



Universiteit  
Leiden  
The Netherlands

## **The impact of increased atmospheric carbon dioxide on microbial community dynamics in the rhizosphere**

Drigo, B.

### **Citation**

Drigo, B. (2009, January 21). *The impact of increased atmospheric carbon dioxide on microbial community dynamics in the rhizosphere*. Netherlands Institute of Ecology, Faculty of Science, Leiden University. Retrieved from <https://hdl.handle.net/1887/13419>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/13419>

**Note:** To cite this publication please use the final published version (if applicable).

## References

- Ainsworth E.A. & Long S.P. (2005). What have we learned from 15 years of free-air CO<sub>2</sub> enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO<sub>2</sub>. *New Phytologist*, 165, 351-372.
- Alberton O, Kuyper TW, Gorissen A (2007) Competition for nitrogen between *Pinus sylvestris* and ectomycorrhizal fungi generates potential for negative feedback under elevated CO<sub>2</sub>. *Plant Soil* 296(1-2):159-172.
- Allard V., Newton P.C.D., Lieffering M., Soussana J.F., Carran R.A. & Matthew C. (2005). Increased quantity and quality of coarse soil organic matter fraction at elevated CO<sub>2</sub> in a grazed grassland are a consequence of enhanced root growth rate and turnover. *Plant and Soil*, 276, 49-60.
- Alley, R., Berntsen, T., Bindoff, N. L., Chen, Z., Chidthaisong, A., Friedlingstein, P., Gregory, J., Hegerl, G., Heimann, M., Hewitson, B., Hoskins, B., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Manning, M., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Qin, D., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Solomon, S., Somerville, R., Stocker, T. F., Stott, P., Stouffer, R. J., Whetton, P., Wood, R. A., and Wratt, D.. Climate change 2007: The Physical Science Basis, Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change, Paris, 2007.
- Allen MF, Klironomos JN, Treseder KK, Oechel WC (2005) Responses of soil biota to elevated CO<sub>2</sub> in a chaparral ecosystem. *Ecol Applic* 15: 1701-1711.
- Alley R., Berntsen T., Bindoff N. L., Chen Z., Chidthaisong A., Friedlingstein P., B., Gregory J., Hegerl G., Heimann M., Hewitson Hoskins, B. Joos, F. Jouzel, J., Kattsov V., Lohmann, U. Manning, M. Matsuno, T. Molina, M. Nicholls, N. Overpeck, J., Qin D., Raga G., Ramaswamy V., Ren J., Rusticucci M., Solomon S., Somerville R., Stocker T. F., Stott P., Stouffer R. J., Whetton, P. Wood, R. A. and Wratt D.: Climate change 2007: The Physical Science Basis, Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change, Paris, 2007.
- Andrade G, Mihara KL, Linderman RG, *et al.* (1999) Bacteria from rhizosphere and hyphosphere soils of different arbuscular-mycorrhizal fungi. *Plant and Soil*, 192, 71-79.
- Arnone JA III, Gordon JC (1990) Effect of nodulation, nitrogen fixation and CO<sub>2</sub> enrichment on the physiology, growth and dry mass allocation of seedlings of *Alnus rubra* Bong. *New Phytol* 116:55-66.
- Azcon R, Ocampo JA (1981) Factors affecting the vesicular-arbuscular infection and mycorrhizal dependency of 13 wheat cultivars. *New Phytologist*, 87, 677-685.
- Baath, E. (2001) Estimation of fungal growth rates in soil using <sup>14</sup>C-acetate incorporation into ergosterol. *Soil Biol. Biochem.*, 33, 2011.
- Bailey V. L., Smith J. L., and Bolton H. (2002) Fungal-to-bacterial ratios in soils investigated for enhanced C sequestration. *Soil Biology and Biochemistry*, 34, 997-1007.
- Bago B, Pfeffer PE, Abubaker J, Jun J *et al.* (2003) Carbon export from arbuscular mycorrhizal roots involves the translocation of carbohydrate as well as lipid. *Plant Physiology*, 131, 1496-1507.

- Bangera M.G. & Thomashow L.S. (1999). Identification and characterization of a gene cluster for synthesis of the polyketide antibiotic 2,4-Diacetylphloroglucinol from *Pseudomonas fluorescens* Q2-87. *Journal of Bacteriology*, 181, 3155–3163.
- Bansal M, Mukerji KG (1994) Positive correlation between vsm-induced changes in root exudation and mycorrhizosphere mycoflora. *Mycorrhiza*, 5, 39-44.
- Bardgett R.D., Kandeler E., Tscherko D., Hobbs P.J., Bezemer T.M., Jones T.H. & Thompson L.J. (1999). Below-ground microbial community development in a high temperature world. *Oikos*, 85, 193-203.
- Barron-Gafford G., Martens D., Grieve K., Biel K., Kudeyarov V., McLain J.E.T., Lipson D. & Murthy R. (2005). Growth of eastern cottonwoods (*Populus deltoides*) in elevated [CO<sub>2</sub>] stimulates stand-level respiration and rhizodeposition of carbohydrates, accelerates soil nutrient depletion, yet stimulates above- and belowground biomass production. *Global Change Biology*, 11, 1220-1233.
- Beare M. H. (1997) Fungal and bacterial pathways of organic matter decomposition and nitrogen mineralization in arable soils, in: *Soil Ecology in Sustainable Agricultural Systems*, edited by: Brussaard, L. and Ferrera-Cerrato, R., Lewis Publishers, Boca Raton, FL, 37–70.
- Berg, G., Eberl, L. & Hartmann, A. (2005) The rhizosphere as a reservoir for opportunistic human pathogenic bacteria. *Environmental Microbiology*, 1673-1685.
- Berg G., Eberl L. & Hartmann A. (2005). The rhizosphere as a reservoir for opportunistic human pathogenic bacteria. *Environmental Microbiology*, 7, 1673-1685.
- Bergsma-Vlami M., Prins M.E., Staats M. & Raaijmakers J.M. (2005). Assessment of genotypic diversity of antibiotic-producing *Pseudomonas* species in the rhizosphere by denaturing gradient gel electrophoresis. *Applied Environmental Microbiology*, 71, 993-1003.
- Berntson G.M. & Bazzaz F.A. (1997). Nitrogen cycling in microcosms of yellow birch exposed to elevated CO<sub>2</sub>: Simultaneous positive and negative below-ground feedbacks. *Global Change Biology*, 3, 247-258.
- Billes G, Rouhier H, Bottner P (1993) Modifications of the carbon and nitrogen allocations in the plant (*Triticum-Aestivum* L) soil system in response to increased atmospheric CO<sub>2</sub> concentration. *Plant Soil* 157: 215-225.
- Billings, S.A. & Ziegler, S.E. (2005) Linking microbial activity and soil organic matter transformations in forest soils under elevated CO<sub>2</sub>. *Global Change Biol.*, 11, 203-212.
- Borcard D, Legendre P, Drapeau P (1992) Partialling out the spatial component of ecological variation. *Ecology*, 73, 1045-1055.
- Boschker H (2004) In: Kowalchuck GA, de Bruijn FJ *et al.* (Eds) Linking microbial community structure and functioning: stable isotope (<sup>13</sup>C) labeling in combination with PLFA analysis *Molecular Microbial Ecology Manual II*. Kluwer academic Publishers, Dordrecht, the Netherlands, pp.1673-1688.
- Boschker H.T.S. & Middelburg J.J. (2002). Stable isotopes and biomarkers in microbial ecology. *FEMS Microbial Ecology*, 40, 85-95.
- Boschker, H.T.S., de Brouwer, J.F.C. & Cappenberg, T.E. (1999) The contribution of macrophyte-derived organic matter to microbial biomass in salt-marsh sediments: stable carbon isotope analysis of microbial biomarkers. *Limnol. Oceanogr.*, 44, 309-319.

