CATÓLICA FACULTY OF BIOTECHNOLOGY PORTO

JÜLICH FORSCHUNGSZENTRUM

Climate change impact on legume nutrition and nutritional quality

Rafael D.C. Duarte [a], Juan Quirós-Vargas [b], Onno Muller [b], Marta W. Vasconcelos [a]

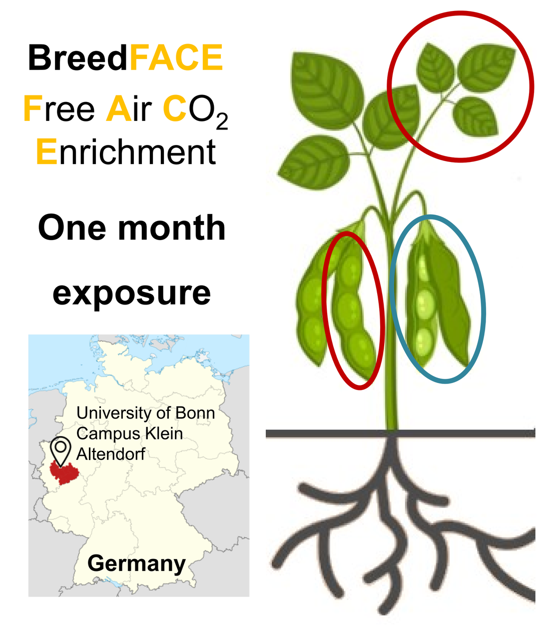
[a] Universidade Católica Portuguesa, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal

[b] Institute of Biogeosciences, IBG2: Plant Sciences, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Introduction

Climate change is a multilayered type of stress, with one of the focal points being the continuous increase of carbon dioxide (CO_2) presence in the atmosphere, as it is expected to reach 550 parts per million (ppm) by 2050 (Soares et al., 2019). Therefore, understanding the impact of these elevated [CO_2] (e[CO_2]) in legumes, key contributors of essential nutrients for human health, iron (Fe) and zinc (Zn), is crucial. In that way, this work relied on free air CO_2 enriched (FACE) experiments, a unique platform to study the increasing levels of atmospheric CO_2 in plants, focusing three genotypes of common bean (*Phaseolus vulgaris L.*) (G1-G2-G3). The genotypes were grown permanently in ambient [CO_2] (control, a[CO_2]) or were exposed to a month of e[CO_2] (600 pm) during pod-filling stage, to unravel the effects underlying e[CO_2] responses on biomass yield and nutritional value.

Methods



1. Biomass assessment (G1-G3)

Above ground biomass representative samples

2. Mineral analysis (G1-G3)

Mineral analysis of collected samples, was assessed using ICP-OES methodology (Santos et al., 2015)

3. Phenolic content and antioxidant capacity (G1/2)

Determined by Folin–Ciocalteu method (Ramos et al., 2019) and DPPH scavenging assay methodology (Gonçalves et al., 2009), respectively.

Results and Discussion

1. Biomass

Genotype	Treatment		Overall biomass (g) Shoot	Grains	Empty pods	Seed analysis Seed weight (g)	Seed size (mm)
G1	a[CO_2]	Average	106.67	30.41	28.52	0.21	56.42
		SD	36.82	4.67	2.49	0.09	8.83
	e[CO_2]	Average	146.67	64.37	48.50	0.28	63.84
		SD	9.43	32.33	17.20	0.10	10.75
	% of change		27.27	52.77	41.20	25.00***	11.63***
G2	a[CO_2]	Average	80.00	75.02	51.76	0.41	70.08
		SD	20.00	11.33	2.37	0.10	10.35
	e[CO_2]	Average	165.00	109.14	76.50	0.38	81.52
		SD	25.00	23.10	9.55	0.08	11.01
	% of change		51.52*	31.26	32.34*	7.89	14.03**
G3	a[CO_2]	Average	130.00	69.14	40.10	0.45	75.71
		SD	40.00	15.00	6.75	0.12	20.00
	e[CO_2]	Average	175.00	87.90	53.48	0.49	73.24
		SD	35.00	19.54	14.10	0.14	9.98
	% of change		25.71	21.34	25.02	8.16	3.37

*** = $p<0.01$; ** = $p<0.05$; * = $p<0.10$ <10%   10-30%   >30%

Figure 1- Average shoot, grains, empty pods, seed biomass (g), and average seed size (mm) of *P. vulgaris* genotypes.

