Sustainable by Nature
Biofertilisers Pave the Way for Food Security

Marcellous le Roux
Department of Agronomy (Faculty of AgriSciences)
University of Stellenbosch
mrl@sun.ac.za

Attempts are underway globally to increase food production in order to feed the burgeoning population, but it is unreservedly acknowledged that this should not occur at the expense of the environment

Although there is wide recognition for the role that fertilizers (and other agrochemicals) have played to subdue food insecurity of the global populace, through providing essential nutrients to crop plants, it has become apparent that the overuse thereof has compromised environmental integrity. Moreover, the low use-efficiency of chemical fertilizers has been well documented. Another undesirable outcome of the use of high levels of fertilizers is that current commercialized plant genotypes are responsive to high chemical fertility of soils, at the expense of biological fertility.

The supply of agrochemicals (pesticides, herbicides, fertilizers) has in part, de-linked the association between agrobiodiversity and agro ecosystem functioning. For example, nitrogen (N) fertilizers may partially replace the function of rhizobial (nodulating) or freeliving N_2-fixing bacteria within the N cycle, while phosphorus (P) fertilizers may partially replace the role of arbuscular myccorhizal fungi (AMF) associated with crop plants. Thus, the commercial varieties of plants used(other than legumes) do not readily benefit from microbial associations. Therefore, best management practices and nutrient decision support systems aimed at increasing crop yields that focuses on microorganisms known to improve soil fertility and enhance plant nutrition, ha sreceived renewed impetus. Biostimulants(or biofertilizers) in an agricultural context include diverse substances and microorganisms that stimulate crop growth. The global market for biostimulants is projected to have a turnover of US$2.24 million by 2018 and to have a compound annual growth rate of 12.5% between now and 2018. The use of biostimulants forms one of the mainstay tenets of integrated nutrient management, which may prove to be cost effective and renewable. In recent times, ecological approaches to improve both crop productivity and human nutrition have garnered wide appeal. Ecological approaches naturally implicate the interactions between several organisms and how their respective functionalities find expression in a wide spectrum of diverse environments.