- Bossuyt H., Deneff K., Six J., Frey S. D., Merckx R., and Paustian K. (2001) Influence of microbial populations and residue quality on aggregate stability. *Applied Soil Ecology*, 16, 195–208.
- Brinkman E.P., van Veen J.A. & van der Putten W.H. (2004). Endoparasitic nematodes reduce multiplication of ectoparasitic nematodes, but do not prevent growth reduction of *Ammophila arenaria* (L.) Link (marram grass). *Applied Soil Ecology*, 27, 65-75.
- Bruce K.D., Jones T.H., Bezemer T.M., Thompson L.J. & Ritchie D.A. (2000). The effect of elevated atmospheric carbon dioxide levels on soil bacterial communities. *Global Change Biology*, 6, 427-434.
- Brussaard L, Behan-Pelletier VM, Bignell DE, Brown VK, Didden W, Folgarait P, Fragoso C, Freckman DW, Gupta V, Hattori T, Hawksworth DL, Klopatek C, Lavelle P, Malloch DW, Rusek J, Soderstrom B, Tiedje JM, Virginia RA (1997) Biodiversity and ecosystem functioning in soil. *Ambio* 26: 563-570.
- Butler J.L., Williams M.A., Bottomley P.J. & Myrold D.D. (2003). Microbial community dynamics associated with rhizosphere carbon flow. *Appl Environ Microb*, 69, 6793-6800.
- Cardon Z.G. (1996). Influence of rhizodeposition under elevated CO<sub>2</sub> on plant nutrition and soil organic matter. *Plant and Soil*, 187, 277-288.
- Cardon Z.G., Hungate B.A., Cambardella C.A., Chapin F.S., Field C.B., Holland E.A. & Mooney H.A. (2001). Contrasting effects of elevated CO<sub>2</sub> on old and new soil carbon pools. *Soil Biology and Biochemistry*, 33, 365-373.
- Carney K.M., Hungate B.A., Drake B.G. & Megonigal J.P. (2007). Altered soil microbial community at elevated CO<sub>2</sub> leads to loss of soil carbon. *Proceedings of the National Academy of Science USA*, 104, 4990-4995.
- Carter MR (1993) *Soil sampling and methods of analysis*. CRC Press, Boca Raton, FL.
- Casgrain P, Legendre P (2001) The R package for multivariate and spatial analysis. Département de sciences biologiques, Université de Montréal, Montréal, Canada.
- Cavender-Bares J, Ackerly DD, Baum DA, Bazzaz FA (2004). Phylogenetic Overdispersion in Floridian Oak Communities. *The American Naturalist*, 163, 823-843.
- Cheng WX, Gershenson A (2007) Carbon fluxes in the rhizosphere In: Cardon ZG and Whitbeck JL(eds). *The Rhizosphere: An Ecological Perspective*, Elsevier Academic Press, London, UK, pp. 31-56.
- Cheng WX, Johnson DW (1998) Elevated CO<sub>2</sub>, rhizosphere processes, and soil organic matter decomposition. *Plant Soil* 202: 167-174.
- Cheng WX, Sims DA, Luo YQ, Coleman JS, Johnson DW (2000) Photosynthesis, respiration, and net primary production of sunflower stands in ambient and elevated atmospheric CO<sub>2</sub> concentrations: an invariant NPP : GPP ratio? *Global Change Biol* 6: 931-941.
- Chung HG, Zak DR, Lilleskov EA (2006) Fungal community composition and metabolism under elevated CO<sub>2</sub> and O<sub>3</sub>. *Oecologia* 147: 143-154.
- Cotrufo M F, Ineson P, Scott A (1998) Elevated CO<sub>2</sub> reduces the nitrogen concentration of plant tissues. *Global Change Biol* 4: 43–54.
- Coûteaux MM, Kurz C, Bottner P, Raschi A (1999) Influence of the increased atmospheric CO<sub>2</sub> concentration on quality of plant material and litter decomposition. *Tree Physiol* 19: 301–311.

- Curtis PS (1996) A meta-analysis of leaf gas exchange and nitrogen in trees grown under elevated carbon dioxide. *Plant Cell Environ* 19: 127-137.
- Curtis PS, Balduman LM, Drake BG, Whigham DF. (1990) Elevated Atmospheric CO<sub>2</sub> Effects on Belowground Processes in C-3 and C-4 Estuarine Marsh Communities. *Ecology* 71:2001-2006.
- Curtis PS, Wang XZ (1998) A meta-analysis of elevated CO<sub>2</sub> effects on woody plant mass, form, and physiology. *Oecologia* 113: 299-313.
- Curtis TP, Sloan WT, Scannell JW (2002) Estimating prokaryotic diversity and its limits. *Proc Nat Acad Sciences USA* 99: 10494–10499.
- Darrah P.R. (1996). Rhizodeposition under ambient and elevated CO<sub>2</sub> levels. *Plant and Soil*, 187, 265-275.
- De Boer W, Folman LB, Summerbell RC *et al.* (2005) Living in a fungal world: impact of fungi on soil bacterial niche development. *FEMS Microbiology Reviews*, 29, 795-811.
- De Boer W, Kowalchuk GA, van Veen JA (2006) 'Root-food' and the rhizosphere microbial community composition. *New Phytologist*, 170, 3-6.
- De Ridder-Duine AS, Kowalchuk GA, Gunnewiek P *et al.* (2005) Rhizosphere bacterial community composition in natural stands of *Carex arenaria* (sand sedge) is determined by bulk soil community composition. *Soil Biology & Biochemistry*, 37, 349-357
- De Ruiter P, Moore J, Zwart K, Bouwman L, Hassink J, Bloem J., De Vos J, Marinissen J, Didden W, Lebbink G, Brussard L (1993) Simulation of nitrogen mineralization in the belowground food webs of two winter-wheat fields. *J. Appl Ecol* 30: 95-106.
- de Souza J.T. & Raaijmakers J.M. (2003). Polymorphisms within the *prnD* and *pltC* genes from pyrrolnitrin and pyoluteorin-producing *Pseudomonas* and *Burkholderia* spp. *FEMS Microbiology Ecology*, 43, 21–34.
- Denef K, Bubenheim H, Lenhart K, Vermeulen J, Van Cleemput O, Boeckx P, Muller C (2007). Community shifts and carbon translocation within metabolically-active rhizosphere microorganisms in grasslands under elevated CO<sub>2</sub>. *Biogeosciences* 4: 769-779.
- Diaz S, Grime JP, Harris J, McPherson E (1993) Evidence of a feedback mechanism limiting plant response to elevated carbon dioxide. *Nature* 364: 616-617.
- Douds DD, Pfeffer PE, Shachar-Hill Y (2000) Application of in vitro methods to study carbon uptake and transport by AM fungi. *Plant and Soil*, 226, 255-261.
- Drigo B, Kowalchuk GA, Yergeau E, Bezemer TM, Boschker HTS, Van Veen JA (2007) Impact of elevated carbon dioxide on the rhizosphere communities of *Carex arenaria* and *Festuca rubra*. *Global Change Biol* 13: 2396-2410.
- Drissner D., Blum H., Tschirko D. & Kandeler E. (2007). Nine years of enriched CO<sub>2</sub> changes the function and structural diversity of soil microorganisms in a grassland. *European Journal of Soil Science*, 58, 260–269.
- Duffy B., Keel C. & Defago G. (2004). Potential Role of Pathogen Signaling in Multitrophic Plant-Microbe Interactions Involved in Disease Protection. *Applied and Environmental Microbiology*, 70, 1836-1842.
- Duineveld BM, Kowalchuk GA, Keijzer A *et al.* (2001) Analysis of bacterial communities in the rhizosphere of *Chrysanthemum* via denaturing gradient gel electrophoresis of PCR-amplified 16S rRNA as well as DNA fragments coding for 16S rRNA. *Applied & Environmental Microbiology*, 67, 172–178

- Ebersberger D., Wermbter N., Niklaus P.A. & Kandeler E. (2004). Effects of long term CO<sub>2</sub> enrichment on microbial community structure in calcareous grassland. *Plant and Soil*, 264, 313-323.
- Elhottova D, Triska J, Santruckova H, Kveton J, Santrucek J, Simkova M (1997). Rhizosphere microflora of winter wheat plants cultivated under elevated CO<sub>2</sub>. *Plant Soil* 197: 51-259.
- Field C.B., Chapin III F.S., Matson P.A. & Mooney H.A. (1992). Responses of terrestrial ecosystems to the changing atmosphere: a resource-based approach. *Annual review of ecology and systematics*. Vol. 23, Published by Annual Reviews Inc., Editors Fautin D.G. and et al., 201-235.
- Filion M, Dutilleul P, Potvin C (2000) Optimum experimental design for Free-Air Carbon dioxide Enrichment (FACE) studies. *Global Change Biology*, 6, 843-854.
- Filion M, St-Arnaud M, Fortin JA (1999) Direct interaction between the arbuscular mycorrhizal fungus *Glomus intraradices* and different rhizosphere micro-organisms. *New Phytologist*, 141, 525-533.
- Fitter AH, Heinemeyer A, Husband R, Olsen E, Ridgway KP, Staddon PL (2004). Global environmental change and the biology of arbuscular mycorrhizas: gaps and challenges. *Can J. Botany* 82: 1133-1139.
- Fitter AH, Heinemeyer A, Staddon PL (2000). The impact of elevated CO<sub>2</sub> and global climate change on arbuscular mycorrhizas: a mycocentric approach. *New Phytol* 147:179-187.
- Fransson PMA, Taylor AFS, Finlay RD (2001) Elevated atmospheric CO<sub>2</sub> alters root symbiont community structure in forest trees. *New Phytol* 152: 431-442.
- Frey S. D., Elliott E. T., Paustian K., and Peterson G. A. (2000). Fungal translocation as a mechanism for soil nitrogen inputs to surface residue decomposition in a no-tillage agroecosystem, *Soil Biology and Biochemistry*, 32, 689–698.
- Frey-Klett P., Garbaye J. & Tarkka M. (2007). The mycorrhiza helper bacteria revisited. *New Phytologist*, 176, 22-36.
- Findlay, R.H. & Dobbs, F.C. (1993) Quantitative description of microbial communities using lipid analysis. In: *Handbook of Methods in Aquatic Microbial Ecology* (eds. Kemp PF, Sherr BF, Sherr EB & Cole JJ). Lewis Publishers, Boca Raton, pp 271-284.
- Fromin N, Tarnawski S, Roussel-Delif L, Hamelin J, Baggs EM, Aragno M (2005) Nitrogen fertiliser rate affects the frequency of nitrate-dissimilating *Pseudomonas* spp. in the rhizosphere of *Lolium perenne* grown under elevated pCO<sub>2</sub> (Swiss FACE). *Soil Biol Biochem* 37: 1962-1965.
- Frostegard A, Baath E (1996) The use of phospholipid fatty acid analysis to estimate bacterial and fungal biomass in soil. *Biology and Fertility of Soils*, 22, 59-65.
- Frostegard, A., Tunlid, A. & Baath, E. (1993) Phospholipid fatty-acid composition, biomass, and activity of microbial communities from 2 soil types experimentally exposed to different heavy-metals. *Appl. Environ. Microbiol.*, 59, 3605-3617.
- Gadkar V, Driver JD, Rillig MC (2006) A novel in vitro cultivation system to produce and isolate soluble factors released from hyphae of arbuscular mycorrhizal fungi *Biotechnology Letters*, 28, 1071-1076.
- Gamper H, Hartwig UA, Leuchtmann A (2005) Mycorrhizas improve nitrogen nutrition of *Trifolium repens* after 8 yr of selection under elevated atmospheric CO<sub>2</sub> partial pressure. *New Phytol* 167:531-542.

