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Water-Soil-Nutrients: Integrated Solutions for Assuring Global Food and Water Security

29 February - 2 March 2016
Rabin Auditorium – CEE, Technion-IIT, Haifa, Israel

Abstract Book

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Dept. of Environmental, Water and Agricultural Engineering

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THE STEPHEN & NANCY GRAND WATER RESEARCH INSTITUTE

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Current demographic trends and projected growth in global population and standards of living are estimated to result in about 70 percent increase in food demand by 2050. Global climatic changes, the increase in population growth and societal demands pose extreme challenges on water and land resources, which together with sustainable plant-nutrient provision are essential resources for securing food production. Achieving global food security while reconciling demands on ecosystems and natural resources is one of the greatest challenges faced by humanity.

The symposium will re-examine research and development directions, needs and knowledge gaps, and identify modes to cope with the challenges to secure global food production while confronting water scarcity threats. This while considering preservation of fertile soils and sustainable provision of nutrients to plants. Emphasis will be both on irrigated and rain-fed agriculture with specific attention paid to potential solutions for developing regions and problems associated with climate change effects. Sustainable approaches for confronting global food and water security while reconciling environmental demands and conservation of natural resources will receive special attention.

Symposium Format

A three-day symposium will be held, with podium presentations delivered mainly by keynote and invited speakers. These will be accompanied by discussions aimed at: identifying knowledge gaps; generating ideas for new R&D directions and cooperation among participants; and exploring ways for knowhow dissemination focusing on regions with special needs.

Poster sessions with special encouragement given to presentations by graduate students and early-stage postdocs will be held on the **1st and 2nd March after lunches** and prizes will be awarded to outstanding posters presented by the young presenters.

A post-symposium professional tour will be held on the fourth day (***3rd March***). Participants will be exposed to Israel's latest technological developments in agriculture and water use. A program is provided below detailing the time schedule for all events, oral presentations and a detailed list (alphabetic order) of posters to be presented by graduate students and postdocs (beginners) that will compete for “Outstanding Poster Prizes” and posters to be presented by researchers.

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Session 1

Global estimates: Closing Gaps of the Increasing Food and Water Demand While Preserving Natural Resources and Challenging Ecological Demands

Chaired by Avi Shaviv

AGRICULTURE, POPULATION GROWTH, AND THE CHALLENGE OF CLIMATE CHANGE

Lincoln Taiz

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Homo sapiens evolved in Africa about 200,000 years ago, subsequently spreading throughout Eurasia and beyond. During its first 190,000 years, modern humans made their living as hunter-gatherers, slowly growing in population to about 5 million. The invention of agriculture ~10,000 years ago allowed the population to increase to about 250 million by the Bronze Age. Over the next two thousand years to the present day the population has exploded to 7.4 billion and is expected to increase to about nine billion people by 2050.

Historically, crop yields have kept up with population growth by farmland expansion and by agricultural advances. Following the invention of agriculture, the introduction of the three main staple crops (grains, legumes, and roots/tubers) enabled the population to increase ~10X to about 50 million. Over the next four thousand years the domestication of fruit trees and numerous types of vegetables, combined with innovations such as the use of the plow and irrigation and the application of fertilizer enabled the population to grow to ~250 million people. Perhaps the most significant factor, however, was the rapid expansion of land under cultivation in both the Old and New Worlds. Between ~800 CE and 1825 the population increased 4-fold to reach 1 billion people. During this period the food supply expanded due to the globalization of crops and farm animals, and by advances in agronomy. The amount of farmland was also increased by deforestation. From 1825 to 1927 the world population doubled to 2 billion people. Food production kept pace because of addirtional expansions of farmland. Advances in plant nutrition led to the widespread use of chemical fertilizers, and the development of the Haber-Bosch process for industrial nitrogen fixation made cheap nitrogen fertilizers available. The world population reached 3 billion in 1960, facilitated by another large increase in arable land and a shift to farm mechanization. Yields were also increased by the introduction of herbicides and insecticides, and by the development of hybrid maize varieties. Fifteen years later the world population added another billion people for a total of 4 billion people, who were fed thanks to the "Green Revolution" based on new semi-dwarf wheat and rice varieties. The Green Revolution continued to fuel population growth to 5 billion people by 1986, without significantly increasing the amount of land under cultivation. By the year 2000 the population rose to 6 billion people. At this point world cereal production began to decrease, signaling a leveling off of the benefits of the Green Revolution. In 2014 the human population reached 7 billion. During this period the amount of farmland devoted to crops genetically engineered for herbicide- or insect-resistance increase by 100-fold, equivalent to the state of Alaska.

Despite the successes of agriculture in feeding the human population to its current level, there is increasing concern about the negative impacts on the environment caused by the dependence on fossil fuels, the over-use of chemical fertilizers and pesticides, and soil salination resulting from over-irrigation. Problems of food distribution are highlighted by the simultaneous problems of malnutrition alongside obesity for about a quarter of the population. On the economic front, as per capita incomes rise around the word, so will meat consumption, diverting more and more agricultural production to animal feed. Analyses indicate that the current yield trends are insufficient to keep up with the current rate of population growth, which is projected to rise to as high as 12.3 billion by the end of the century. Further farmland expansion would deplete the few remaining biodiversity hotspots, robbing us of a potentially vital resource. Finally, global warming and climate change could severely impact crop yields in the future, with dire human and geopolitical consequences.

Fortunately, the field of genetic engineering is advancing rapidly, and it is now possible to target specific genes for crop improvement and achieve results far faster than by conventional breeding programs. Examples so far include nutritional improvement and resistance to both biotic and abiotic stress. Gene-editing via CRISPR-Cas9 now produces transgenic crops that are virtually indistinguishable from spontaneous or chemically-induced mutants, containing no foreign DNA, removing the last serious objection to public acceptance of GE crops.

Finally, the loss of soil organic carbon and the destruction of mycorrhizae caused by plowing is a major cause of soil degradation and contributes to global warming. No-till agriculture has the potential to prevent this loss in reduce our dependence on chemical fertilizers. To feed the projected 10-12 billion people by the end of the century we will need an “Evergreen Revolution” that combines GE-crops with conservation practices in an integrated approach.

TRAJECTORIES IN CROP YIELDS, WATER AND NUTRIENT EFFICIENCIES

Kenneth G. Cassman

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The magnitude of challenge to feed 9.6 billion by 2050 without environmental catastrophe has motivated some to propose alternative futures that rely on large reductions in projected food demand—such as global vegetarianism and elimination of food waste. But these paths require substantial change in human behavior, and there is no evidence that such change is possible at a global scale required for consequential impact. Hence, government officials responsible for food security must focus on ensuring adequate food production capacity in a world with limited land and water supply. Key issues distill down to two essential questions: how much additional food will be required, and how much land is available to produce it?

Most projections call for 50-100% increase in food production by 2050, with differences due to assumptions about rate of increase in incomes and cost of food as determined by supply. Food supply projections largely depend on rate of gain in crop yields, which in turn depend on assumptions about amount of land with suitable quality, climate or water resources for irrigation. So what do we know about the trajectory in crop yields and the availability of good farm land?

It is sobering to note that whereas food demand was mostly met by rising yields during the last half of the 20th Century, rapid expansion of production area has been required in the new Millennium because crop yields are not rising fast enough on existing cropland (Grassini et al., 2013). Indeed, since 2002 harvested crop area has increased more than 10 Mha-yr^{-1}, faster than any time in history. We also know: (i) nearly all prime cropland is already being used, (ii) remaining land is of lower quality due to soil or climate constraints, and (iii) more than 100 Mha will be needed for urbanization—most of it from current prime farmland at the periphery of large cities. Likewise, all major irrigated agricultural domains are currently over-drafted, which gives little scope for expansion of irrigated area except via improvements in irrigation water use efficiency to get more crop per drop. The exception is Sub-Saharan Africa where significant scope for expansion of irrigated crop production still exists (Cassman and Grassini, 2013).

Considering the big picture described above, ecological intensification (EI) on existing farmland is the only path to ensure both food security and conservation of natural resources (Cassman, 1999). Key elements of EI include: (i) closing yield gaps to ~80% of yield potential on every hectare of existing cropland with favorable soils and climate or under irrigation, (ii) increasing nitrogen use efficiency by 40-100% depending on crop and current yield level (Cassman et al., 2002; Zhang et al., 2015), (iii) maintaining or increasing soil quality, (iv) minimizing need for pesticides through integrated pest management, (v) highly efficient irrigation systems in irrigated agriculture. The good news is that we now have robust methods for estimating current yield gaps at local to global scales (van Bussel et al., 2015), and high-yields and high efficiencies for nutrients, water, and energy are not mutually exclusive goals in commercial scale, irrigated production systems (Grassini and Cassman, 2012). There are, however, major challenges including: stagnating crop yields in many of the world's most important cereal production regions and need for substantial acceleration in yield gains of the major staple food crops (Grassini et al. 2013), and difficulty of achieving both high yields and high N efficiency in rainfed systems due to large year-to-year variation in yield and associated uncertainty in crop N demand. Regardless, the N surplus framework provides a robust benchmark for measuring and monitoring progress towards improved N fertilizer efficiency while reducing the risk of environmental N losses (Zhang et al., 2015).