*AgriKultuur/Culture no 24, May 2015, www.agrikultuur.co.za

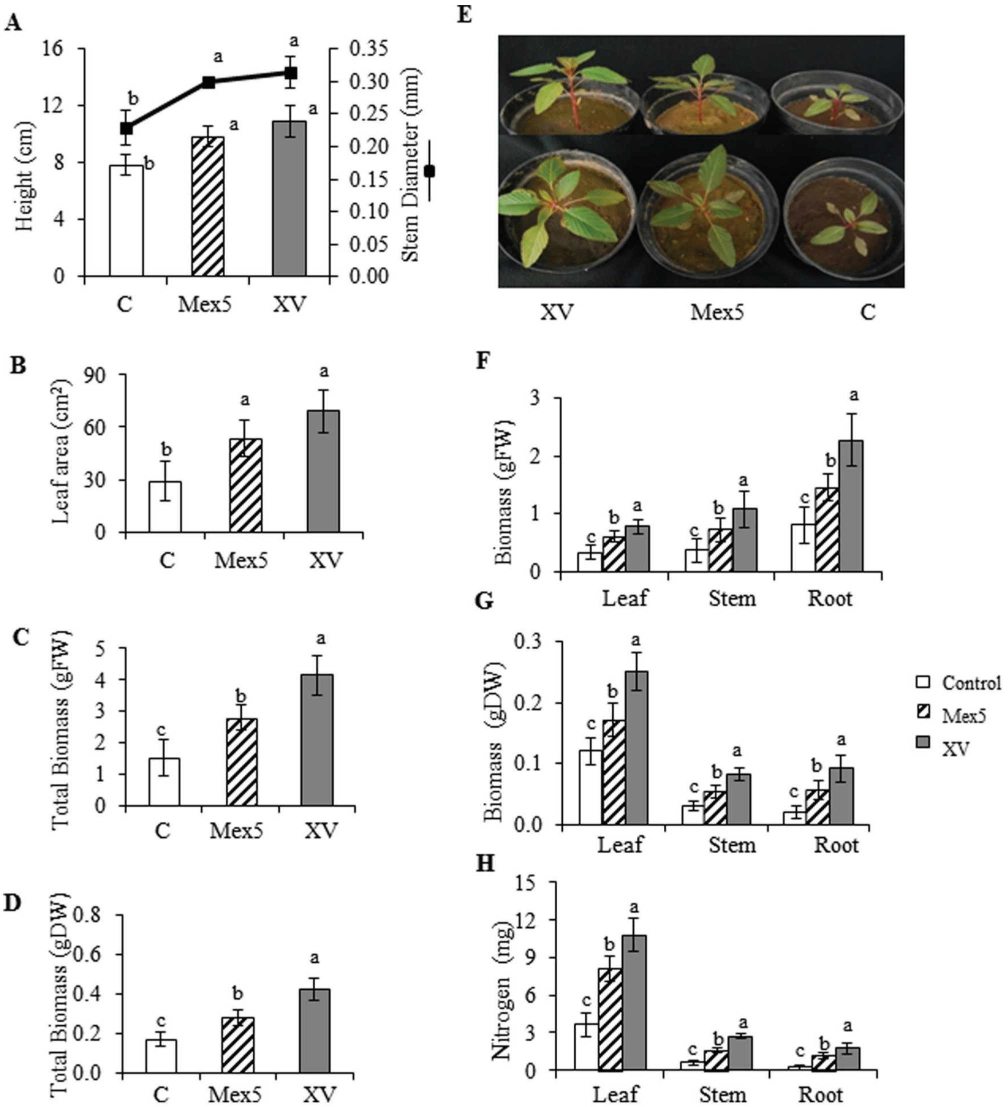

Figure 1. Effect of two different PGPR strains, *Burkholderia ambifaria* (Mex5) and B. *caribensis* (XV) on growth and nitrogen content of *Amaranthus cruentus* plants after 7 weeks of growth in low fertility soil (Source: Parra-Cota et al., 2014)

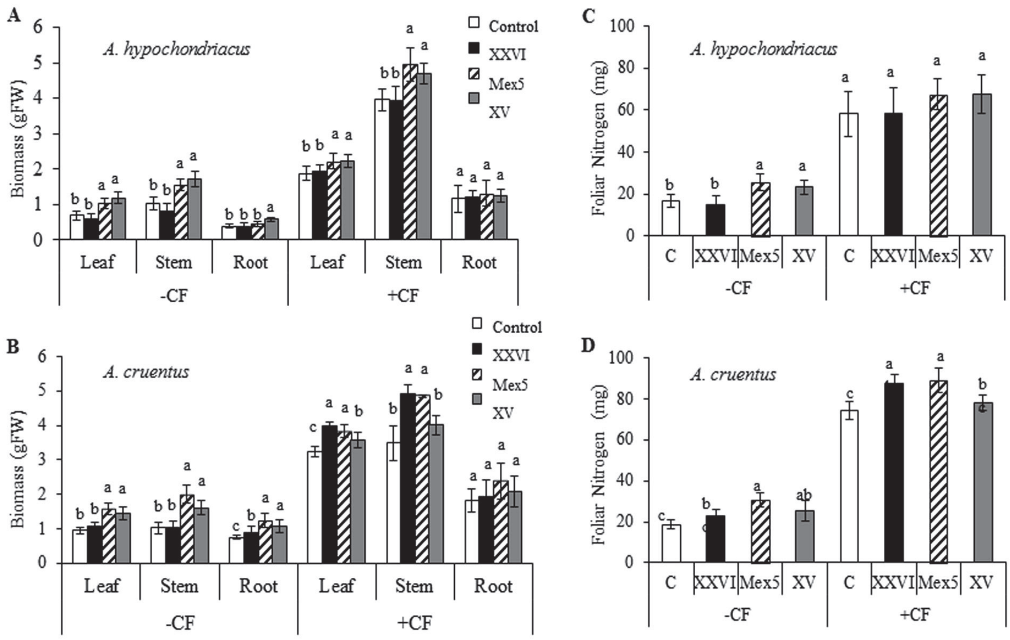

Figure 2. Effect of three different PGPR strains on growth and nitrogen content of grain Amaranth plants after 8 weeks of growth in a rich substrate with (+CF) or without (–CF) chemical fertilization; (Source: Parra-Cota et al., 2014)