- Gamper H, Peter M, Jansa J, Luscher A, Hartwig UA, Leuchtman A (2004) Arbuscular mycorrhizal fungi benefit from 7 years of free air CO<sub>2</sub> enrichment in well-fertilized grass and legume monocultures. *Global Change Biol* 10: 189-199.
- Garbeva P., van Veen J.A. & van Elsas J.D. (2003). Predominant *Bacillus* spp. in agricultural soil under different management regimes detected via PCR-DGGE. *Microbial Ecology*, 45, 302-316.
- Garbeva P, van Veen JA & van Elsas JD (2004). Assessment of the diversity, and antagonism towards *Rhizoctonia solani* AG3, of *Pseudomonas* species in soil from different agricultural regimes. *FEMS Microbiol Ecology*, 47, 51.
- Gebauer RLE, Strain BR, Reynolds JF (1997) The effect of elevated CO<sub>2</sub> and N availability on tissue concentrations and whole plant pools of carbon-based secondary compounds in loblolly pine (*Pinus taeda*). *Oecologia*, 113: 29-36.
- Gill R. A., Polley H.W., Johnson H. B., Anderson L. J., Maherali H. & Jackson R. B.(2002). Nonlinear grassland responses to past and future atmospheric CO<sub>2</sub>. *Nature*, 417, 279–282.
- Giovannetti, M. & Mosse, B. (1980) An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection roots. *New Phytol.*, 84, 489-500.
- Graham JH, Abbott LK (2000) Wheat responses to aggressive and non-aggressive arbuscular mycorrhizal fungi. *Plant and Soil*, 220, 207-218.
- Grayston S.J., Campbell C.D., Lutze J.L. & Gifford R.M. (1998). Impact of elevated CO<sub>2</sub> on the metabolic diversity of microbial communities in N-limited grass swards. *Plant and Soil*, 203, 289-300.
- Grayston SJ, Vaugham D, Jones D (1997) Rhizosphere carbon flow in trees, in comparison with annual plants: importance of root exudation and its impact on microbial activity and nutrient availability. *Applied Soil Ecology*, 5: 29-56.
- Greipsson S. & El-Mayas H. (1999). Large-scale reclamation of barren lands in Iceland by aerial seeding. *Land Degradation & Development*, 10, 185-193.
- Griffiths B.S., Ritz K., Ebbelwhite N. & Dobson G. (1999). Soil microbial community structure: Effects of substrate loading rates. *Soil Biology and Biochemistry*, 31, 145-153.
- Griffiths B.S., Ritz K., Ebbelwhite N., Paterson E. & Killham K. (1998). Ryegrass rhizosphere microbial community structure under elevated carbon dioxide concentrations, with observations on wheat rhizosphere. *Soil Biology and Biochemistry*, 30, 315-321.
- Griffiths RI, Whiteley AS, O'Donnell AG, Bailey MJ (2000). Rapid method for coextraction of DNA and RNA from natural environments for analysis of ribosomal DNA- and rRNA-based microbial community composition. *Applied and Environmental Microbiology*, 66, 5488–5491.
- Guckert, J.B., Antworth, C.P., Nichols, P.D. & White, D.C. (1985) Phospholipid, ester-linked fatty acid profiles as reproducible assays for changes in prokaryotic community structure of estuarine sediments. *FEMS Microbiol. Lett.*, 31, 147.
- Hagn A., Wallisch S., Radl V., Charles Munch J. & Schlöter M. (2007). A new cultivation independent approach to detect and monitor common *Trichoderma* species in soils. *J. Microbiological Methods*, 69, 86-92.
- Harman and Björkman, 1998 G.E. Harman and T. Björkman, Potential and existing uses of *Trichoderma* and *Gliocladium* for plant disease control and plant growth enhancement. In: C.P. Kubicek and G.E. Harman, Editors, *Trichoderma and*

- Gliocladium, Enzymes, Biological Control and Commercial Applications* vol. 2, Taylor and Francis, London (1998).
- Heinemeyer A, Ineson P, Ostle N, Fitter AH (2006). Respiration of the external mycelium in the arbuscular mycorrhizal symbiosis shows strong dependence on recent photosynthates and acclimation to temperature. *New Phytologist*, 171, 159-170.
- Heuer H., Krsek M., Baker P., Smalla K. & Wellington E. (1997). Analysis of actinomycete communities by specific amplification of genes encoding 16S rRNA and gel-electrophoretic separation in denaturing gradients. *Appl Environ Microb*, 63, 3233–3241.
- Hodge A (1996) Impact of elevated CO<sub>2</sub> on mycorrhizal associations and implications for plant growth. *Biol. Fertil Soils* 23: 388-398.
- Hodge A (2000) Microbial ecology of the arbuscular mycorrhizal. *FEMS Microbiology Ecology*, 32, 91-96.
- Hodge A, Paterson E, Grayston SJ, Campbell CD, Ord BG, Killham K (1998) Characterisation and microbial utilization of exudate material from the rhizosphere of *Lolium perenne* grown under CO<sub>2</sub> enrichment. *Soil Biol Biochem* 30: 1033.
- Hodge A. & Millard P. (1998). Effect of elevated CO<sub>2</sub> on carbon partitioning and exudate release from *Plantago lanceolata* seedlings. *Physiologia Plantarum*, 103, 280-286.
- Hoeksema JD, Lussenhop J, Teeri JA (2000). Soil nematodes indicate food web responses to elevated atmospheric CO<sub>2</sub>. *Pedobiologia* 44: 725-735.
- Hu S, Chapin FS, Firestone MK, Field CB, Chiariello NR (2001) Nitrogen limitation of microbial decomposition in a grassland under elevated CO<sub>2</sub>. *Nature* 409: 188-191.
- Hu S.J., Firestone M.K. & Chapin F.S. (1999). Soil microbial feedbacks to atmospheric CO<sub>2</sub> enrichment. *Trends in Ecology and Evolution*, 14, 433-437.
- Hugenholtz P., Goebel B.M. & Pace N.R. (1998). Impact of culture-independent studies on the emerging phylogenetic view of bacterial diversity. *Journal of Bacteriology*, 180, 4765–4774.
- Hughes, JB, Bohannan BJM (2004) Application of ecological diversity statistics in microbial ecology. In: Kowalchuk, GA, de Bruijn, FJ, Head, IM, Akkermans, AD, van Elsas, JD (eds). *Molecular Microbial Ecology Manual*, 2nd edition, Kluwer Acad Publ, Dordrecht, The Netherlands, pp. 1321-1344.
- Hungate B.A., Jaeger C.H., Gamara G., Chapin F.S. & Field C.B. (2000). Soil microbiota in two annual grasslands: responses to elevated atmospheric CO<sub>2</sub>. *Oecologia*, 124, 589-598.
- Hungate BA, Dukes JS, Shaw MR, Luo Y, Field CB (2003) Atmospheric Science: Nitrogen and Climate Change. *Science* 302:1512-1513.
- Hungate BA, Holland EA, Jackson RB, Chapin FS., Mooney HA, Field CB (1997) The fate of carbon in grasslands under carbon dioxide enrichment. *Nature* 388: 576-579.
- Insam H., Baath E., Berreck M., Frostegard A., Gerzabek M.H., Kraft A., Schinner F., Schweiger P. & Tschuggnall G. (1999). Responses of the soil microbiota to elevated CO<sub>2</sub> in an artificial tropical ecosystem. *Journal of Microbiological Methods*, 36, 45.
- IPCC, Climate Change 2007: Synthesis Report. Summary for Policymakers. www.ipcc.ch. November 2007.
- Jackson RB, Mooney HA, Schulze ED (1997) A global budget for fine root biomass, surface area, and nutrient contents. *Proc Nat Acad Sciences USA* 94: 362-7366.