Cassman, K.G. 1999. Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. Proc. National Acad. Sci. (USA) 96: 5952-5959

Cassman, K.G., Dobermann, A., and Walters, D. 2002. Agroecosystems, nitrogen-use efficiency, and nitrogen management. AMBIO 31:132-140

Cassman KG and Grassini P. 2013. Can there be a green revolution in Sub-Saharan Africa without large expansion of irrigated crop production? Global Food Security 2: 203-209

Grassini P and Cassman KG. 2012. High yield maize with large net energy yield and low global warming potential. Proc. Natl. Acad. Sci. 109:1074-1079

Grassini P, Eskridge KM, and Cassman KG. 2013. Distinguishing between yield advances and yield plateaus in historical crop yield trends. Nat. Commun. 4:2918. doi:10.1038/ncomms3918

Van Bussel, L.G.J., P. Grassini, J. van Wart, J. Wolf, L. Claessens, HS. Yang, H. Boogaard, H. de Groot, et al. 2015. From field to atlas: Upscaling of location-specific yield gap estimates. Field Crops Res. 177: 98–108

Zhang X, Davidson EA, Mauzerall DL, Searchinger TD, Dumas P, and Shen Y. 2015. Managing nitrogen for sustainable development. Nature 528: 51-59

GRAND CHALLENGES IN GLOBAL SECURITY: THE WATER, CLIMATE, SOIL AND FOOD NEXUS

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Land degradation, water quality and quantity, air quality, climate change, soil contamination, and food security are foremost issues of our time. We must be at the forefront in addressing and providing solutions to these vexing challenges that threaten humankind. It is also incumbent that we tackle the research needs in an interdisciplinary manner by forging collaborations with natural scientists, social scientists, engineers, and humanists. We must also communicate the results and solutions in a meaningful way to decision makers and the public.

This presentation will include case studies dealing with soil, air, and water contamination and carbon cycling/sequestration to show how the application of a multi-scale, interdisciplinary approach can provide important insights into environmental degradation and restoration.

ASSESSING CLIMATE CHANGE IMPACTS ON FOOD SECURITY: THE ROLE OF SOIL AND WATER

Elias Fereres

Institute for Sustainable Agriculture (CSIC) and University of Cordoba, Spain

Food security is about producing sufficient food globally and about facilitating its access to all human beings. Given the trends in population growth and economic development, there will be a need to produce more food in the future. However, the vast majority of recently published analyses of the impacts of climate change (CC) on world agricultural production predict negative effects of global warming on the future yields of the major crops, particularly for the second half of the XXI Century (e.g., Rozensweig et al., 2014). Such analyses are founded on meta-analysis of published results or on inter-model comparisons, whereby large teams of scientists compare various simulation models (e.g., Asseng et al., 2015) and model ensembles in an attempt to reduce the large uncertainty in individual model predictions. Despite the advances in crop physiology, it is not clear to what extent the negative effects of higher temperatures will be compensated for by the increased CO_2 assimilation, and more importantly, by the positive impacts of the adaptive measures that agriculturalists will develop to cope with global warming. Thus, CC impacts on future food production still have a high degree of uncertainty, although main regional response patterns are emerging.

One major threat of CC on food production is the predicted increase in the frequency of extreme events, floods and droughts, for example. In the areas affected by El Niño/La Niña events (primarily around the Pacific Ocean), current climate models predict an increased frequency of extreme events under CC which would arise from a projected surface warming over the eastern equatorial Pacific that will occur faster than in the surrounding ocean waters, facilitating more intense atmospheric convection in the eastern equatorial region. In other world areas where climate patterns are less well understood, there is insufficient empirical evidence from past climate records to assess CC impacts on the frequency of extreme events. Nevertheless, there is an urgent need to assess the risks associated with such an increase because the responses of food systems to the sudden shocks caused by extreme weather have significant socio-economic consequences, and we must increase the resilience of food systems in response to extremes.

The relevance of soil and water in determining the overall CC impacts in the arid and semi-arid regions cannot be overemphasized. On the one hand, instead of further expanding land use for agriculture, the degradation of the soil resource by erosion and salinization must be stopped and there are technical means to do it, but other constraints limit their use. The assessment of the extent of soil degradation has a surprising level of uncertainty given our current capacity for its characterization; for instance, figures as diverse as 0.25 to 1.5 million ha/year losses to salinity may be found in international sources. On the other hand, removing the severe soil fertility constraints in many areas of Africa will be crucial for ensuring future food security in the Region.

The predicted global increase in precipitation due to CC, unfortunately will not be spatially and temporally distributed according to human needs. Current natural variability is such that, given the increasing demands from a growing population and from other sectors of society, water scarcity will increase even in the absence of global warming. Future CC scenarios depict even more severe scarcity in some regions leading to the need to develop innovative adaptation measures. Food production will increasingly depend on the sustainable intensification of current agricultural systems. Among them, irrigated agriculture is essential for ensuring food security, having an average productivity 2.75 times higher than rainfed agriculture on a global basis. Availability of sufficient water to maintain or even increase the area under irrigation in the future will most likely require additional surface storage where feasible, and wiser management of groundwater resources. The hope is that, given the large water productivity gap that exists in most areas, there are ample opportunities for the adoption of best management practices and of advanced technologies to bridge such gap, thus making a significant contribution to future food security.

Rosenzweig, C., Elliott, J., & Deryng, D. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. PNAS, 111(9), 3268-3273.

Asseng, S. et al., 2015. Rising temperatures reduce global wheat production. Nature Climate Change, 5,143–147.

Session 2

Sustainable Approaches for Increasing Crop Production Sustaining Soil Fertility and Improving Nutrient Use Efficiency

Chaired by Gad Shahar

INTEGRATED SOIL-CROP SYSTEMS MANAGEMENT FOR FOOD SECURITY AND SUSTAINABILITY

Fan Mingsheng, Zhang Fusuo

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China's economy has made great strides since 1949, and especially since China has initiated economic reforms and the open-door policy in the 1980's. The growth in agricultural production has been one of the main national accomplishments. China was feeding 22% of the global human population with only 7% of the world's arable land. The use of fertilizers and irrigation has played a crucial role. However, further increases in crop production will be more problematical than has been the case. The availability of water is a major limiting factor for China. Agricultural inputs must be reduced, especially N and phosphorus (P) fertilizer, overuse of which have led to environmental problems such as increased greenhouse gas emissions and severe water pollution in parts of China (Fan et al., 2012). Greater advances in crop production are needed during the coming 20 years to achieve a substantial increase in grain yields and ensure food security. Toward this, the science of crop and soil management and agricultural practice also needs to be given particular emphasis as part of a food-security grand challenge. Here, we advocate an integrated soil-crop system management (ISSM) approach addressing key constraints such as low soil fertilizer, water shortage, low nutrient-use efficiencies and impacts of climate change in further improving crop production with efficient resource use in China. In this approach, the key principles include: (1) increasing yield further with the objective in closing yield gap, (2) integrate utilization of various nutrient resources and match nutrient supply to crop requirements (3) considering all possible measures for improving soil inherent productivity, (zhang et al. 2011). Some significant progresses in producing more food with less resources (nutrient and water) input and environmental cost in major cereal cropping systems on using ISSM approach are presented in this paper (Chen et al., 2014).

Fan MS, Shen JB, Yuan LX, Jiang RF, Chen XP, Davies WJ, et al. 2012. Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China. Journal of Experimental Botany. 63(1): 13-24.

Zhang, F., Cui, Z., Fan, M., et al. 2011. Integrated Soil-Crop System Management: Reducing Environmental Risk While Increasing Crop Productivity and Improving Nutrient Use Efficiency in China. Journal of Environmental Quality, 40, 1051-1057.

Chen XP, Cui ZL, Fan MS, Vitousek P, Zhao M, Ma WQ, et al. 2014. Producing more grain with lower environmental costs. Nature. 514: 486-489.

GLOBAL AND REGIONAL FERTILIZER CONSUMPTION DEVELOPMENTS

Hillel Magen and Patricia Imas

ICL Fertilizers

World fertilizer consumption has continued in an upward trend reflecting the growing global food demand. However, for the last 20 years, rises in fertilizer consumption was predominantly in developing countries.

To meet growing demand for crops to feed the world population, more fertilizer will be required. Over the next decade, fertilizer use will increase by almost 2% annually, which is consistent with overall crop production growth trends. Potassium is projected to have the highest growth rate (~ 3% annual growth), in part to address the under application of this nutrient in recent years. Phosphate consumption is expected to grow by 2.0-2.5% annually while nitrogen consumption is expected to grow at less than 2.0% per year

World fertilizer consumption has expanded by 1.5%, to 183.4 Mt nutrients in 2014/15. Nitrogen consumption rose modestly (by 0.4% to 110.3 Mt); world P consumption rebounded (+1.6% to 41.1 Mt) following a drop in previous year; K consumption rose firmly (+5.4%, to 32.0 Mt).

Developing countries still consume fewer nutrients per area unit. In some regions (e.g. SSA) the consumption is very low, and in addition, many regions have higher crop intensity, leading to a higher potential of consumption per area unit. In contrast, in developed countries, increased productivity is achieved in developed countries with the same or sometimes even lower levels of nutrient consumption, due to increased efficiency of fertilizer use.

In addition to the increasing consumption of N, P and K fertilizers, there has been a strong increase more recently in the demand for sulphur (S) and zinc (Zn). This demand is as a result of years of depletion in soils and a reduction of S deposits in the atmosphere (due to reduced pollution), as well as the expansion of severely depleted, inferior soils (e.g. in India and SSA). The need to include S and Zn on a large scale has led to a significant increase in the number of new tailored NPK fertilizers containing these nutrients.