- ❑ Overall biomass and seed weight and size statistically significant increase at e[CO_2]
  - **Differential genotypic responses**: G1 and G2 could be more susceptible to the e[CO_2] than G3

2. Mineral fluctuations

Mineral (µg g^{-1})	Genotype 1 a[CO_2]	Genotype 1 e[CO_2]	Genotype 2 a[CO_2]	Genotype 2 e[CO_2]	Genotype 3 a[CO_2]	Genotype 3 e[CO_2]
Mn	62 ± 8^{a}	51 ± 7^{a}	56 ± 2^{a}	81 ± 6^{a}	69 ± 1^{a}	56 ± 7^{a}
Zn	9 ± 1^{a}	4 ± 1^{b}	18 ± 1^{a}	20 ± 2^{a}	14 ± 1^{a}	18 ± 2^{a}
Fe	438 ±18^{a}	889 ± 79^{b}	427 ± 87^{a}	922 ± 16^{b}	809 ± 151^{a}	513 ± 141^{a}
B	28 ± 5^{a}	19 ± 2^{a}	36 ± 2^{a}	26 ± 5^{a}	25 ± 1^{a}	26 ± 4^{a}
Cu	4 ± 0.4^{a}	5 ± 1^{a}	5 ± 0.4^{a}	6 ± 1^{a}	5 ± 0.1^{a}	5 ± 0.2^{a}
Ni	2 ± 0.2^{a}	1 ± 0.5^{a}	2 ± 0.3^{a}	4 ± 0.4^{b}	2 ± 0.8^{a}	3 ± 0.4^{a}
Mg	3066 ± 300^{a}	3749 ± 133^{a}	2567 ± 41^{a}	2620 ± 33^{a}	3197 ± 162^{a}	2573 ± 116^{a}
K	6674 ± 762^{a}	6095 ± 398^{a}	10854 ± 910^{a}	15602 ± 1258^{b}	9950 ± 407^{a}	13879 ± 1396^{b}
Ca	46994 ± 6268^{a}	38004 ± 6141^{a}	36529 ± 3111^{a}	29774 ± 3290^{a}	33108 ± 3218^{a}	26853 ± 2026^{a}
P	1128 ± 104^{a}	1728 ± 268^{a}	1722 ± 75^{a}	1675 ± 91^{a}	1465 ± 160^{a}	1837 ± 198^{a}

Mineral (µg g^{-1})	Genotype 1 a[CO_2]	Genotype 1 e[CO_2]	Genotype 2 a[CO_2]	Genotype 2 e[CO_2]	Genotype 3 a[CO_2]	Genotype 3 e[CO_2]
Mn	8 ± 1^{a}	7 ± 1^{a}	17 ± 2^{a}	19 ± 2^{a}	27 ± 7^{a}	23 ± 4^{a}
Zn	50 ± 2^{a}	25 ± 3^{b}	52 ± 5^{a}	59 ± 2^{a}	67 ± 9^{a}	44 ± 3^{b}
Fe	74 ± 5^{a}	31 ± 1^{b}	82 ± 10^{a}	107 ± 3^{b}	168 ± 3^{a}	120 ± 8^{b}
B	8 ± 1^{a}	7 ± 1^{a}	15 ± 1^{a}	18 ± 1^{a}	22 ± 1^{a}	19 ± 1^{a}
Cu	9 ± 1^{a}	8 ± 1^{a}	7 ± 1^{a}	10 ± 1^{a}	13 ± 0.2^{a}	12 ± 3^{a}
Ni	8 ± 2^{a}	5 ± 0.5^{a}	8 ± 0.6^{a}	12 ± 1^{b}	7 ± 0.1^{a}	7 ± 0.2^{a}
Mg	1159 ± 42^{a}	1216 ± 29^{a}	2559 ± 54^{a}	3133 ± 188^{a}	3322 ± 277^{a}	2769 ± 334^{a}
K	10375 ± 481^{a}	10524 ± 306^{a}	23053 ± 982^{a}	25174 ± 1089^{a}	29326 ± 1334^{a}	26126 ± 3972^{a}
Ca	976 ± 44^{a}	729 ± 71^{a}	1970 ± 276^{a}	2280 ± 378^{a}	4250 ± 671^{a}	4131 ± 686^{a}
P	3657 ± 272^{a}	3527 ± 166^{a}	5364 ± 85^{a}	6723 ± 518^{b}	7846 ± 21^{a}	5294 ± 792^{b}

Figure 2- Leaves and grains mineral accumulation, respectively, of *P. vulgaris* three genotypes (G1-G3) grown under a[CO_2] and e[CO_2] conditions.

Leaves

- ✓ Decrease in [Zn] concentration for G1
- ✓ Increase on [Fe] concentration for G1 and decreased in G3.

Grains

- ✓ Decreased [Zn] and [Fe] for G1 and G3
- ✓ Increase in [Fe] for G2 was also reported.