- Janus L, Angeloni N, McCormack J, Rier S, Tuchman N, Kelly J (2005) Elevated Atmospheric CO<sub>2</sub> Alters Soil Microbial Communities Associated with Trembling Aspen (*Populus tremuloides*) Roots. *Microb Ecol* 50: 102-109.
- Jastrow J.D., Miller R.M., Matamala R., Norby R.J., Boutton T.W., Rice C.W. & Owensby C.E. (2005). Elevated atmospheric carbon dioxide increases soil carbon. *Global Change Biology*, 11, 2057-2064.
- Johnson D., Leake J.R., Ostle N., Ineson P. & Read D.J. (2002). In situ <sup>13</sup>CO<sub>2</sub> pulse-labeling of upland grassland demonstrates a rapid pathway of carbon flux from arbuscular mycorrhizal mycelia to the soil. *New Phytologist*, 153, 327-334.
- Johansson JF, Paul LR, Finlay RD (2004) Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture. *FEMS Microbiology Ecology*, 48, 1-13.
- Johnson, D., Leake, J.R., Ostle, N., Ineson, P. & Read, D.J. (2002) In situ <sup>13</sup>C-CO<sub>2</sub> pulse-labeling of upland grassland demonstrates a rapid pathway of carbon flux from arbuscular mycorrhizal mycelia to the soil. *New Phytol.*, 153, 327-334.
- Johnson NC, Gehring CA (2007) Mycorrhizas: Symbiotic mediators of rhizosphere and ecosystem processes. In: Cardon ZG and Whitbeck JL(eds). The Rhizosphere: An Ecological Perspective, Elsevier Academic Press, London, UK, pp. 31-56
- Johnson NC, Wolf J, Koch GW (2003) Interactions among mycorrhizae, atmospheric CO<sub>2</sub> and soil N impact plant community composition. *Ecol Let* 6: 532-540.
- Jones DL, Hodge A, Kuzyakov Y (2004) Plant and mycorrhizal regulation of rhizodeposition. *New Phytol* 163: 459-480.
- Jones T.H., Thompson L.J., Lawton J.H., Bezemer T.M., Bardgett R.D., Blackburn T.M., Bruce K.D., Cannon P.F., Hall G.S., Hartley S.E., Howson G., Jones C.G., Kampichler C., Kandeler E. & Ritchie D.A. (1998). Impacts of rising atmospheric carbon dioxide on model terrestrial ecosystems. *Science*, 280, 441-443.
- Jongen M, Jones MB, Hebeisen T, Blum H, Hendrey G (1995) The effects of elevated CO<sub>2</sub> concentrations on the root growth of *Lolium perenne* and *Trifolium repens* grown in a FACE system. *Global Change Biol* 1: 361-371.
- Jossi M., Fromin N., Tarnawski S., Kohler F., Gillet F., Aragno M. & Hamelin J. (2006). How elevated pCO<sub>2</sub> modifies total and metabolically active bacterial communities in the rhizosphere of two perennial grasses grown under field conditions. *FEMS Microbiology Ecology*, 55, 339-350.
- Kaneda, T. (1991) Iso- and anteiso-fatty acids in bacteria: biosynthesis, function, and taxonomic significance. *Microbiol. Mol. Biol. Rev.*, 55, 288-302.
- Kandeler E, Tscherko D, Bardgett RD, Hobbs PJ, Kampichler C, Jones TH (1998) The response of soil microorganisms and roots to elevated CO<sub>2</sub> and temperature in a terrestrial model ecosystem. *Plant Soil* 202, 251-262.
- Kandeler E., Mosier A. R., Morgan J. A., Milchunas D. G., King J. Y., Rudolph S. & Tscherko D. (2006) Response of soil microbial biomass and enzyme activities to the transient elevation of carbon dioxide in a semi-arid-grassland, *Soil Biology and Biochemistry*, 38, 2448–2460.
- King JS, Hanson PJ, Bernhardt E, DeAngelis P, Norby RJ, Pregitzer KS (2004) A multiyear synthesis of soil respiration responses to elevated atmospheric CO<sub>2</sub> from four forest FACE experiments. *Global Change Biol* 10: 1027-1042.
- King JS, Thomas RB, Strain BR (1997) Morphology and tissue quality of seedling root systems of *Pinus taeda* and *Pinus ponderosa* as affected by varying CO<sub>2</sub>, temperature, and nitrogen. *Plant Soil* 195: 107-119.

- Klamer M., Roberts M.S., Levine L.H., Drake B.G. & Garland J.L. (2002). Influence of elevated CO<sub>2</sub> on the fungal community in a coastal scrub oak forest soil investigated with terminal-restriction fragment length polymorphism analysis. *Applied and Environmental Microbiology*, 68, 4370-4376.
- Klironomos J.N., Allen M.F., Rillig M.C., Piotrowski J., Makvandi-Nejad S., Wolfe B.E. & Powell J.R. (2005). Abrupt rise in atmospheric CO<sub>2</sub> overestimates community response in a model plant-soil system. *Nature*, 433, 621-624.
- Klironomos JN, Hart MM (2001) Food-web dynamics animal nitrogen swap for plant carbon. *Nature*, 410, 651–652.
- Klironomos JN, Rillig MC, Allen MF (1996) Below-ground microbial and microfaunal responses to *Artemisia tridentata* grown under elevated atmospheric CO<sub>2</sub>. *Functional Ecol* 10: 527–534.
- Klironomos JN, Rillig MC, Allen MF, Zak DR, Kubiske M, Pregitzer KS (1997). Soil fungal-arthropod responses to *Populus tremuloides* grown under enriched atmospheric CO<sub>2</sub> under field conditions. *Global Change Biol* 3: 473-478.
- Korner C (2000) Biosphere responses to CO<sub>2</sub> enrichment. *Ecological Application*, 10, 590-1619.
- Korner C, Arnone JA (1992) Responses to elevated carbon dioxide in artificial tropical ecosystems. *Science*, 257, 1672-1675.
- Kowalchuk GA, Buma DS, de Boer W *et al.* (2002) Effects of above-ground plant species composition and diversity on the diversity of soil-borne microorganisms. *Antonie Van Leeuwenhoek International Journal of General and Molecular Microbiology*, 81, 509-520.
- Kreuzer-Martin HW (2007) Stable isotope probing: Linking functional activity to specific members of microbial communities. *Soil Science Soc America J* 71: 611-619.
- Kuikman PJ, Lekkerkerk LJA, Van Veen JA (1991) Carbon dynamics of a soil planted with wheat under elevated CO<sub>2</sub> concentration. In: Wilson, WS (ed.) *Advances in Soil Organic Matter Research: The Impact on Agriculture and the Environment*, vol Special Publication 90. The Royal Society of Chemistry. Cambridge, UK, pp. 267-274.
- Kuzyakov Y. & Domanski G. (2000). Carbon input by plants into the soil. Review. *Journal Of Plant Nutrition And Soil Science-Zeitschrift Fur Pflanzenernahrung Und Bodenkunde*, 163, 421-431.
- Legendre P, Anderson MJ (1999) Distance-based redundancy analysis: Testing multispecies responses in multifactorial ecological experiments. *Ecological Monographs*, 69, 512-512.
- Lekkerkerk, LJA, Van de Geijn, SC, Van Veen ,JA (1990): Effects of elevated atmospheric CO<sub>2</sub>-levels on the carbon economy of a soil planted with wheat. In: Bowman AF (ed). *Soils and the greenhouse effect*, Chichester, John Wiley. p 423-429.
- Linderman RG (1998) VA (Vesicular-Arbuscular) Mycorrhizal symbiosis. *ISI Atlas of Science, Animal and Plant Science*, 1, 183-188.
- Lingoes JC (1971) Some boundary conditions for a monotone analysis of symmetric matrices. *Psychometrika*, 36, 195–203.
- Lipson D.A., Blair M., Barron-Gafford G., Grieve K. & Murthy R. (2006). Relationships between microbial community structure and soil processes under elevated atmospheric carbon dioxide. *Microbial Ecology*, 51, 302-314.