The adoption of new agricultural technologies that increase crop production through the optimal use of scarce resources such as land, water, and fertilizers is also increasing. A water-soluble fertilizer, for example, is specifically designed to be used in fertigation systems, which include sprinkler and drip irrigation systems. High value crops, such as fruits and vegetables, and greenhouse crops are driving demand; the global market for water-soluble fertilizers was valued at US$11.05 billion in 2014 and is projected to reach US$15.30 billion by 2020, at an estimated annual growth rate of 5.6% from 2015 to 2020.

In conclusion, fertilizers have played a crucial role in increased crop production and will continue to be a cornerstone of the agricultural sector if it is to feed the expanding word population and ensure global food security.

NEED FOR RE-EXAMINING FERTILIZER UTILIZATION APPROACHES

Avi Shaviv

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Challenging the increasing needs for securing crop production and preserving fertile soils, water and nutrient resources while minimizing environmental threats must also proceed under continuous improvement in nutrient use efficiency - NUE. There are several approaches for facing this challenge worldwide. These, focus on integrated nutrient management with efforts to better synchronize nutrients supply with plant demand, while providing balanced inputs conforming with cropping systems, climate and soil characteristics (e.g., Dungait et al., 2012; Zhang et al., 2012). Fertilizers and fertilization approaches continue to be a key player in achieving these goals. Despite their important role and continuous increase of fertilizer utilization, the following statement was made in a recent review (Bindraban et al., 2015): "there have been no fundamental reflections about the role and functioning of mineral fertilisers over the past 5 decades or more, and compared to other sectors, dismal investments have been made in mineral fertiliser research and development (R&D)". Timilsena et al., (2014) emphasize in their review the importance of Enhanced Efficiency Fertilisers (EEFs) for closely matching nutrient demand of plants while improving crop quality, increasing yields, and reducing environmental pollution. They too, identify the need to intensify professional, economic and technological efforts to promote cost effective utilization of EEFs.

During the last three decades, important achievements were obtained in developing fertilizers and fertilization modes with potential for improving NUE (e.g., Shaviv, 2005; Trenkel, 2010; Timilsena et al., 2014). Focus was put on improving the synchronization between plant demand and nutrient supply (temporal and quantity wise), while conforming to the right nutrient compositions according to plant requirements and environmental conditions (e.g. Shaviv, 2005). These principles are provided in a more applicable manner as the "4R Nutrient Stewardship" (IPNI, 2014). Fertilization approaches and specific fertilizers that have the potential to improve NUE and achievement to the principles mentioned above; and mainly in rain-fed crop production include (e.g., Shaviv 2005):

- Application mode based on localized application (i.e., depot, bands, nests, super-granules) or granules consisting of enhance mixtures of nutrients;
- Use of Bio-Inhibitor amendments (e.g., nitrification and/or urease inhibitors) and combination of the application mode with amendments;
- Slow or Controlled and Release Fertilizers –SRFs/ CRFs.

These options will be re-examined in the presentation with an effort to check directions of improved and expanded utilization in practice as important means for closing yield gaps while achieving sustainable NUE. The potential of farther enhancing NUE via improved nutrient availability indicators will be examined as well.

Prem S. Bindraban, Christian Dimkpa, Latha Nagarajan, Amit Roy & Rudy Rabbinge. 2015. Revisiting fertilisers and fertilisation strategies for improved nutrient uptake by plants. Biol Fertil Soils 51:897–911.

Jennifer A.J. Dungait, Laura M. Cardenas, Martin S.A. Blackwell, Lianhai Wu, Paul J.A. Withers, David R. Chadwick, Roland Bol, Philip J. Murray, Andrew J. Macdonald, Andrew P. Whitmore, Keith W.T. Goulding. 2012. Advances in the understanding of nutrient dynamics and management in UK agriculture. Science of the Total Environment 434:39–50.

IPNI (2014) - 4r http://www.ipni.net/article/IPNI-3255.

Timilsena, Yakindra Prasad, Raju Adhikari, Phil Casey, Tim Muster, Harsharn Gilla and Benu Adhikaria. 2014. Enhanced efficiency fertilisers: a review of formulation and nutrient release patterns. J Sci. Food Agric. 95 (6) 1131-1142.

Shaviv, A. 2005. Concepts for Environmental Friendly Nitrogen Fertilization. Life Sciences, (Series C of Science in China), 48(Spec. Issue), 937-947.

Trenkel M.E. 2010. Slow- and Controlled-release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture. International Fertilizer Industry Association (IFA), Paris (2010).

Zhang, Fusuo, Zhenling Cui, Xinping Chen, Xiaotang Ju, Jianbo Shen, Qing Chen, Xuejun Liu, Weifeng Zhang, Guohua Mi, Mingsheng Fan, and Rongfeng Jiang. 2012. Integrated Nutrient Management for Food Security and Environmental Quality in China. Advances in Agronomy, Volume 116:1-40.

AN APPROACH TO EVALUATE POTENTIALITY FOR BIOLOGICAL NITROGEN FIXATION IN SOIL: METAGENOMIC ANALYSIS OF NIFH SEQUENCES IN DNA AND RNA EXTRACTED FROM ARGENTINEAN SOILS UNDER DIFFERENT AGRICULTURAL MANAGEMENT

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Biologically available N is often a limiting nutrient in agriculture. Biological reduction of molecular N2 gas to assimilable ammonium (BNF) is considered the main route by which fixed nitrogen enters the biosphere by natural processes (Galloway et al., 2004). BNF, catalyzed only by prokaryotic cells, requires nitrogenase, a two component complex enzyme. The nifH gene, which encodes Component II, is highly conserved across the bacterial and archaeal domains.

Since 1980, agriculture has rapidly expanded in Argentina, replacing grasslands, with the widespread adoption of limited tillage systems, particularly no-till with crop rotation (Kovalevski & García, 2007). Within the context of a global project on soil biology, a large effort was made to provide microbial indicators of the sustainability of agricultural no-till systems in the Central Pampas Argentina. This study is a specific survey of only the N2-fixing microbial communities in soil, using deep pyrosequencing of the nifH gene. Firstly, we aimed to examine the abundance, diversity and structure of diazotrophic communities in a gradient of Argentinean agricultural soils subjected to the following no-till treatments: intensive crop rotation, nutrient replacement and minimal use of agrochemicals (good agricultural practices, GAP); soybean monoculture, low nutrient replacement and high agrochemical use (poor agricultural practices, PAP), and a grassland soil used as a reference natural environment (NE).

A dataset of 87020 nifH reads and 16782 unique nifH protein sequences obtained over 2 years from four locations across a gradient of agricultural soil types in Argentina were analyzed. At 98% similarity, the 1558 operational taxonomic units (OTUs) for the entire study were assigned to 17 subclusters of the four major nifH clusters previously defined by Zehr et al. (2003). Phylogenetic analysis revealed an expected high proportion of

Alpha-, Beta- and Deltaproteobacteria, mainly relatives to Bradyrhizobium, Methylosinus/Methylocystis and Pelobacter/Geobacter, but a surprising paucity of Gammaproteobacteria. A significant difference in diazotrophic diversity was observed across the four locations but not among management treatments. Analysis of variance and stepwise regression modelling suggested location and treatment-specific influences of soil type on diazotrophic community composition and organic carbon concentrations on nifH diversity. nifH gene abundance, determined by quantitative real-time polymerase chain reaction, was higher in agricultural soils than in non-agricultural soils, and was influenced by soil chemistry under intensive crop rotation but not under monoculture .

Active diazotrophic populations were also examined by deep sequencing of cDNA-nifH amplicons from RNA extracted from the Argentinean soils subjected to the two previously described no-till practices and sampled each at 10 and 20 cm depth. Most abundant OTUs where related to Geobacter, Bradyrhizobium, Nostoc and Anabaena. The composition is similar to that observed in the potential community, except cyanobacteria which represented less than 1% of total ADN-nifH sequences. In cultivated soils, a significant change is observed in the composition of the community in the depths analyzed. For example, Geobacter OTUs increased their relative proportion in the 20 cm whereas Bradyrhizobium displays the opposite trend. On the other hand, relative abundance of Cyanobacteria and Desulfovibrionales were significant (>1%) only in the first 10 cm (1B 33%) and 20 cm (3B 15%). Contrarily, communities at both depths in grassland soil (NE) were similar, with high proportion of Geobacter and Rhizobiales. Using the OTU richness and diversity estimators, NE was the more diverse and both estimators were lower at deeper sampling in pristine and GAP, whereas increased in the 20 cm depth of PAP.

Differences in diversity across sites appear to be mainly associated with the statistical distribution of the pores, hydrophobicity, structural stability and levels of soil organic carbon. Correlations suggest that diversity increased along the occurrence of different niches e.g. pore diameter, and their structural stability.

In contrast to the diazothropic community detected in DNA from soil, we conclude that diversity and richness of the active populations seem to be affected by agricultural practices, and also by soil depth and soil parameters.

Galloway J.N., F.J. Dentener, D.G. Capone, E.W. Boyer, R.W. Howarth, S.P. Seitzinger, G.P. Asner, C.C. Cleveland, P.A. Green, E.A. Holland, D.M. Karl, A.F. Michaels, J.H. Porter, A.R. Townsend, C.J. Vörösmarty , 2004. Nitrogen cycles: Past, present, and future. Biogeochemistry, 70:153-226.

Zehr, J.P., Jenkins, B.D., Short, S.M., and Steward, G.F. 2003. Nitrogenase gene diversity and microbial community structure: a cross-system comparison. Environ Microbiol 57: 539–554.