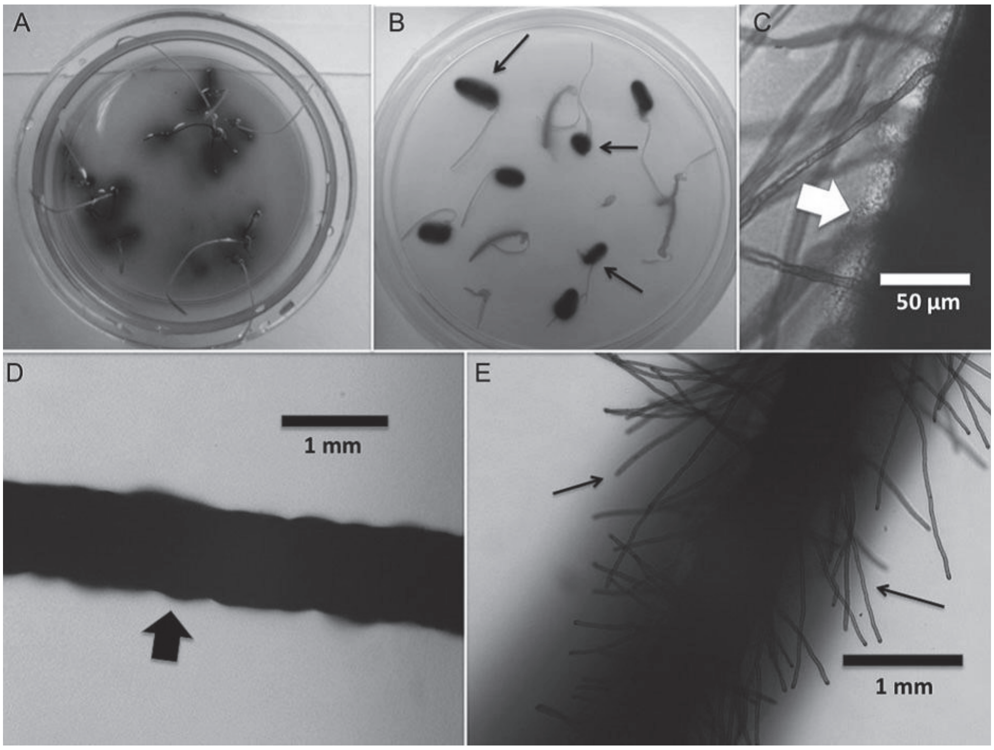

Figure 3. Poa annua seedlings showing reactive oxygen (H2O2) staining around roots. (A) Seedlings growing on 0.7 % agarose showing diffuse zones of reactive oxygen (brown) around roots. (B) Seedlings growing on 0.1 % albumin agarose showing dense zones of reactive oxygen (arrows) around roots. (C) Root surface showing root hairs and layer of bacteria (arrow). (D) Root without bacteria growing in 0.7 %water agarose medium, showing absence of root hairs. (E) Root with bacteria growing on 0.7 %water agarose medium, showing reactive oxygen zone and root hairs (arrows).

(Source: White JF, Chen Q, Torres MS, Mattera R, Irizarry I, Tadych M, Bergen M. 2015. Collaboration between grass seedlings and rhizobacteria to scavenge organic nitrogen in soils. AoB PLANTS 7: plu093; doi:10.1093/aobpla/plu093)