Highly dependent on the genotype, mineral and tissue tested

3. Phenolic compounds and antioxidant activity

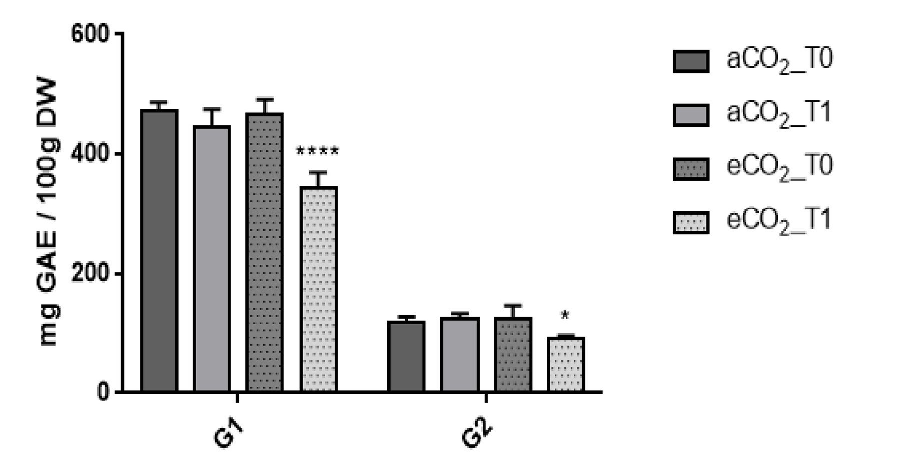


Figure 3- Comparison, through Folin-Ciocalteu method, of total phenolic of *P. vulgaris* grains, G1 and G2, grown at either a[CO_2] and e[CO_2] conditions

- ❑ Significant reductions (**27-28 %**) in TPC of G1 and G2 under e[CO_2] conditions.
- ❑ G2 TPC clearly lower than G1.

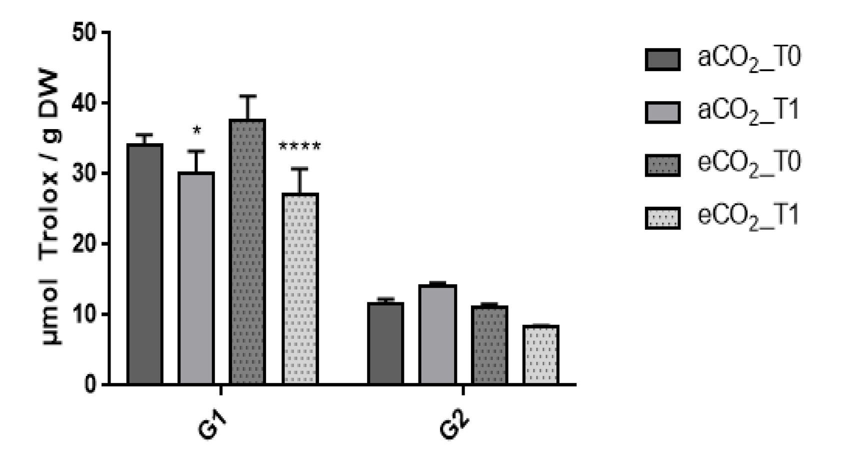


Figure 4- Comparison, through DPPH• scavenging effect, of antioxidant activity of *P. vulgaris* grains, G1 and G2, grown at either a[CO_2] and e[CO_2] conditions

- ❑ 28% reduction for G1 considering the DPPH assay under e[CO_2] conditions.
- ❑ Lower antioxidant activity is observed for G2.

Besides, the effect of e[CO_2] exposure, it is again perceivable a **clear contrast between the genotypes tested**.

Conclusions

- ❑ Overall biomass increase in e[CO_2] conditions, with different responses regarding the genotype.
  - ✓ G2 presenting the higher increase for the vegetative tissue
  - ✓ G1 the most yield-responsive biomass accumulation in grains
- ❑ Mineral fluctuations detected in all three genotypes
  - ✓ Suggests a response that may operate on a molecular level instead of biomass dilution-effect.
- ❑ Decreased phenolic content (G1 and G2) and antioxidant activity (G1), impacting their nutritional value.

These findings elucidate common bean, *P. vulgaris*, responses to a short-term e[CO_2] exposure, providing a "root to grain" standpoint, while clarifying the importance of genotypic variability of this crop.

References

Gonçalves, B., Falco, V., Moutinho-Pereira, J., Bacelar, E., Peixoto, F. & Correia, C. 2009. Effects of elevated CO2 on grapevine (Vitis vinifera L.): volatile composition, phenolic content, and in vitro antioxidant activity of red wine. J Agric Food Chem, 57, 265-73.

Ramos, P. a. B., Moreirinha, C., Silva, S., Costa, E. M., Veiga, M., Coscueta, E., Santos, S. a. O., Almeida, A., Pintado, M. M., Freire, C. S. R., Silva, A. M. S. & Silvestre, A. J. D. 2019. The Health-Promoting Potential of Salix spp. Bark Polar Extracts: Key Insights on Phenolic Composition and In Vitro Bioactivity and Biocompatibility. Antioxidants (Basel), 8.

Santos, C. S., Roriz, M., Carvalho, S. M. P. & Vasconcelos, M. W. 2015. Iron partitioning at an early growth stage impacts iron deficiency responses in soybean plants (Glycine max L.). Frontiers in plant science, 6, 325-325.

Soares, J. C., Santos, C. S., Carvalho, S. M. P., Pintado, M. M. & Vasconcelos, M. W. 2019. Preserving the nutritional quality of crop plants under a changing climate: importance and strategies. Plant and Soil, 443, 1-26.

Acknowledgements

This work was supported by the European Union's Horizon 2020 Research and Innovation Programme EPPN2020 and by the German Ministry of Education and Research (DPPN: Grant-Number: 031A053A/B/C).

FCT Fundação para a Ciência e a Tecnologia MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

EPPN 2020