Kovalevski E, García F: Norte de argentina bajo siembra directa, 2007. 1:159–172

Collavino MM, H J Tripp, I E Frank, M L Vidoz, P A Calderoli, M Donato, J P Zehr, and O Mario Aguilar. 2014. nifH pyrosequencing reveals the potential for location specific soil chemistry to influence N_2-fixing community dynamics. Environ Microbiol, DPI 10.1111/1426-2930.12423

Session 2 (continued)

Chaired by Oene Oenema

DIVERSE CROP SYSTEMS AS A MODEL FOR OPTIMIZING NITROGEN CYCLING

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Rainfed annual crop systems, such as corn and soybean in the Midwest USA, lose large amounts of nitrate to surface and groundwaters. Although improved nitrogen (N) fertilizer management is the most commonly recommended approach to address this problem, recent analyses demonstrate that this technology has limited potential to reduce nitrate loss. For example, three independent analyses of the Midwest USA using three independent methods (meta-analysis, statistical modeling and process modeling) demonstrate that N fertilizer management can reduce nitrate loss by just 12-15% (Gassman et al., 2015; Iowa Nutrient Reduction Strategy, 2013; McLellan et al., 2015). In contrast, diverse crop rotations, a relatively under-utilized technology, can produce larger reductions in nitrate loss than improved N fertilizer management. The advantage of diversified crop rotations may stem from the failure of conventional N fertilizer management programs to properly account for plant-microbe competition for gross N mineralization as well as the ability of crops to successfully compete with microbes for N. Conventional N fertilizer management programs meet crop N demand by saturating microbial N demand; this approach requires maintenance of large inorganic N pools that are easily leached to water resources. However, recent evidence suggests that crops can win a portion of the competition events for N mineralized from organic N sources thus enabling N management strategies that reduce inorganic N pools despite increased crop-available N. We propose a new conceptual model that explores N cycling in two contrasting strategies of N fertilizer management: 1) a conventional system that attempts to optimize large inputs of exogenous inorganic N fertilizer that is highly susceptible to environmental loss, and 2) an alternative, diversified system that attempts to optimize microbial cycling of endogenous organic N pools that are more resistant to environmental loss. We evaluate this model with data from a long-term field experiment that compares a simple rotation dependent on inorganic fertilizer with more diverse rotations receiving organic N inputs that can increase microbial N cycling rates and reduce inorganic N inputs. The diversified rotations increased N cycling rates, reduced

indicators of environmental N loss, and increased corn yield. Our conceptual model builds on previous models of ecological approaches to nutrient management that focus on recoupling carbon and N cycling to synchronize inorganic N release with crop N demand (Drinkwater and Snapp, 2007) by explicitly incorporating the processes of gross N mineralization and immobilization to suggest that crops can compete with microbes for inorganic N despite small pools of inorganic N. Our model can help to explain why N fertilizer management strategies that aim to better synchronize inorganic N availability and crop N demand have little-to-no effect on nitrate loss reductions: to reduce nitrate loss and increase crop N fertilizer use efficiency, soil organic matter sinks *and* sources of inorganic N must be managed.

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CONTROLLED / SLOW RELEASE FERTILIZERS: AGRO-PRODUCTION AND ENVIRONMENT IN CHINA

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1. Importance of controlled release fertilizer (CRF) and slow release fertilizer (SRF) in present agriculture in China

From 90's of the 20th century CRF/SRF has received nationwide attention as new fertilizer to increase fertilizer use efficiency in China. Since the first specified program on CRF supposed by China national natural science foundation in 1998, CRF/SRF research and application have entered a broadly promotion stage through three phases with the support of national key projects from the 10th to the 12th five years' plan. The 1st phase was study on CRF/SRF manufacture during the 10th five years' plan, the 2nd one innovation of key industry technology in 11th and the 3rd phase integration and industrialization of CRF/SRF technology over China in the 12th. Great attention has been paid to the CRF/SRF production and application by government and fertilizer enterprises currently under the policy of zero increase of chemical fertilizer in the nation from 2016 to 2020.

2. CRF/SRF and their manufacture in China

China is the biggest one to manufacture and apply CRF/SRF in the world with four types such as polymer coated fertilizer being CRF, chemically synthesized organic nitrogen such as ureaformaldehyde (UF), stabilized N fertilizer and sulfur coated urea (SCU). The later three types belong to slow release fertilizer. Up to now, Chinese scientists have possessed a lot of patterns with its own intellectual property right to manufacture coated controlled release fertilizers. The technology to manufacture CRF in China include synthesizing coating material, coating methods, controlling nutrient release, manufacturing coating machine, testing method to predict longevity of the CRF quickly and manufacturing nutrition synchronized fertilizer by use of the CRF and the other fertilizers. The advance of the technology to produce CRF developed by Chinese scientist is as followings. (1) Nutrients release is controlled by use of multy-layer coating and channel on coating induced by porogen. (2) Longevity of the CRF is increased by modification of surface of substrate by sealant. (3) The nutrition synchronized fertilizer technology is an integrated technology based on both plant nutrition characteristics and fertilizer properties.

3. Present status of CRF/SRF industry in China

China is not only the biggest manufacturer of the CRF/SRF, but the earliest user of the CRF /SRF for field corps to increase fertilizer use efficiency in the world as well. According to the estimation of sino-chem information and our investigation, the total capacity of the CRF/SRF is about 5.5 million tons (MT). The present production is 2.8 MTs in which CRF is 100% coated fertilizer without consideration of CRF derived nutrition synchronized fertilizers. If considering the nutrition synchronized fertilizers in which CRF occupies 20% to 30% of the total amount as CRF/SRF, the production is from 3.65 to 4.65 MTs in China.

4. Effect of CRF application on environment

Utilization of the CRF/SRF has great contribution to increase fertilizer use efficiency and protect environment. Results indicate that nitrogen use efficiency (NUE) has been raised 50% for fruit tree such as banana and more than 30% for food crops such as rice and corn. Nitrate leaching has been decreased more than 60% and apparent losses including ammonia volatilization decreased by 50%. Daily average emission of nitro oxide under CRF treatment is only 1/3 of the substrate. Nitrogen losses through nitrification and denitrification had been declined by 50% more. The globe warming potential is decreased greatly. Therefore, promotion and application of CRF/SRF is an effective measure to reduce total consumption of chemical fertilizers and minimize the risk of chemical fertilizer to farmland and environment.

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NOVEL PROCESSES FOR ENERGY AND NUTRIENT RECOVERY FROM SWINE WASTE

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Swine represent approximately 40% of the world's meat production, and swine wastes contain high concentrations of organic matter, nitrogen (N), phosphorus (P) and potassium (K) (Choi, 2007). Swine production is intensifying as meat demand increases and concentrated animal feeding operations (CAFOs) are becoming increasingly common, making it difficult to treat the waste generated. In this study, two systems for recovery of energy, N and P from swine CAFOS wee compared. Both systems apply anaerobic digestion (AD) for methane production and solids stabilization followed by precipitation of struvite ($MgNH_4PO_4$•$6H_2O$) for P and partial N recovery. Two different approaches were investigated for further removal of NH_4+ remaining in the waste after AD and struvite precipitation. The first relies on recovery of NH_4+ and K+ using ion exchange (IX) onto natural zeolites for subsequent use as fertilizer. The second relies on IX onto natural zeolites followed by regeneration using electrochemical oxidation. Both processes have the potential to mitigate both eutrophication of receiving waters and greenhouse-gas emissions. The objectives of this study were to: (1) Demonstrate the feasibility of the proposed processes, (2) evaluate water quality and the fate of nutrients and ions through pilot- and bench-scale experiments, and (3) compare the economic benefits and costs of the proposed processes.

AD was carried out in mesophilic pilot scale reactor operated at 21 day solids residence time, treating pig waste from a local farm. The average CH_4 yield was 0.4 m^3 CH_4/ kg VS added. Effluent was collected from the digester and dewatered by centrifugation. Bench scale struvite precipitation tests were then performed in a batch reactor using two alternatives to raise the pH to 8.5 (NaOH addition and aeration). During precipitation, approximately 85% of the P and 50% of N were recovered. The precipitate was confirmed as being struvite by X-ray diffraction (XRD) and Scanning electron microscope (SEM) imaging with Energy Dispersive X-ray spectroscopy (SEM-EDX).

Nutrient recovery experiments were carried out at the University of South Florida. IX was performed using two zeolite alternatives (chabazite and clinoptilolite) in a batch process with a dose of 150 g/L of zeolite and a 24 hour contact time. The majority of the remaining N and P, were removed during IX, with overall removal efficiencies > 90%. In addition, approximately 85% of K was recovered during IX. The proposed process has the potential to dramatically reduce the eutrophication potential of the waste effluent while generating a salable fertilizer.

Regeneration experiments were carried out at the Technion. The process consisted of a daily sequential operation of IX (180 min), chemical regeneration (125 min) and electrooxidation of NH_4+ in the regeneration solution (8 h, applied during low-cost electricity hours), and was shown feasible for reducing the NH4+ concentration in the wastewater from ~1,000 to ~60 mg/L. The process enabled > 90% NH_4+ removal without the need to replace the regenerant solution. Electrooxidation efficiency consistently exceeded 90% due to the high Cl- concentration (>17 g/L) maintained in the regeneration solution and because only a small mass of organic matter was transferred to the regenerant solution following the IX step.