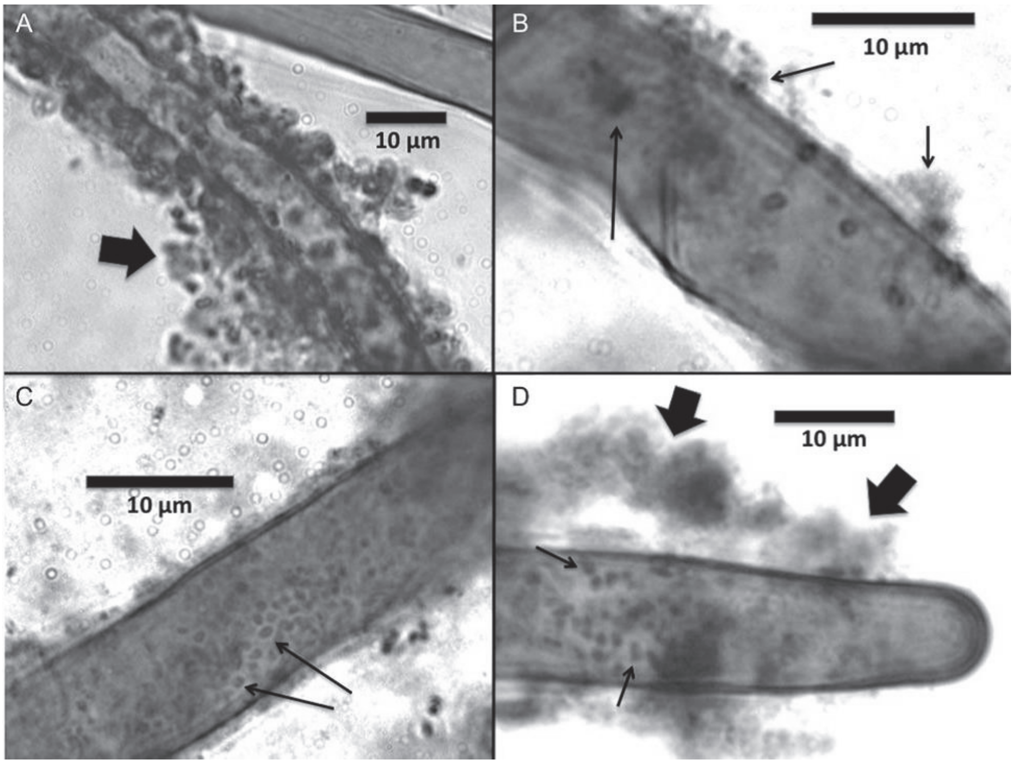

Figure 4. Bacteria on root hairs of cool-season grass seedlings; stained with DAB/peroxidase for reactive oxygen (brown) and counterstained with aniline blue/lacto-phenol for protein. (A) Bacteria (arrow) on surface of root hair of Lolium perenne seedling. (B) Bacteria and bacterial protein (arrows) on surface of root hair of Poa annua seedling. (C) Bacteria (arrows) on surface of root hair of P. annua seedling. (D) Bacteria (small arrows) and denatured proteins (large arrows) on the surface of root hair of P. annua seedling.

(Source: White JF, Chen Q, Torres MS, Mattera R, Irizarry I, Tadych M, Bergen M. 2015. Collaboration between grass seedlings and rhizobacteria to scavenge organic nitrogen in soils. AoB PLANTS 7: plu093; doi:10.1093/aobpla/plu093)

Soils are recognized as a reservoir for various biotas that facilitate decomposition and nutrient cycling and provide the critical resources for sustained agricultural productivity. The biggest players, by virtue of numbers, are the plant growth promoting rhizobacteria (PGPR). These are free-living rhizospheric bacteria or endophytic bacteria that have been implicated in plant growth enhancement directly through better plant nutrition or indirectly through mitigating plant stresses, including disease control. Significant increases in growth and yield of agronomically important crops, likely due to increased N uptake (see Figures 1 & 2), nutrient use efficiency and disease-control benefits imparted by PGPR, have been reported. Moreover, PGPRs may substitute, at least partially, for the high fertiliser requirement of some crops, while showing equivalent or higher nutritive value compared to chemically fertilised counterparts. Thus, the potential for increasing agricultural productivity in a more natural and sustainable manner may be attainable through PGPR as advocated by several proponents of this 'bio-technology'. Breeding efforts over the years have aimed at improving crop plants, implicated in food security, and their responses to nutrient additions under ideal conditions, a situation under which nutritional mutualists have inevitably become redundant. An alternative complementary route to a more sustainable agriculture and one 'rooted' in a more ecologically intensive agriculture, is via so-called 'neodomestication' of plant germplasm that actively engage beneficial endophytic microorganisms. This should pave the way for improving plant mineral nutrition (also, water supply and other eco-logical functions) 'naturally'. Similarly, breeding of superior varieties has been done under high soil disturbances, which impedes the proliferation of soil mutualists. The practice of intensive tillage has been shown to decimate mycorrhizal numbers and prompted the now widely adopted reduced tillage methods under the auspices of conservation agriculture (CA). The latter has seen a steady recovery of AMF judging from the increased glomalin levels in soils. Breeding programmes should, then, also be tailored to exploit the myriad of aboveground-belowground interactions.

Finally, an over dependence on agrochemicals is not sustainable, and a moderate use of both fertilizers and ecological nutrient cycling will likely result in improved resource use, and nutrient use efficiency and hence profits in farming. In addition, diverse agroecosystems with their complex suite of all these aforementioned role-players may contribute to food security due to the complementary interactions among the various constituents of the system, without diminishing productivity, profitability and environmental health. Here, microbe-based 'symbioses' as a low-input, yet effective and highly productive sustainable agricultural system is promoted. The stakes have never been higher, but so too the impending rewards.

Acknowledgements:
The complete referenced text is available from the author at mrl@sun.ac.za