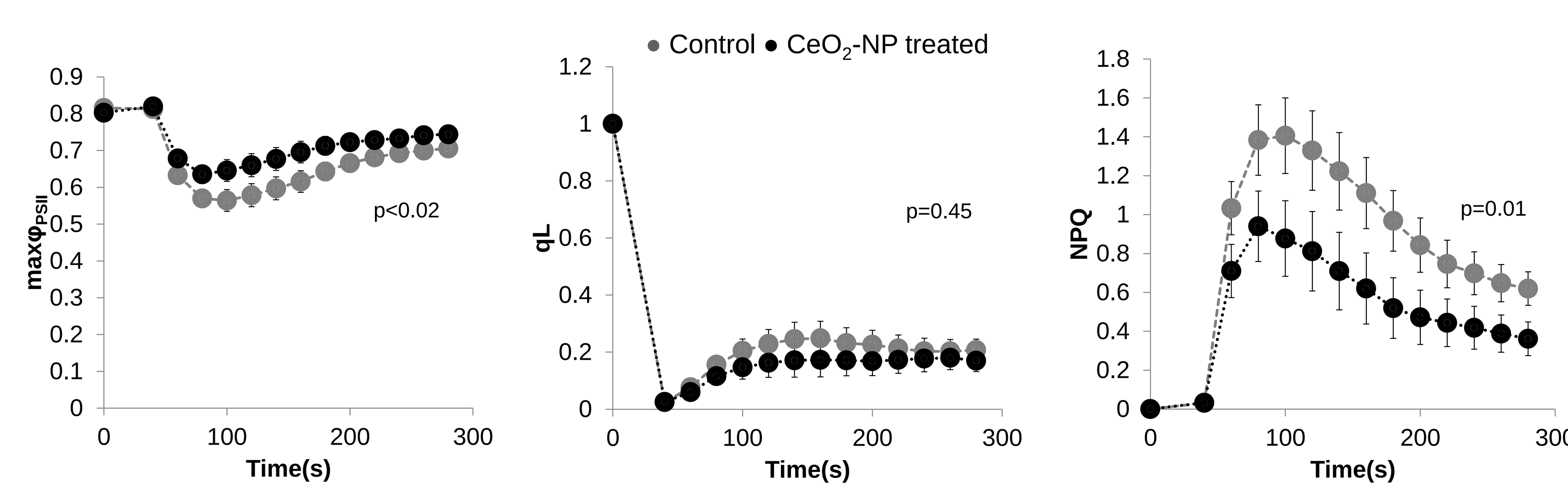

Figure 4: Mean of chlorophyll fluorescence profile of *Ocimum basilicum* 28 days after the exposition to CeO2-Nanoparticles. Time equal 0 represents measure made in dark-adapted leaf. Error bars give standard error.

- The increase in Quinona A oxidation rates (qL) presented by *Rudbeckia sp.* and *Helianthus sp* it is linked with an immune response at level of photosystem I.

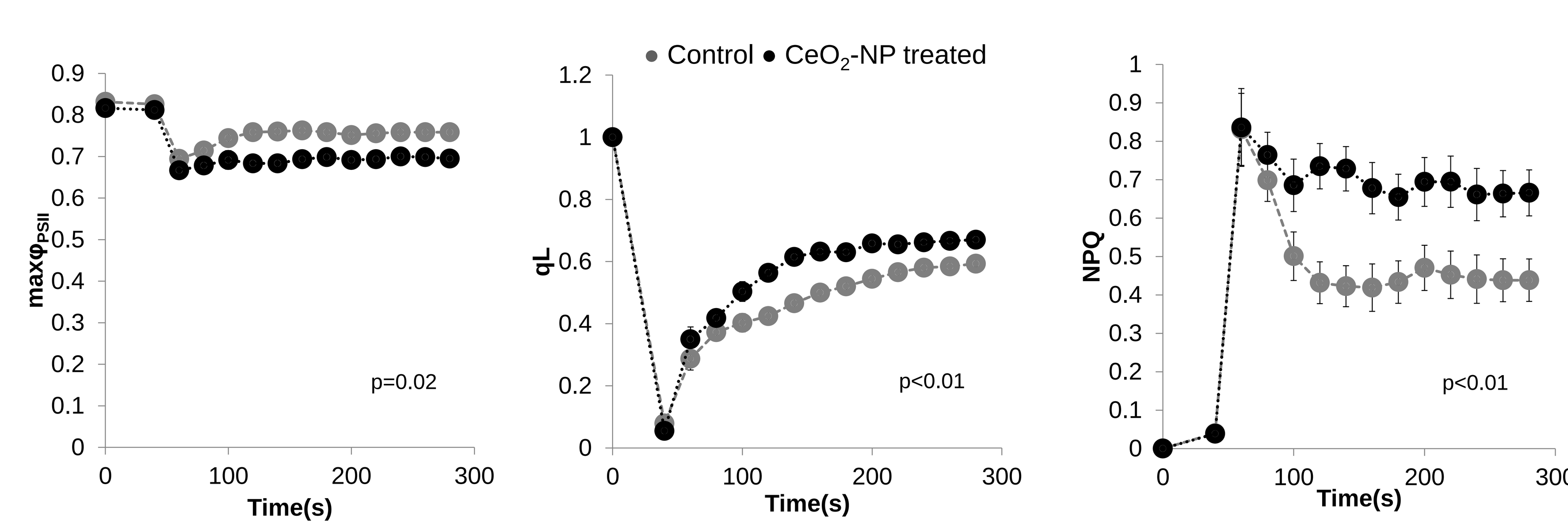

Figure 5: Mean of chlorophyll fluorescence profile of *Rudbeckia hirta* 14 days after the exposition to CeO2-Nanoparticles. Time equal 0 represents measure made in dark-adapted leaf. Error bars give standard error.

CONCLUSION

- *Brassica oleracea* and *Salvia officinalis* did not show significant changes in photosystem II functionality in response to CeO_2-NP.
- The response of *Quercus robur* is interpreted as direct physical injury in response to CeO_2-NP.
- Responses of *Ocimum basilicum, Zea mays, Helianthus annuus* and *Rudbeckia hirta* to CeO_2-NP are similar to patterns described as defense-related metabolism.

ACKNOWLEDGMENTS

We would like to thank Christine Fritz and her effort in this work. This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) of Brazilian Ministry of Education.

REFERENCES

Ju-Num Y. and Lead J. R. (2008) Manufactured nanoparticles: An overview of their chemistry, interactions and potential environmental implications. The Science of the total environment 400: 396-414

Park B, Donaldson K, Duffin, R, Tran L, Kelly F, Mudway I, Morin J, Guest R, Jenkison P, Samaras Z´, Giannouli M, Kouridis H, Martin P. (2008) Hazard and risk assessment of a nanoparticulate cerium oxide-based diesel fuel additive – A case study. Inhalation Toxicology 20: 547-566

Dietz K. and Herth S. (2011) Plant nanotoxicology. Trends in Plant Science 16: 582-589

Stael S, Kmiecik P, Willems P, der Kelen KV, Coll NS, Teige M and Breusegem FV (2015) Plant innate immunity – sunny side up? Trends in Plant Science 20: 3-11