Water quality was shown to greatly improve throughout both treatment processes. The reclaimed water may also be suitable for reuse in a variety of on-farm water reuse applications. The effluent water quality has high chemical oxygen demand (COD) (2,803 mg O_2/L) and E. coli (6.8l og CFU/100ml); therefore, other reuse options may be limited.

A life cycle cost assessment on both systems showed that they could have < 70% of the total lifetime cost of a conventional biological nutrient removal (BNR) system. From a cost perspective, precipitation using aeration is preferred to using NaOH and IX using clinoptilolite provides better savings than chabazite. In comparing the two alternatives for NH4+ removal, IX using clinoptilolite has a lifetime cost of ~$0.20/kg N, while electrochemical regeneration has a total cost estimated at ~$3/kg N. Results also showed that larger scale systems tend to provide higher cost savings; however, this must be balanced with quality of animal care.

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IDENTIFYING POTNETIAL STRATEGIES IN THE KEY SECTORS OF CHINA'S FOOD CHAIN TO IMPLEMENT SUSTAINABLE PHOSPHORUS MANAGEMENT

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Phosphorus (P) is a finite natural resource and is a major limiting nutrient in agriculture in many parts of the world (Sattari et al. 2012). The growing consumption of P fertilizers from mining of nonrenewable phosphate rock has contributed to the production of food for the nearly 7 billion people on earth (Tilman et al. 2002). The rapidly depleting world P reserves are increasingly considered to be a new global sustainability challenge of the twenty-first century (Cordell and Neset 2014). Hence, a more efficient utilization of P reserves is needed to delay the impact of dwindling amounts of extractable P and increasing costs of P fertilizer production on food security.

China is the world's largest consumer (30% on just 7% of the world's arable land) and an important producer (37.5% of the global total), and is playing a critical role in global P production and consumption trends (Sattari et al. 2014). High extraction of phosphate reserves and low phosphorus utilization efficiency (PUE) in the food chain in China result in large P losses and serious environmental pollution. Thus, an improvement in the PUE in the food chain in China will have an important impact on the worldwide use efficiency of P resources. The P fertilizer industry, soil P surplus, livestock manure P and wastewater P recycling have been identified as the priority sectors based on summarizing several systemic and in-depth reviews of P flows analysis. In current study, Material Flow Analysis (MFA), a complete, systematic and in-depth approach, is used to understand the nature and magnitude of P flows at these priority sectors in China.

Mineral P fertilizer production has reached 7.4 Mt P in 2012, which is more than seven times the value in 1980. The large P surpluses in arable land resulted in soil P accumulation of up to 64 Mt during the period 1951-2010. Livestock numbers have increased dramatically (more than ten times) during the period 1949-2012 in China, especially pigs and poultry, and so has the quantity of manure that they produce. The average loading of manure P on arable land in China has increased significantly from 9.5 kg P ha^{-1} in 1980 to 20.4 kg P ha^{-1} in 2010. Up to 0.49 Mt of wastewater P discharged without treatment also exerted great pressure on the environment in 2012. Based on an understanding of P interactions in these key sectors, an integrated set of policy options and technical measures is proposed. Taking P flows in China in 2010 as an example, if all of the strategies recommended in this study are adopted in P management, about 4.3, 2.5, 1.6 and 0.3 Mt of P resources, respectively, will be saved in the P fertilizer industry, arable land production, livestock manure and wastewater sectors.

China can learn from other countries with intensive agriculture that have been dealing with large nutrient surpluses (i.e. in Europe) such as innovation of technology and policy to reduce over-application of P fertilizers in intensive agriculture by at least 30%, in vegetable, fruit and high value cash crop production systems. China also needs the appropriate incentives and regulations from the government to promote the large-scale and effective re-use of P resources from all wastes and by-products. Most important is to develop a novel knowledge transfer and technology extension system for millions of small-holder farmers in order to realize the new governmental policies of zero-increase in chemical fertilizer input in crop production by 2020 and transformation of high input and high output agriculture to efficient and sustainable intensification. This requires an integrated effort of scientists, policy makers, farmers and other stakeholders by working together and inducing fundamental change in P utilization.

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DOES ORGANIC MANAGEMENT AFFECT SOIL ORGANIC MATTER AND IMPROVE SOIL FERTILITY UNDER MEDITERRANEAN CLIMATE?

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Definition of the research problem: Sustainability of agricultural production systems is highly dependent on maintaining soil productivity. Depletion of soil organic matter (SOM) is a global phenomenon under conventional management of agricultural soils. Organic management practice is becoming a common tool as a means of counteracting this trend. However, most of the studies have been conducted under temperate climate conditions and there is lack of information on the effects of organic management practice on soil fertility and properties in the Mediterranean region under semi-arid and arid climates.

Objectives: The goal of the research was to investigate the effects of organic management practice and the rate of compost application on reversing the processes of SOM, soil fertility depletion and on soil structure deterioration under semi-arid and arid climates.

Hypotheses: Compost application was expected to enhance soil fertility due to its ability to increase SOM and available nutrients quantity, affect SOM properties, and improve soil aggregate stability. We expected that the impact of organic management practice on SOM would be stronger in soils poor in organic matter as typically found in arid zones.

Methodology: The research program was based on field studies. We investigated the effects of applied compost dose (0, 20, 40 and 60 m^3 ha^{-1}) in combination with green manure on soil organic matter content and properties in two sites: Newe Ya'ar (clay soil, semi-arid region) and Gilat (loam, arid region), with the following initial organic C contents: 1.40 and 0.74%, respectively. In both sites the treatments were applied annually for 5 years to rotational crops common in each region.

Results: In both sites soil organic C and N contents, soluble and exchangeable K and available P were significantly elevated with the increase in compost dose. In Gilat labile components of the organic C and N increased significantly and consistently with the increase in compost dose, whereas in Newe Ya'ar no significant effect was obtained. In Newe Ya'ar aggregates stability increased with compost dose under organic management, whereas no significant effect was obtained in Gilat. In Gilat, Na and K fraction of the exchangeable complex increased with the increase in compost dose. The values of exchangeable K reached a level where it could lead to reduction in aggregate stability that probably counteracted the expected positive effect of the added organic matter. In Newe Ya'ar no significant effects of compost application on biomass production was found. In Gilat, increasing compost dose enhanced biomass production of several crops in the rotation whereas higher wheat yield was obtained under the conventional management. In both sites the yield of K and P in some crops in the rotation increased with the increase compost dose. In both sites crop yields were severely restricted by uncontrolled weeds.

Conclusions: Organic management practice reversed SOM depletion and improved N, P and K availability in two Mediterranean soils under semi-arid and arid climates. The organic management practice also enhanced labile pools of organic N and C in the poor organic matter arid soil. Such management has the potential to improve agricultural soil productivity but for this goal the weed problem under this management practice should be addressed. Compost application may improve soil aggregates stability but the contents of K and Na in the compost should be minimized to avoid counter effects. The required dose of compost application should be examined for different environmental conditions and crops. Further research on organic N and C properties and their distribution between live and dead organic pools are required to better understand the mechanisms of compost application effects.

Session 3

Advances in Plant Biology to Secure Food and Water Productivity

Chaired by Nirit Bernstein

GENETICALLY MODIFIED PLANTS AS THE SOLUTION FOR THE COMING FOOD, WATER AND ENERGY GLOBAL CRISES

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Growing competition for land, water and energy will affect our ability to produce food. The effects of climate change are a further threat. New agricultural approaches based on genetic engineering may suggest possible solutions for these challenges.

In addition to the research from traditional agricultural science, plant biotechnology research, which includes genetic engineering and the transfer of genes from unrelated plants and microorganisms started to show important benefits for farmers in developed countries in the mid-1990s.

We have developed a generic technology based on the manipulation of the plant hormone cytokinins (CK) known to control plant aging. The transgenic plants were designed to express the key gene of cytokinins biosynthesis (ipt), that was fused to an aging promoter (pSARK). The autoregulatory system of cytokinins biosynthesis assures the homeostasis of cytokinins levels and normal growth throughout plant development and aging. By extending the production of this hormone until very late phase of plant development, we were able to delay the process of the tobacco plant aging. In addition to the higher biomass and fruit yield, the transgenic plants exhibit longer shelf life of the excised leaves. Surprisingly these transgenic plants, display also significant drought tolerance and they could survive long periods of drought. These plants can grow on as little as 30% of water compared the known optimal watering regimes with almost no loss of plant yield. Since stress-induced senescence can be delayed by cytokinins, we hypothesized that it is possible to enhance stress tolerance through regulated manipulations of cytokinin biosynthesis. As expected, WT plants displayed reduced photosynthetic activity under drought conditions whereas the pSARK:IPT plants where less sensitive to drought conditions. Systematic and quantitative study of this phenomenon confirmed the result that transgenic plants expressing the pSARK::IPT exhibited enhanced photosynthetic rates and water use efficiency as reflected by minimal biomass loss even after watering with only 30% of the optimal water requirement. The SARK promoter induced *ipt* gene expression not only during the senescence phase but also at the onset of drought stress allowing the production of CK in leaves leading to enhanced vigorous acclimation responses resulting in increased drought tolerance with minimal yield loss. Since the SARK:IPT plants showed significant tolerance mainly against drought, it was important to generate plants that would tolerate other environmental stresses as well. We have created tolerant plants to a wider spectrum of abiotic stresses by fusing a promoter of a gene known to be activated under various abiotic stresses (Mt) to the ipt gene. Indeed, these plants displayed tolerance not only against drought stress but also against salinity, heat and cold stresses. Biofuel plants have been modified by the same construct and displayed similar phenomena namely delayed aging and tolerance to various abiotic stresses that resulted with increased biomass, which is critical for the efficient biofuel production.