- Lipson DA, Wilson RF, Oechel WC (2005) Effects of elevated atmospheric CO<sub>2</sub> on soil microbial biomass, activity, and diversity in a chaparral ecosystem. *Appl Environ Microbiol* 71: 8573-8580.
- Long S.P., Ainsworth E.A., Rogers A. & Ort D.R. (2004). Rising atmospheric carbon dioxide: plants face the future. *Annual Review of Plant Biology*, 55, 591-628.
- Lu Y.H. & Conrad R. (2005). In situ stable isotope probing of methanogenic archaea in the rice rhizosphere. *Science*, 309, 1088-1090.
- Lu Y.H., Rosencrantz D., Liesack W. & Conrad R. (2006). Structure and activity of bacterial community inhabiting rice roots and the rhizosphere. *Environmental Microbiology*, 8, 1351-1360.
- Lueders T, Pommerenke B, Friedrich MW (2004) Stable-isotope probing of microorganisms thriving at thermodynamic limits: Syntrophic propionate oxidation in flooded soil. *Applied and Environmental Microbiology*, 70, 5778-5786.
- Lueders T., Manefield M. & Friedrich M.W. (2004) Enhanced sensitivity of DNA and rRNA based stable isotope probing by fractionation and quantitative analysis of isopycnic centrifugation gradients. *Environmental Microbiology*, 6, 73-78.
- Lugtenberg B.J.J., Dekkers L. & Bloemberg G.V. (2001) Molecular determinant of rhizosphere colonization by *Pseudomonas*. *Annual Review of Phytopathology*, 39, 461-490.
- Luo Y, Su B, Currie W, Dukes J, Finzi A, Hartwig U, Hungate B, McMurtrie R, Oren R, Parton W, Pataki D, Shaw M, Zak D, Field C (2004) Progressive nitrogen limitation of ecosystem responses to rising atmospheric carbon dioxide. *Bioscience* 54: 731-739.
- Lussenhop J, Treonis A, Curtis PS, Teeri JA, Vogel CS (1998) Response of soil biota to elevated atmospheric CO<sub>2</sub> in poplar model systems. *Oecologia* 113: 247-251.
- Lynch J.M. & Whipps J.M. (1990). Substrate flow in the rhizosphere. *Plant Soil*, 129, 1.
- Marilley L., Hartwig U.A. & Aragno M. (1999). Influence of an elevated atmospheric CO<sub>2</sub> content on soil and rhizosphere bacterial communities beneath *Lolium perenne* and *Trifolium repens* under field conditions. *Microbial Ecology*, 38, 39-49.
- Maherali H, Klironomos JN (2007). Influence of Phylogeny on fungal community assembly and ecosystem functioning. *Science*, 316, 1746-1748.
- Manefield M., Whiteley A.S., Ostle N., Ineson P. & Bailey M.J. (2002) Technical considerations for RNA-based stable isotope probing: an approach to associating microbial diversity with microbial community function. *Rapid Communications In Mass Spectrometry*, 16, 2179-2183.
- Mansfeld-Giese, K., Larsen, J. & Bodker, L. (2002) Bacterial populations associated with mycelium of the arbuscular mycorrhizal fungus *Glomus intraradices*. *FEMS Microbiol. Ecol.*, 41, 133-140.
- Mauclaire, L., Pelz, O., Thullner, M., Abraham, W.R., and Zeyer, J. (2003) Assimilation of toluene carbon along a bacteria-protist food chain determined by <sup>13</sup>C-enrichment of biomarker fatty acids. *J. Microbiol. Methods*, 55, 635-649.
- Marschner P, Baumann K (2003) Changes in bacterial community structure induced by mycorrhizal colonisation in split-root maize. *Plant and Soil*, 251, 279-289.
- Manefield M, Whiteley AS, Griffiths RI, Bailey MJ (2002). RNA stable isotope probing, a novel means of linking microbial community function to phylogeny. *Applied and Environmental Microbiology*, 68, 5367-5373.

- Marschner P, Crowley DE, Lieberei R (2001) Arbuscular mycorrhizal infection changes the bacterial 16 S rDNA community composition in the rhizosphere of maize. *Mycorrhiza*, 11, 297-302.
- Matamala R., Gonzalez-Meler M.A., Jastrow J.D., Norby R.J. & Schlesinger W.H. (2003). Impacts of fine root turnover on forest NPP and soil C sequestration potential. *Science*, 302, 1385-1387.
- Mathur N and Vyas A (2000) Influence of arbuscular mycorrhizae on biomass production, nutrient uptake and physiological changes in *Ziziphus mauritiana* Lam. under water stress. *Journal of Arid Environmental*, 45, 191-195.
- Mayr C, Miller M, Insam H (1999) Elevated CO<sub>2</sub> alters community-level physiological profiles and enzyme activities in alpine grassland. *Journal of Microbiological Methods*, 36, 35.
- Montealegre C.M., van Kessel C., Blumenthal J.M., Hur H.G., Hartwig U.A. & Sadowsky M.J. (2000). Elevated atmospheric CO<sub>2</sub> alters microbial population structure in a pasture ecosystem. *Global Change Biology*, 6, 475-482.
- Moore J.C. M.K. & de Ruiter P. (2007) Soil rhizosphere food webs, their stability, and implications for soil processes in ecosystems. In: *The Rhizosphere: An Ecological Perspective*, (eds Zoe G. Cardon & Julie L. Whitbeck). Elsevier Academic Press, San Diego, CA, USA, pp. 101-125.
- Moore JC, Hunt HW (1998) Resource compartmentation and the stability of real ecosystems. *Nature* 333: 261-263.
- Moscatelli M. C., Lagomarsino A., de Angelis P., and Grego S. (2005). Seasonality of soil biological properties in a polar plantation growing under elevated atmospheric CO<sub>2</sub>. *Applied Soil Ecology*, 30, 162–173.
- Mougel C, Offre P, Ranjard L *et al.* (2006) Dynamic of the genetic structure of bacterial and fungal communities at different developmental stages of *Medicago truncatula* Gaertn. cv. *Jemalong* line J5. *New Phytologist*, 170, 165-175.
- Muchovej J.J., Muchovej R.M.C. & Gonçalves E.J. (1991). Effect of kind and method of fungicidal treatment of bean seed on infections by the VA-mycorrhizal fungus *Glomus macrocarpum* and by the pathogenic fungus *Fusarium solani*. *Plant and Soil*, 132, 47-51.
- Muyzer G, de Waal EC, Uitterlinden AG (1993) Profiling of complex microbial populations by denaturing gradient gel electrophoresis analysis of polymerase chain reaction-amplified genes coding for 16S rRNA. *Applied & Environmental Microbiology*, 59, 695–700.
- Neher DA, Weicht TR, Moorhead DL *et al.* (2004) Elevated CO<sub>2</sub> alters functional attributes of nematode communities in forest soils. *Functional Ecology*, 18, 584-591.
- Neufeld J.D., Wagner M. & Murrell J.C. (2007). Who eats what, where and when? Isotope-labelling experiments are coming of age. *ISME Journal*, 1, 103.
- Nguyen C. (2003). Rhizodeposition of organic C by plants: mechanisms and controls. *Agronomie*, 23, 375-396.
- Niklaus PA, Alpehi J, Ebersberger D, Kamphikler C, Kandler E & Tscherko D (2003) Six years of in situ CO<sub>2</sub> enrichment evoke changes in soil structure and soil biota of nutrient-poor grassland. *Global Change Biol* 9:585-600.
- Niklaus PA, Glockler E, Siegwolf R, Korner C (2001) Carbon allocation in calcareous grassland under elevated CO<sub>2</sub>: a combined <sup>13</sup>C-pulse-labelling/soil physical fractionation study. *Funct Ecol* 15: 43-50.