These data offer novel approach for developing stress tolerant plants and it is clear that CK homeostasis and signaling components are important engineered targets for the development of stress-tolerant crops and diminishing the damage caused by stress-induced senescence as well as the spoilage of postharvest vegetables, fruits and flowers. Since manipulated dicots as well as monocot plants display this phenomenon, we suggest using this approach as a generic technology for growing crops under environmental stress conditions for food production or for biofuel extraction.

IMPROVING NUTRIENT EFFICIENCY BY PLANTS

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Plant nutrient use efficiency (NUE) is inherently complex, as each step including nutrient-regulated root growth and development, nutrient uptake, translocation, assimilation, and remobilization is commonly governed by multiple interacting genetic and environmental factors. The limiting factors in plant metabolism for maximizing NUE are different at high and low nutrient supplies, indicating great potential for improving the NUE, particularly the nitrogen (N) use efficiency of the current cultivars which were bred in well-fertilized soil.

Plants take up both nitrate and ammonium as main N sources. Although ammonium is the predominant form in anaerobic flooded paddy soil, rice and other wetland plants may take up significant amounts of nitrate formed by nitrification of ammonium in the rhizosphere. We demonstrated that the nitrate transport system of OsNAR2/OsNRT2 two components plays important role in rice N nutrition. We detected that OsNAR2.1 expressed mainly in the root epidermal cells and interacted with OsNRT2.1 and OsNRT2.2 for nitrate transport at relative higher affinity level and with OsNRT2.3a at relative lower affinity level. OsNRT2.3a functions in long-distance translocation of nitrate from roots to shoots. Alteration of the NAR2/NRT2 two component system could enhance nitrate influx, transport to shoot, phloem pH homeostasis, which further increased root ammonium uptake and total N use efficiency of rice at the different genetic backgrounds and N supply levels.

Potassium (K) plays the key role in transport of assimilates in the phloem as an ionic osmo-regulator. K deficiency drastically decreases sucrose export in the phloem exudate and confines root growth and reproductive organs development, resulting in sugar accumulation in source leaves, decreases of root to shoot ratio, nutrient acquisition and grain yield. In order to maintain root growth for adapting low K condition, we tested the ectopic expression of WOX11 known as an integrator of auxin and cytokinin signaling in regulating root cell proliferation, in low K supplied roots. We found that the expression of WOX11 controlled by the promoter of OsHAK16 encoding a low K-enhanced K transporter led to an extensive root system and adventitious roots, and more effective tiller numbers in rice. In addition, we detected that different effects of ectopic expression of a sugar partitioning regulator (SPR) in rice controlled respectively by the promoters of low-K-enhancing transporter genes and ubiquitin. Enhanced expression of OsHAK16p:WOX11 or SPR by the promoter of a phloem localized K-transporter gene largely increased N, P, K use efficiency and grain yield, particularly at K-deficient soil. The expression improved the sugar partitioning from leaf blades to both roots and spikelets and the nutrient acquisition as indicated by up-regulation of a number of closely related enzymes activity and transporters in these organs. Our findings suggest that appropriately enhancing sugar metabolism and allocation from source to sink organs could provide an effective strategy for maximizing cereal crop productivity and NUE.

The plant NUE could also be indirectly improved by properly diagnosis of the nutrient status for guiding the fertilization. We isolated a rice phosphate transporter gene, *OsPT6* which is expressed in the leaves only under P deficiency condition. We generated a visual reporter system in tobacco to monitor plant P status by expressing a Purple gene (Pr) controlled by the *OsPT6* promoter. The leaves of *OsPT6*pro:*Pr* transgenic tobacco continuously turned into dark purple with the increase of duration and severity of P deficiency, and recovered rapidly to basal green color upon P resupply. Such additive purple color was not detected by deficiencies of other major- and micro-nutrients or stresses of salt, drought and cold. There was an extremely high correlation between P concentration and anthocyanin accumulation in the transgenic leaves. The color-based visual "smart-monitoring" system could be specifically and readily used for reporting the P status by naked eyes and accurately assessed by spectral reflectance.

SENSING SUGAR AND SAVING WATER

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Water is the major factor limiting the growth and development of many land plants, and stomata, composed of two guard cells, are the chief gates controlling plants’ water loss. Many environmental and physiological stimuli control stomatal opening, but they all do so through the regulation of guard-cell osmolarity. Increased guard-cell osmolarity leads to the opening of the stomata and decreased osmolarity causes the stomata to close. The prevailing paradigm is that sugars act as osmoticum in the guard cells, thereby contributing to the opening of the stomata. In contrast, we discovered that sugars close stomata via a non-osmotic mechanism. Furthermore, our results show that the guard cells’ response to sugars is dependent on the sugar-sensing enzyme hexokinase (HXK), which triggers the abscisic acid-signaling pathway within the guard cells, leading to stomatal closure. These findings reveal a feedback-inhibition mechanism that is mediated by the product of photosynthesis, sugar, via HXK. HXK in the guard cells senses the sugar level and stimulates stomatal closure, thereby coordinating the sugar level with the rate of transpiration. Increased expression of HXK in guard cells decreases the transpiration rate and improves whole-plant water-use efficiency, with no negative effects on photosynthesis, growth or yield.

HYDRAULIC LIMITATIONS OF PINE TREES AND A MODEL OF NECTARINE CANOPY CONDUCTANCE AND WATER USE

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Trees build hydraulic systems in their stems that can supply water to transpiring leaves far above the ground. When soil water content declines tree hydraulic systems are challenged to maintain their integrity and maintain leaf water supplies. Stomata and their response to environment are major factors in meeting this challenge. Some of the properties of the hydraulic system and its adaptations to arid conditions are demonstrated by differences in xylem properties of Pinus halepensis provenances. Vulnerability to cavitation and xylem pit membrane structure were found to vary, with provenance aridity being associated with pit membrane strength and cavitation resistance. Complementing the anatomical adaptations, P. halepensis and other trees limit water uptake to that which will not challenge xylem integrity.

The resulting mid-day water uptake is stable and depends on soil water status, reflected in pre-dawn leaf water potential (Ψ_{pd}) and mid-day stem water potential (Ψ_{md}), tree hydraulic conductance and a more-or-less constant mid-day leaf water potential (Ψ_l) maintained by the stomata. Stabilization of Ψ_l can be represented by a linear relationship between canopy resistance (R_c) and vapor pressure deficit (D), and the slope (B_D) is proportional to the steady state water uptake. By analyzing sap flow (*SF*), meteorological, and Ψ_{md} measurements during a series of wetting and drying (D/W) cycles in a nectarine orchard, we found that for the range of Ψ_{md} relevant for irrigated orchards the slope of the relationship of R_c to D, B_D is a linear function of Ψ_{md}. R_c was simulated using the above relationships, and its changes in morning and evening were simulated using a rectangular hyperbolic relationship between leaf conductance and photosynthetic irradiance, fitted to leaf level measurements. The latter was integrated with a model of radiation distribution in the canopy and simulated R_c was used in the Penman-Monteith equation to simulate tree transpiration, which was validated by comparing with *SF* from a separate data set. The model gave accurate estimates of diurnal and daily total tree transpiration for the range of Ψ_{md}'s used in regular and deficit

irrigation. Diurnal changes in tree water content were determined from the difference between simulated transpiration and measured *SF*. Changes in water content caused a time lag of 90 to 105 minutes between transpiration and sap flow for Ψ_{md} between -0.8 and -1.55 MPa, and water depletion reached 3 L h^{-1} before noon. Estimated mean diurnal changes in water content were 5.5 L day^{-1} $tree^{-1}$ at Ψ_{md} of -0.9 MPa and increased to 12.5 L day^{-1} $tree^{-1}$ at -1.45 MPa, equivalent to 6.5 and 16.5% of daily tree water use, respectively. 16% of the dynamic water volume was in the leaves. Inversion of the model shows that Ψ_{md} can be predicted from *D* and R_c, which may have some importance for irrigation management to maintain target values of Ψ_{md}.

Session 4

Sustainable Improvements in Water productivity, Soil Fertility and Nutrient Use Efficiency in Irrigated Crop Production

Chaired by Alex Furman

PLANT RESPONSE AND NUTRITIONAL NEEDS AS AFFECTED BY SALINITY AND DROUGHT STRESS

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Arid regions face increasing scarcity of fresh water, increasing salinization of water and soil resources and often increasing demand to minimize nutrient loading to drainage waters. Understanding the interaction of abiotic stress on crop production is essential for management and optimization of resources as well as economic crop production. We discuss plant response to interactive effects of combinations of salinity, drought, nitrogen and boron stress.

Often plant response studies and subsequent recommendations regarding water requirements and drought stress, salinity stress and management, boron toxicity and nutrient requirements are provided from single stress experiments. Under field conditions there are often multiple stresses occurring simultaneously. The simplest model, adding the individual responses to abiotic stress to predict yield, has been discredited, but there are conflicting reports regarding how multiple abiotic stresses interact. Many models consider an interactive effect that is multiplicative of the response to stresses, in contrast some recommendations are to consider only the most severe stress when managing for yield loss.

Many literature reports on salinity and nitrogen conclude that increased fertilization increases yield under saline conditions. However most of these reports consider only two treatments; saline with current nutrient practices and saline with added nutrients. Unless these studies have established the minimal requirements under non-stress conditions the conclusions are not justified and are only useful for current management at that specific site. Studies with either multiple salinity and nutrient levels or measurement of nutrient status in the plant and soil, generally reach an opposite conclusion: Nitrogen requirements are best considered as proportional (scaled) to the relative yield. Thus with expected yield loss due to salinity, less N is generally required than under non-stressed conditions. There is information that Cl salts can reduce nitrate uptake but as will be explained under field conditions this is of lessor consideration than the reduced N demand caused by salinity. Examples from various studies are provided. Although there are some crops that demonstrate decreased K uptake under saline conditions it is not clear that increased K application can be recommended for saline environments, and in fact in many regions increased soil salinity is also associated with increased soluble K. P nutrition and salinity interaction has been reported but as will be discussed, is more related to solution composition (Ca, and pH or alkalinity) than osmotic stress.

There are many studies with the objective of evaluating the effects of water and salinity stress, most are difficult to evaluate because they generally consist of irrigation with waters of varying salinity, superimposed on different fixed applications of water. Reduced transpiration of salt stressed plants results in higher water content and less water (matric potential) stress than non saline treatments with the same water application. Comparison of response to water stress under saline and non-saline conditions requires direct measurement of soil water content or matric potential. Estimation of water consumption based on reduction in biomass production is not adequate as it assumes that water use efficiency is constant under salt stress- an assumption that has been found to not be valid for many crops. Further, the response to these potentials (osmotic and matric) does not appear to be equal.

What are needed are experiments evaluating response to multiple abiotic stresses. These studies are difficult due to experimental constraints, but there are a few that consider three stresses simultaneously. At present with insufficient information, the multiplicative response models provide the best estimate of the effect of these combined stresses, but still may overestimate yield loss.

DETERMINING BEST MANAGEMENT PROTOCOLS FOR IRRIGATION AND FERTIGATION: A MULTIDISCIPLINARY CASE STUDY FOR OIL OLIVES

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Advancements in technologies, modernization of cropping systems, and requisite environmental responsibility make conventional agronomic practices obsolete and necessitate new/updated protocols for crop management. Oil olive cultivation has undergone revolutionary change and modernization in the recent past, including introduction of drip irrigation and fertigation and large knowledge gaps regarding best orchard practices. We take oil olive cultivation in Israel as a case study and present multidisciplinary integrated efforts to address irrigation and fertigation needs and strategies. The conceptual framework involved: 1) Establishing a consortium of experts to define needs and objectives, to centralize efforts, and to advance cooperation. 2) Promoting activity by attaining funds and working on common projects. 3) Conducting applied scientific research using a combination of controlled and field experimental methodologies with various levels of relevance to field conditions. Overarching issues driving the efforts included: Determining water requirements and efficient irrigation regimes; Water status/stress identification; Discovering how variables including water quality and fruit load affect decision making regarding optimal irrigation regimes; Plant response to macro-elements; Fertilizer requirements as a function of plant growth stage and irrigation water quality; Long-term effects of fertigation management alternatives on the environment. Examples of studies and their ramifications on protocols for growers will presented dually by two speakers, the first focusing on irrigation and water and the second on plant nutrition and fertigation.

In lysimeters, where whole-tree-scale water and solute balance was measured, methods for evaluating water status/stress were compared, the effect of fruit load on water consumption was quantified and root zone and plant response to water salinity and leaching determined. In field experiments, optimal water regimes were determined/confirmed, regulated deficit irrigation strategies investigated, and remote and proximal sensing of water status promoted. Annual irrigation at a rate of 75% return of potential crop evapotranspiration was found to be optimal for oil production. Water application rates above this brought only slight increases in yield and significantly decreased oil quality (Ben-Gal et al., 2011a, b). Fruit load was found to have a significant influence on water requirements with high loaded trees consuming up to 30% more than trees with no fruit or low yields (Bustan et al., 2016).

The effect of exposure to macronutrient level on olive tree growth and function and on oil quality was determined in a series of pot experiments. Results were used to determine fertilizer treatment levels in field experiments. Long-term field trials were conducted as well to evaluate the contribution of recycled wastewater on soils and the environment and on tree nutrient status and fertilizer needs. A few examples of practical results can be summarized concerning macro-nutrient fertilization. Exposure to large amounts of nitrogen caused reduced yields and poor oil quality, which analysis of nitrogen in diagnostic leaves failed to indicate (Erel et al., 2013 a,b). Phosphorus was found to play an important role in tree fertility, promoting flowering and fruit set. Contrarily, olive trees were found to be much less sensitive to potassium fertilization than previously assumed (Erel et al 2008, 2013b).

The program’s results have strongly influenced current protocols for best management practice in commercial Israeli olive orchards. Contributions include increased water and fertilizer productivity and benefits to yields and oil quality. The success of the program can largely be credited to strong leadership and collaboration, connection to the field, a multidisciplinary team allowing integrated consideration of the crop, scale-appropriate experimental set ups to address specific issues, and the ability to move relatively quickly from laboratory to orchard with new concepts.

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DEVELOPMENT OF DRIP IRRIGATION IN FOOD PRODUCTION – FROM A SINGLE FARMER TO MEGA PROJECTS FOR SMALL HOLDERS

Yossi Ingber

Projects & Engineering / Netafim

By mid-century, the global population will reach 9 billion people, which will require a 60% increase in food production and increase pressure on available water resources.

It is estimated that a 40 percent overall gap between global water supply and demand will exist by 2030. If current trends continue, by 2030 two thirds of the world's population will live in areas of high water stress. More than 70% of world water consumption goes to agriculture, where food, feed, fiber and fuel compete for each drop. Water for agriculture has to be managed in a sustainable way.

Because 60% of Israel is desert and the rest is semi-arid, its water economy is always on the brink of disaster. In recent years, Israel's water reserves have dropped below all red lines and severe short-term measures were taken: water allocations and quotas, "drought taxes" and prohibition of landscape irrigation.

To cope with its water scarcity problems, Israel needed to establish a comprehensive approach to water use and management by developing and adopting several long-term measures. Technology and innovation play a dominant role in these measures. Drip irrigation is a vital part of it.

The breakthrough concept of drip irrigation was introduced in Israel 50 years ago. It was born out of a necessity – the need to make the Israeli desert bloom in spite of water scarcity and poor soil conditions.

Today in Israel 75% of irrigated agriculture uses drip irrigation, and flood irrigation is prohibited. 85% of Israel's effluent is reused, distributing wastewater through drip irrigation systems to eliminate environmental contamination. Drip irrigation saves water and increases yields. In the last 25 years water quantities consumed for agriculture remained stable, while production and crop yields keep growing.

Globally the picture is different. Drip irrigation is only 5% of all irrigated fields. In some countries it is growing (in California it is 38%), but there is a long way to go.

Since its inception we see several major development in drip irrigation:

1. <u>Geography</u>: outside of Israel drip irrigation was adopted in its early years mainly in the developed world. The first installation outside Israel was for an avocado

plantation in San Diego County, California. Australia, South Africa, Italy and France followed. Today there are more installations in the developed world. India is our second largest market.

2. <u>Crops</u>: at first drip irrigation was used for high value crops: grapes, strawberries, greenhouses, citrus, almonds etc. today there is a shift towards basic food crops: sugarcane, corn, potatoes and cassava.
3. <u>Scale of farms</u>: a shift from advanced large scale farmers to smallholders
4. <u>Emission rates</u>: from relatively high flow drippers (2 to 4 liters per hour) to very low flow (0.5 L/H), from systems which could use only good quality water to systems which handle poor quality, brackish or treated wastewater
5. <u>Fertigation</u>: from basic fertilizer tanks which could handle basic soluble fertilizers to sophisticated fertigation and chemigation
6. <u>Automation & Control</u>: introduction of relatively low cost remote control and automation systems, along with smart decision support utilities.

Drip irrigation improves the livelihood of millions of farmers by helping them grow more with less. It increases crop productivity from 15% to 200%, while delivering substantial water and fertilizer saving. It is the Answer to the challenging water – food nexus.

Session 4 (continued)

Chaired by Anat Lowengart -Aycicegi

SUSTAINABLE USE OF TREATED WASTEWATER FOR IRRIGATION – THE ISRAELI EXPERIENCE

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Utilization of treated wastewater (TWW) in agriculture in Israel increased dramatically in the last three decades, providing nowadays about 40% of irrigation water for agricultural production (which is > 75% of the TWW in the country, e.g. Shaviv, 2009; Lavee, 2014). This significant increase occurred as a result of R&D efforts backed by governmental decisions that sustainable utilization of this very scarce and precious natural resource must also be significantly based on the use of treated domestic wastewater. While the utilization of the TWW represents important values of conservation, waste recycling and re-use of nutrients it also has the potential of exposing human beings and the agro-ecosystem (soil, water, crops) to problems and threats. These may include: - soil salinization affecting plants and water resources; exposure to pathogens; - boron accumulation in soils at levels toxic to plants; - soil sodification (high SAR and ESP) leading to structural damage to soil aggregates which may reduce infiltration and increase runoff; - potential accumulation of excess N and P in soil and water resources; - undesired effects of dissolved organics; - potential accumulation of pharmaceuticals, hormones, cosmetics and similar compounds. The need to account for the sewage-sludge resulting from TWW treatment is also an important issue to be taken care of (e.g. Shaviv, 2009; Levy et al., 2010).

Awareness to the potential problems led to a conceptual change in the attitude to TWW utilization, emphasizing the importance of sustainable use of this resource, and the need to consider much more carefully long-term effects, rather than rely to soil's buffering capacity that may tolerate low or medium quality TWW.