- Niklaus P.A., Alpei J., Ebersberger D., Kamphikler C., Kandler E. & Tscherko D. (2003). Six years of in situ CO<sub>2</sub> enrichment evoke changes in soil structure and soil biota of nutrient-poor grassland. *Global Change Biology*, 9, 585-600.
- Norby R.J. (1994). Issues and perspectives for investigating responses to elevated atmospheric carbon-dioxide. *Plant and Soil*, 165, 9-20.
- Olf H, Hoorens B, de Goede RGM *et al.* (2000) Small-scale shifting mosaics of two dominant grassland species: the possible role of soil-borne pathogens. *Oecologia*, 125, 45-54.
- Olsrud M, Melillo JM, Christensen TR, Michelsen A, Wallander H, Olsson PA (2004). Response of ericoid mycorrhizal colonization and functioning to global change factors. *New Phytol* 162: 459-469.
- Olsson, P.A., Van Aarle, I.M., Allaway, W.G., Ashford, A.E. & Rouhier, H. (2002) Phosphorus effects on metabolic processes in monoxemic arbuscular mycorrhiza cultures. *Plant Physiol.*, 130, 1162-1171.
- Olsson P.A. & Johnson N.C. (2005). Tracking carbon from the atmosphere to the rhizosphere. *Ecology Letters*, 8, 1264-1270.
- Olsson PA (1999) Signature fatty acids provide tools for determination of the distribution and interactions of mycorrhizal fungi in soil. *FEMS Microbiology Ecology*, 29, 303-310.
- Orlowska E., Ryszka P., Jurkiewicz A. & Turnau K. (2005). Effectiveness of arbuscular mycorrhizal fungal (AMF) strains in colonization of plants involved in phytostabilisation of zinc wastes. *Geoderma*, 129, 92-98.
- Ostle N., Whiteley A.S., Bailey M.J., Sleep D., Ineson P. & Manefield M. (2003). Active microbial RNA turnover in a grassland soil estimated using a (CO<sub>2</sub>)-C-13 spike. *Soil Biology and Biochemistry*, 35, 877-885.
- Owen AG, Jones D. (2001) Competition for amino acids between wheat roots and rhizosphere microorganisms and the role of amino acids in plant N acquisition. *Soil Biol Biochem* 33: 651-657.
- Pace N.R. (1997). A molecular view of microbial diversity and the biosphere. *Science*, 276, 734-740.
- Parrent JL, Morris WF, Vilgalys R (2006) CO<sub>2</sub>-enrichment and nutrient availability alter ectomycorrhizal fungal communities. *Ecology* 87:2278-2287.
- Paterson E, Grayston SJ, Campbell CD, *et al.* (1998) Characterization and microbial utilization of exudate material from the rhizosphere of *Lolium perenne* grown under CO<sub>2</sub> enrichment. *Soil Biology & Biochemistry*, 30, 1033.
- Paterson E, Hall JM, Rattray EAS, Griffiths BS, Ritz K, Killham K (1997) Effect of elevated CO<sub>2</sub> on rhizosphere carbon flow and soil microbial processes. *Global Change Biol* 3: 363-377.
- Paterson E, Hodge A, Thornton B, Millard P, Killham K (1999) Carbon partitioning and rhizosphere C-flow in *Lolium perenne* as affected by CO<sub>2</sub> concentration, irradiance and below-ground conditions. *Global Change Biol* 5: 669-678.
- Paterson E, Rattray EAS, Killham K (1996) Effect of elevated atmospheric CO<sub>2</sub> concentration on C-partitioning and rhizosphere C-flow for three plant species. *Soil Biology and Biochemistry*, 28, 195.
- Pendall E., Bridgman S., Hanson P.J., Hungate B., Kicklighter D.W., Johnson D.W., Law B.E., Luo Y.Q., Meconigal J.P., Olsrud M., Ryan M.G. & Wan S.Q. (2004). Below-ground process responses to elevated CO<sub>2</sub> and temperature: a discussion of observations, measurement methods, and models. *New Phytologist*, 162, 311-322.

- Petit E, Valiere N. 2006. Estimating population size with noninvasive capture–mark–recapture data. *Conservation Biology*. 20, 1062–1073.
- Phillips DA, Fox TC, Six J (2006) Root exudation (net efflux of amino acids) may increase rhizodeposition under elevated CO<sub>2</sub>. *Global Change Biol* 12: 561-567.
- Phillips DA, Fox TC, Ferris H, Moore JC (2006) The influence of elevated CO<sub>2</sub> on diversity, activity and biogeochemical function of rhizosphere and soil bacterial communities. In: Nösberger J, Long SP, Norby RJ et al(eds). *Managed Ecosystems and CO<sub>2</sub> - Case Studies, Processes and Perspectives*. Ecological Studies Serie , vol. 187, Springer, Berlin, Heidelberg, pp. 413-428.
- Phillips DA, Fox TC, King MD, Bhuvanewari TV, Teuber LR (2004) Microbial products trigger amino acid exudation from plant roots. *Plant Physiol* 136: 2887-2894.
- Phillips R.P. (2007). Towards a rhizo-centric view of plant-microbial feedbacks under elevated atmospheric CO<sub>2</sub>. *New Phytologist*, 173, 664-667.
- Phillips RL, Zak DR, Holmes WE, White DC (2002) Microbial community composition and function beneath temperate trees exposed to elevated atmospheric carbon dioxide and ozone. *Oecologia* 131: 236-244
- Pregitzer KS, Laskowski MJ, Burton AJ, Lessard VC, Zak DR (1998) Variation in sugar maple root respiration with root diameter and soil depth. *Tree Physiol* 18: 665-670.
- Pregitzer KS, Zak DR, Loya W M, Karberg N J, King JS, Burton AJ (2007) The contribution of root – Rhizosphere biochemical cycles in changing world. In: Cardon ZG and Whitbeck JL(eds). *The Rhizosphere: An Ecological Perspective*, Elsevier Academic Press, London, UK, pp. 155-178.
- Pregitzer KS, Zak DR, Maziasz J, DeForest J, Curtis PS, Lussenhop J (2000) Interactive effects of atmospheric CO<sub>2</sub> and soil-N availability on fine roots of *Populus tremuloides*. *Ecol Applic* 10: 18-33.
- Raaijmakers J.M., Vlami M. & de Souza J.T. (2002). Antibiotic production by bacterial biocontrol agents. *Antoine Van Leeuwenhoek*, 81, 537–547.
- Raaijmakers J.M., Weller D.M. & Thomashow L.S. (1997). Frequency of antibiotic-producing *Pseudomonas* spp. in natural environments. *Applied Environmental Microbiology*, 63, 881–887.
- Radajewski S., Ineson P., Parekh N.R. & Murrell J.C. (2000). Stable-isotope probing as a tool in microbial ecology. *Nature*, 403, 646-649.
- Randlett DL, Zak DR, Pregitzer KS, et al. (1996) Elevated atmospheric carbon dioxide and leaf litter chemistry: Influences on microbial respiration and net nitrogen mineralization. *Soil Science Society of America Journal*, 60, 1571-1577.
- Rangel-Castro J.I., Killham K., Ostle N., Nicol G.W., Anderson I.C., Scrimgeour C.M., Ineson P., Meharg A. & Prosser J.I. (2005). Stable isotope probing analysis of the influence of liming on root exudate utilization by soil microorganisms. *Environmental Microbiology*, 7, 828-838.
- Richter M, Hartwig UA, Frossard E, Nosberger J, Cadisch G (2003) Gross fluxes of nitrogen in grassland soil exposed to elevated atmospheric pCO<sub>2</sub> for seven years. *Soil Biol. Biochem* 35: 1325-1335.
- Rickel D, Sancho F, Ananth S (1994) Vesicular-arbuscular endomycorrhizal colonization of wetland plants. *Journal of Environmental Quality*, 23, 913-916.
- Rillig M.C. & Allen M.F. (1998). Arbuscular mycorrhizae of *Gutierrezia sarothrae* and elevated carbon dioxide: Evidence for shifts in C allocation to and within the mycobiont. *Soil Biology & Biochemistry*, 30, 2001-2008.

- Rillig M.C. & Allen M.F. (1999). What is the role of arbuscular mycorrhizal fungi in plant-to-ecosystem responses to Elevated atmospheric CO<sub>2</sub>? *Mycorrhiza*, 9, 1-8.
- Rillig M.C., Hernandez G.Y. & Newton P.C.D. (2000). Arbuscular mycorrhizae respond to elevated atmospheric CO<sub>2</sub> after long-term exposure: evidence from a CO<sub>2</sub> spring in New Zealand supports the resource balance model. *Ecology Letters*, 3, 475-478.
- Rillig M.C., Scow K.M., Klironomos J.N. & Allen M.F. (1997). Microbial carbon-substrate utilization in the rhizosphere of *Gutierrezia sarothrae* grown in elevated atmospheric carbon dioxide. *Soil Biology & Biochemistry*, 29, 1387-1394.
- Rillig MC, Allen MF, Klironomos JN, Chiariello NR, Field CB (1998) Plant species-specific changes in root-inhabiting fungi in a California annual grassland: responses to elevated CO<sub>2</sub> and nutrients. *Oecologia* 113: 252-259.
- Rillig MC, Field CB (2003). Arbuscular mycorrhizae respond to plants exposed to elevated atmospheric CO<sub>2</sub> as a function of soil depth. *Plant Soil* 254: 383-391.
- Rillig MC, Field CB, Allen MF (1999) Soil biota responses to long-term atmospheric CO<sub>2</sub> enrichment in two California annual grasslands. *Oecologia*, 119, 572-577.
- Rillig MC, Mummey DL (2006) Mycorrhizas and soil structure. *New Phytol* 171: 41-53.
- Rillig, M.C., Mummey, D.L., Ramsey, P.W. Klironomos, J.N. & Gannon, J.E. (2006) Phylogeny of arbuscular mycorrhizal fungi predict community composition of symbiosis-associated bacteria. *FEMS Microbiol. Ecol.*, 57, 389-395.
- Rillig MC, Mummey DL, Ramsey PW *et al.* (2006) Phylogeny of arbuscular mycorrhizal fungi predicts community composition of symbiosis-associated bacteria. *FEMS Microbiology Ecology*, 57, 389-395.
- Rillig MC, Scow KM, Klironomos JN *et al.* (1997) Microbial carbon-substrate utilization in the rhizosphere of *Gutierrezia sarothrae* grown in elevated atmospheric carbon dioxide. *Soil Biology & Biochemistry*, 29, 1387-1394.
- Rillig MC, Wright SF, Kimball BA, Leavitt SW (2001) Elevated carbon dioxide and irrigation effects on water stable aggregates in a *Sorghum* field: a possible role for arbuscular mycorrhizal fungi. *Global Change Biol* 7:333-337.
- Rillig MC, Wright SF, Shaw MR, Field CB (2002) Artificial climate warming positively affects arbuscular mycorrhizae but decreases soil aggregate water stability in an annual grassland. *Oikos* 97: 52-58.
- Rogers H.H., Runion G.B., Krupa S.V. (1994) Plant-Responses to atmospheric CO<sub>2</sub> enrichment with emphasis on roots and the rhizosphere. *Environ Pollution*, 83, 155-189.
- Ronn R, Ekelund F, Christensen S (2003) Effects of elevated atmospheric CO<sub>2</sub> on protozoan abundance in soil planted with wheat and on decomposition of wheat roots. *Plant Soil* 251: 13-21.
- Ronn R, Gavito M, Larsen J, Jakobsen I, Frederiksen H, Christensen S (2002) Response of free-living soil protozoa and microorganisms to elevated atmospheric CO<sub>2</sub> and presence of mycorrhiza. *Soil Biol Biochem* 34: 923-932.
- Sadowsky MJ, Schortemeyer M (1997) Soil microbial responses to increased concentrations of atmospheric CO<sub>2</sub>. *Global Change Biol* 3: 217-224.
- Salles J.F., De Souza F.A. & van Elsas J.D. (2002). Molecular method to assess the diversity of Burkholderia species in environmental samples. *Applied Environmental Microbiology*, 68, 1595-1603.
- Sanders IR, Streitwolf-Engel R, van der Heijden MGA, Boller T, Wiemken A (1998) Increased allocation to external hyphae of arbuscular mycorrhizal fungi under CO<sub>2</sub> enrichment. *Oecologia* 117: 496-503.

- Schäppi B. & Körner C. (1996) Growth responses of an alpine grassland to elevated CO<sub>2</sub>, *Oecologia*, 1, 43–52.
- Stöcklin J., Schweizer K. & Körner C. (1998) Effects of elevated CO<sub>2</sub> and phosphorus addition on productivity and community composition of intact monoliths from calcareous grassland. *Oecologia*, 116, 50–56.
- Schimel D, Melillo J, Tian H, McGuire AD, Kicklighter D, Kittel T, Rosenbloom N, Running S, Thornton P, Ojima D, Parton W, Kelly R, Sykes M, Neilson R Rizzo B (2000) Contribution of increasing CO<sub>2</sub> and climate to carbon storage by ecosystems in the United States. *Science* 287: 2004-2006.
- Schortemeyer M., Hartwig U.A., Hendrey G.R. & Sadowsky M.J. (1996). Microbial community changes in the rhizospheres of white clover and perennial ryegrass exposed to Free Air Carbon dioxide Enrichment (FACE). *Soil Biology and Biochemistry*, 28, 1717-1724.
- Shachar-Hill Y, Pfeffer PE, Douds D *et al.* (1995) Partitioning of intermediary carbon metabolism in vesicular-arbuscular mycorrhizal leek. *Plant Physiology*, 108, 7-15.
- Smalla K, Wieland G, Buchner A, *et al.* (2001) Bulk and rhizosphere soil bacterial communities studied by denaturing gradient gel electrophoresis: Plant-dependent enrichment and seasonal shifts revealed *Applied and Environmental Microbiology*, 67, 4742-4751.
- Smith S.E. & Read D.J. (1997). *Mycorrhizal Symbiosis*. Academic Press, San Diego.
- Sonnemann I, Wolters V (2005) The microfood web of grassland soils responds to a moderate increase in atmospheric CO<sub>2</sub>. *Global Change Biology*, 11, 1148-1155.
- Sood SG (2003) Chemotactic response of plant-growth-promoting bacteria towards roots of vesicular-arbuscular mycorrhizal tomato plants. *FEMS Microbial Ecology*, 45, 219-227.
- Soussana JF, Hartwig UA (1996) The effects of elevated CO<sub>2</sub> on symbiotic N<sub>2</sub> fixation: a link between the carbon and nitrogen cycles in grassland ecosystems. *Plant Soil* 187: 321-332.
- Sowerby A, Blum H, Gray TRG, Ball AS (2000) The decomposition of *Lolium perenne* in soils exposed to elevated CO<sub>2</sub>: comparisons of mass loss of litter with soil respiration and soil microbial biomass. *Soil Biol. Biochem* 32: 1359.
- Staddon P.L. & Fitter A.H. (1998). Does elevated atmospheric carbon dioxide affect arbuscular mycorrhizas? *Trends in Ecology and Evolution*, 13, 455-458.
- Staddon P.L. (2005). Mycorrhizal fungi and environmental change: the need for a mycogenic approach. *New Phytologist*, 167, 635-637.
- Staddon P.L., Ramsey C.B., Ostle N., Ineson P. & Fitter A.H. (2003). Rapid turnover of hyphae of mycorrhizal fungi determined by AMS microanalysis of <sup>14</sup>C. *Science*, 300, 1138.
- Staddon PL, Fitter AH, Graves JD (1999) Effect of elevated atmospheric CO<sub>2</sub> on mycorrhizal colonization, external mycorrhizal hyphal production and phosphorus inflow in *Plantago lanceolata* and *Trifolium repens* in association with the arbuscular mycorrhizal fungus *Glomus mosseae*. *Global Change Biol*, 5: 347-358.
- Staddon PL, Heinemeyer A, Fitter AH (2002) Mycorrhizas and global environmental change: research at different scales. *Plant Soil* 244: 253-261.
- Staddon PL (2004). Carbon isotopes in functional soil ecology. *Trends in Ecology & Evolution*, 19, 148.
- Tarnawski S and Aragno M (2006) The influence of elevated CO<sub>2</sub> on diversity, activity and biogeochemical function of rhizosphere and soil bacterial communities. In:

- Managed Ecosystems and CO<sub>2</sub> - Case Studies, Processes and Perspectives. Ecological Studies Serie* (eds Nösberger J, Long SP, Norby RJ *et al.*), vol. 187, pp. 393-409, Springer, Berlin, Heidelberg .
- Tarnawski S, Hamelin J, Jossi M *et al.* (2006) Phenotypic structure of *Pseudomonas* populations is altered under elevated pCO<sub>2</sub> in the rhizosphere of perennial grasses. *Soil Biology & Biochemistry*, 38, 1193.
- Tenuta M, Ferris H (2004) Relationship between nematode like-history classification and sensitivity to stressor: ionic and osmotic effects of nitrogenous solutions. *J Nematol* 36: 85-94.
- Ter Braak C.J.F., Šmilauer P (2002) CANOCO Reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). Microcomputer Power, Ithaca, NY.
- Ter Braak C.J.F., Verdonschot P (1995) Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences*, 57, 255-289.
- Thomas RB, Richter DD, Ye H, Heine PR, Strain BR (1991) Nitrogen dynamics and growth of seedlings of an N-fixing tree (*Gliricidia sepium* (Jacq.) Walp.) exposed to elevated atmospheric carbon dioxide. *Oecologia* 88:415-421.
- Tiedje J.M., Asuming-Brempong S., Nusslein K., Marsh T.L. & Flynn S.J. (1999). Opening the black box of soil microbial diversity. *Applied Soil Ecology*, 13, 109-122.
- Tietema T (1981) Ecophysiology of the sand sedge, *Carex arenaria* L. In: Thesis, Rijksuniversiteit Utrecht, p.106.
- Tissue DT, Megonigal JP, Thomas RB (1996) Nitrogenase activity and N<sub>2</sub> fixation are stimulated by elevated CO<sub>2</sub> in a tropical N<sub>2</sub>-fixing tree. *Oecologia* 109: 28-33.
- Toljander J.F., Lindahl B.D., Paul L.R., Elfstrand M. & Finlay R.D. (2007) Influence of arbuscular mycorrhizal mycelial exudates on soil bacterial growth and community structure. *FEMS Microbiol. Ecol.*, 61, 295 -304.
- Toljander JF, Artursson V, Paul LR *et al.* (2006) Attachment of different soil bacteria to arbuscular mycorrhizal fungal extraradical hyphae is determined by hyphal vitality and fungal species. *FEMS Microbiology Letters*, 254, 34-40.
- Toljander JF, Lindahl BL, Paul LR *et al.*, (2007) Influence of arbuscular mycorrhizal mycelial exudates on soil bacterial growth and community structure. *FEMS Microbial Ecology*, in press.
- Torsvik V, Ovreas L. (2002) Microbial diversity and function in soil: from genes to ecosystems. *Current Opinion in Microbiology*, 5, 240-245.
- Treonis A.M., Ostle N.J., Stott A.W., Primrose R., Grayston S.J. & Ineson P. (2004). Identification of groups of metabolically-active rhizosphere microorganisms by stable isotope probing of PLFAs. *Soil Biology and Biochemistry*, 36, 533-537.
- Treonis AM, Lussenhop JF (1997) Rapid response of soil protozoa to elevated CO<sub>2</sub> . *Biol Fertil Soils* 25: 60-62.
- Treseder KK, Allen MF (2000) Mycorrhizal fungi have a potential role in soil carbon storage under elevated CO<sub>2</sub> and nitrogen deposition. *New Phytol* 147: 189-200.
- Treseder K.K. (2004) A meta-analysis of mycorrhizal responses to nitrogen, phosphorus, and atmospheric CO<sub>2</sub> in field studies, *New Phytologist*, 164, 347-355.
- Troelstra S.R., Wagenaar R., Smant W. and Peters B.A.M. (2001). Interpretation of bioassays in the study of interactions between soil organisms and plants: involvement of nutrient factors. *New Phytologist*, 150, pp. 697-706.

- Uselman S.M., Qualls R.G. & Thomas R.B. (2000). Effects of increased atmospheric CO<sub>2</sub>, temperature, and soil N availability on root exudation of dissolved organic carbon by a N-fixing tree (*Robinia pseudoacacia* L.). *Plant and Soil*, 222, 191-202.
- Vainio EJ, Hantula J (2000) Direct analysis of wood-inhabiting fungi using denaturing gradient gel electrophoresis of amplified ribosomal DNA. *Mycological Research*, 104, 927–936.
- Van Aarle IM, Olsson PA (2003) Fungal lipid accumulation and development of mycelial structures by two arbuscular mycorrhizal fungi. *Applied and Environmental Microbiology*, 69, 6762-6767.
- Van der Putten WH (1997) Die-back of *Phragmites australis* in European wetlands: an overview of the European Research Programme on Reed Die-Back and Progression (1993-1994). *Aquatic Botany*, 59, 263-275.
- Van Ginkel J.H., Whitmore A.P. & Gorissen A. (1999). *Lolium perenne* grasslands may function as a sink for atmospheric carbon dioxide. *Journal of Environmental Quality*, 28, 2035-2035.
- Vandenkoornhuysen P, Mahe S, Ineson P, Staddon P, Ostle N, Cliquet JB, Francez AJ, Fitter AH, Young JPW (2007). Active root-inhabiting microbes identified by rapid incorporation of plant-derived carbon into RNA. *Proceedings of the National Academy of Sciences of the United States of America*, 104, 16970-16975.
- Vancanneyt, M., Witt, S., Abraham, W.R., Kersters, K. & Fredrickson, H.L. (1996) Fatty acid content in whole-cell hydrolysates and phospholipid fractions of pseudomonads: A taxonomic evaluation. *System. Appl. Microbiol.*, 19, 528-540.
- Van Ginkel JH, Gorissen A (1998) In situ decomposition of grass roots as affected by elevated atmospheric carbon dioxide. *Soil Science Soc America J* 62: 951-958.
- Van Ginkel JH, Gorissen A, Polci D (2000) Elevated atmospheric carbon dioxide concentration: effects of increased carbon input in a *Lolium perenne* soil on microorganisms and decomposition. *Soil Biol Biochem* 32: 449-456.
- Van Veen, JA, Morgan, JAW, Whipps, JM (2007). Methodological approaches to the
- Van Groenigen K. J., Six J., Hungate B. A., de Graaff M. A., van Breemen N. & van Kessel C. (2006). Element interactions limit soil carbon storage. *Proceedings of the National Academy of Sciences of the United States of America*, 103, 6571–6574.
- Van der Putten W.H. and Van der Stoep C.D. (1998). Plant parasitic nematodes and spatio-temporal variation in natural vegetation. *Applied Soil Ecology*, 10, pp. 253–262.
- Waite IS, O'Donnell AG, Harrison A, *et al.* (2003) Design and evaluation of nematode 18S rDNA primers for PCR and denaturing gradient gel electrophoresis (DGGE) of soil community DNA. *Soil Biology Biochemistry*, 35, 1165–1173.
- Walker RF, Geisinger DR, Johnson DW, Ball JT (1997) Elevated atmospheric CO<sub>2</sub> and soil N fertility effects on growth, mycorrhizal colonization, and xylem water potential of juvenile ponderosa pine in a field soil. *Plant Soil* 195: 25-36.
- Wan S, Norby RJ, Pregitzer KS, Ledford J, O'Neill EG (2004) CO<sub>2</sub> enrichment and warming of the atmosphere enhance both productivity and mortality of maple tree fine roots. *New Phytol* 162: 437-446.
- Wardle D. A., Brown V. K., Behan-Pelletier V., St. John M., Wojtowicz T., Bardgett R. D., Brown G. G., Ineson P., Lavelle P., van der Putten W. H., Anderson J. M., Brussaard L., Hunt W.H., Paul E. A., and Wall D. H. (2004). Vulnerability to global change of ecosystem goods and services driven by soil biota, in: Sustaining

- Biodiversity and Ecosystem Services in Soils and Sediments, edited by: Wall, D. H., Island Press, Washington DC, 101–136.
- Wardle DA, Walker LR, Bardgett RD (2004) Ecosystem properties and forest decline in contrasting long-term chronosequences. *Science*, 305, 509-513.
- Widmer F., Seidler R.J., Gillevet P.M., Watrud L.S. & Di Giovanni G.D. (1998). A highly selective PCR protocol for detecting 16S rRNA genes of the genus *Pseudomonas* (*sensu stricto*) in environmental samples. *Applied Environmental Microbiology*, 64, 2545-2553.
- Wiemken V, Laczko E, Ineichen K, Boller T (2001) Effects of elevated carbon dioxide and nitrogen fertilization on mycorrhizal fine roots and the soil microbial community in beech-spruce ecosystems on siliceous and calcareous soil. *Microb Ecol* 42: 126-135.
- Williams, MAC, Rice,W, Owensby WE (2000). C dynamics and microbial activity in tallgrass prairie exposed to elevated CO<sub>2</sub> for 8 years. *Plant Soil* 227:127-137.
- White D. C., Davis W. M., Nickels J. S., King J. D., and Bobbie R. J. (1979) Determination of the sedimentary microbial biomass by extractable lipid phosphate, *Oecologia*, 40, 51–62.
- Wolf J, Johnson NC, Rowland DL, Reich PB (2003) Elevated CO<sub>2</sub> and plant species richness impact arbuscular mycorrhizal fungal spore communities. *New Phytol* 157: 579-588.
- Yeates GW, Newton PCD, Ross DJ (2003) Significant changes in soil microfauna in grazed pasture under elevated carbon dioxide. *Biology and Fertility*, 38, 319-326.
- Yeates GW, Tate KR, Newton PCD (1997). Response of the fauna of a grassland soil to doubling of atmospheric carbon dioxide concentration. *Biol Fertil Soils* 25: 307-315.
- Yergeau E., Filion M., Vujanovic V. & St-Arnaud M. (2005). A PCR-denaturing gradient gel electrophoresis approach to assess *Fusarium* diversity in asparagus. *Journal of Microbiological Methods*, 60, 143-154.
- Zak D.R., Pregitzer K.S., Curtis P.S. & Holmes W.E. (2000). Atmospheric CO<sub>2</sub> and the composition and function of soil microbial communities. *Ecological Applications*, 10, 47-59.
- Zak D.R., Pregitzer K.S., Curtis P.S., Teeri J.A., Fogel R. & Randlett D.L. (1993). Elevated atmospheric CO<sub>2</sub> and feedback between carbon and nitrogen cycles. *Plant and Soil*, 151, 105-117.
- Zak D.R., Ringelberg D.B., Pregitzer K.S., Randlett D.L., White D.C. & Curtis P.S. (1996). Soil microbial communities beneath *Populus grandidentata* crown under elevated atmospheric CO<sub>2</sub>. *Ecological Applications*, 6, 257-262.
- Zak DR, Pregitzer KS, Curtis PS *et al.* (2000) Atmospheric CO<sub>2</sub> and the composition and function of soil microbial communities. *Ecological Applications*, 10, 47-59.
- Zak D.R., Holmes W.E., White D.C., Peacock A.D. & Tilman D. (2003). Plant diversity, soil microbial communities, and ecosystem function: Are there any links? *Ecology*, 84, 2042-2050.
- Zelles, L. 1999. Fatty acid patterns of phospholipids and lipopolysaccharides in the characterization of microbial communities in soil: A review. *Biol. Fertil. Soils* 29, 111–129.
- Zhou GY, Liu SG, Li Z, Zhang DQ, Tang XL, Zhou CY, Yan JH, Mo JM (2006). Old-growth forests can accumulate carbon in soils. *Science*, 314, 1417-1417