Accordingly, significant efforts were devoted in the following direction: (i) R&D both in developing improved wastewater treatment technologies and improved agricultural and irrigation practices (mainly based on drip/trickle irrigation); (ii) intensive surveys on the effects of TWW on farmland and the environment; (iii) continuous re-examination and modification of regulations and development of more strict standards (Inbar, 2007); and (iv) development of effective approaches for dissemination, at all levels, assuring that the information successfully reaches the end users (farmers, agronomists, technologists). This in-turn resulted in: improved management of irrigation and fertilization under the use of TWW (e.g. Levy et al., 2010); new regulations for TWW utilization for irrigation and for TWW disposal to streams (Inbar, 2007); development and construction of new wastewater treatment plants with improved TWW quality.

The heavy droughts faced in the last decade increased the awareness of authorities to the urgent need for creating new sources of water mainly via RO desalination of seawater. The additional supply of desalinized water is mainly directed for domestic use, whereas, the treated domestic wastewater serves as a major source for irrigation. Desalinated water indeed provides lower salinity in the TWW for irrigation. Yet it calls attention to the need of effective removal of Boron from the desalinized (via RO) water (Nir and Lahav, 2015) and post-treatment to correct the highly effective removal of Ca and Mg, whereas Na may remain at relatively high concentration (e.g. Lahav et al. 2010).

The great challenge now is to assure that the overall increase in TWW use occurring concomitantly with sustaining high agricultural production will continue while preserving quality and availability of this precious resource in the region.

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WATER AND NUTRIENT SUPPLY IN GREENHOUSE HORTICULTURE: CONTROL OF PRODUCTION, QUALITY AND SUSTAINABILITY

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The growing world population requires strong increases in vegetable production. Simultaneously, consumers demand that vegetables are of high quality and that they are produced sustainably. To meet all the requirements we need to have a high level of control over the production process. Production in greenhouses or in buildings (often indicated by terms as vertical farming, or city and urban farming) allows a precise control over the production process.

Yield per m^2 of several crops grown in greenhouses has doubled over the last 25 years. For greenhouse grown tomatoes it was estimated that about 25% of the yield improvement was due to breeding and 75% due to improved growth conditions and cultivation techniques. Improved water and nutrient supply have strongly contributed to the increase in yield. Improving product quality and sustainability are nowadays important targets. Quality not only refers to external appearance of harvested products (e.g. size, shape, colour, etc.) and their taste but also to their content of health affecting compounds (e.g. vitamins, NO_3).

In greenhouses many crops are grown on substrates such as stonewool, perlite or coco peat. Water and nutrients are supplied together via drip irrigation per plant, while the excess water and nutrients are recirculated. Despite the fact that there is still room for improvement, this is at present by far the most efficient production system with respect to water and nutrient use. In modern commercial greenhouses in the Netherlands about 15 litres of water are used to produce 1 kg of tomatoes, while the production of 1 kg tomatoes in the open field in the Mediterranean costs about 60 litres of water (Stanghellini, 2014).

Optimal supply of nutrients requires a thorough understanding of the effects of each nutrient and its interaction with other nutrients as well as the above-ground environment. For instance, the relative growth rate of tomato plants increased sharply with increasing P concentration in the plant before it levelled off, resulting in a broad plateau, while the response of relative growth rate to increasing plant N concentration was gradual and levelled off at high N concentrations, resulting in a small plateau. Depending on the severity of the N or P limitation growth reductions were mainly due to reduced assimilation rate or leaf area expansion (De Groot et al. 2003). Calcium plays an important role in the occurrence of several physiological disorders such as blossom-end rot or tip burn (e.g. Ho and Marcelis, 1999). Calcium related problems are a typical example of how above-ground factors interact with below-ground factors. Salinization is a world-wide problem for plant production. Although in some cases high salinity can be used to improve product quality, often production is severely hampered by salinity (e.g. Heuvelink et al., 2003). This yield reduction also depends on above-ground factors such as radiation and crop management strategies. Mechanistic simulation models (Poorter et al., 2013) are an efficient tool both for understanding interactive effects of environmental factors on growth and functioning of plants and for exploring efficient strategies for water and nutrient supply. Improving nutrient and water use efficiency may also require adapted cultivars. Rapid phenotyping methodologies will help to speed up the breeding process (Kuijken et al., 2015).

Effective water and nutrient supply strategies require fine tuning the supply to the demands of the crop, which cannot be considered independent of above-ground conditions. Nutrients can be supplied together with water, but its control should be independent of the supply of water. Furthermore, the supply of individual nutrients should be controlled rather than total salt concentration. To supply water and nutrients in proportion to the demands of the crop online sensors (e.g. chlorophyll fluorescence, plant size or transpiration) are needed to monitor plant functioning as well as growth conditions above- and belowground. Sensor information in combination with simulation models enable to develop information systems and decision support systems for predicting and controlling the water and nutrient supply.

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Drip Irrigation Contribution For Food Security And Climate Change Mitigation: A Holistic Approach For Responsive Implementation

Dubi Raz

Netafim Agronomy Director

Decreasing land and water resources, significant population growth and changes in human diet impose hazard of food security. Agriculture must feed the world in a sustainable way. With Drip Irrigation we can grow more with less.

Although Drip celebrates 50 years, still, only 4% of the irrigated area is on Drip.

In order to increase the area under Drip Irrigation, Netafim, the World leader in Drip is addressing 4 challenges:

- Yield increase

Define the limiting factors, Perform variety tests, Apply nutrigation and well integrated plant protection programs.

- Mechanized solutions

Labor becomes an issue, while introducing new technologies like drip irrigation we should consider saving in labor demand.

- The use of Big Data platforms

It is obvious that the next Agricultural Revolution develops under intensive monitoring tools which are controlled by applications. How can we integrate the vast existing knowledge, into day-to-day decision support tool?

- Environment friendly sustainable approaches

Apply integrated approaches for optimizing the utilizations of precious resources: soil, water and nutrients to assure food security while minimizing environmental and ecological adverse effects.

For "Green Organizations" Agricultural activities impose environmental threats.

How can we change this mind set? One of the tools is Drip Irrigation as a Delivery system. Integrating these four elements will increase the demand for drip, and can make this planet a better place to live in.

EVAPOTRANSPIRATION PARTITIONING IN AN ARID WINE VINEYARD

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Partitioning of energy and water fluxes in vegetated systems can provide valuable information on the productive use of water through plant transpiration (T) and evaporation from the soil (E), which is generally considered an unproductive form of water use. This is relevant for food production, ecosystem functioning, and climate; particularly in the light of increasing water scarcity and drought as a result of anthropogenic activity and projected climate change. In arid areas, E is potentially substantial due to high evapotranspiration (ET) dominating the water balance and the prevalence of sparse vegetation. As E and T differ in their response to environmental conditions, separate assessment is necessary to adequately determine ecosystem energy and water exchange under different weather and climate conditions. This is a challenging task and largely unresolved as of today. In this research we addressed this knowledge gap, aiming to: 1) study the effects of canopy growth, irrigation, and changes in atmospheric conditions on productive and unproductive allocation of water through ET partitioning, and 2) determine the utility of the below canopy energy balance approach towards obtaining continuous estimation of E.

The research was conducted over a season (bud break till harvest) in a wine grape vineyard located in an extreme arid region. A below canopy energy balance approach was applied to continuously estimate E, while system ET was measured using eddy covariance. Below canopy energy balance was assessed at the dry midrow position as well as the wet irrigated position directly underneath the vine row, with E calculated as the residual of measured net radiation, soil heat flux, and computed sensible heat flux. The variables used to compute sensible heat flux included soil surface temperature measured using infrared thermometers and below-canopy wind speed in a soil resistance formulation that required a modified wind factor. The below canopy energy balance approach used in this study allowed continuous assessment of E at daily intervals, however, instantaneous E fluxes could not be assessed due to vertical variability in shading below the canopy. At daily intervals E was reasonable, although it underestimated micro-lysimeter E measurements by up to 16%, suggesting there may have been advected energy from the midrow to the below-vine position. Seasonal partitioning indicated that total E amounted to 9−11% of ET.

Average E/ET and T/ET previously reported for vineyards were 0.41±0.21 and 0.57±0.21, respectively (Kool et al., 2014). For drip-irrigated vineyards, reported E/ET and T/ET averaged 0.30±0.12 and 0.69±0.13 (Ferreira et al., 2012; Kerridge et al., 2013; Poblete-Echeverría et al., 2012; Yunusa et al., 2004). In comparison, water use of the vineyard in this study was extremely efficient with an E/ET of only 9%, or 11% if a 16% underestimation of E is considered.

In addition, empirical functions from the literature (Ferreira et al., 2012; Picón-Toro et al., 2012) relating crop coefficients (K_{cb}) to leaf area index (LAI) or vegetation fraction (f_{veg}), appeared to give reasonable results under full canopy, where K_{cb} reached 0.42. When considering the whole study period, however, all equations overestimated K_{cb} by 30-50% for lower LAI and f_{veg} values. Relationships determined for this study were: [K_{cb}= 0.011 × f_{veg} + 0.248] and [K_{cb}= 0.148 × LAI + 0.229]. This may indicate that relations between K_{cb} and plant size parameters are more universal for fully grown canopies. Non-universality of K_{cb} factors can also be ascribed to the site-specific nature of the wind fitting terms that relate K_{cb} to reference ET. Additionally, the significant scatter in observed K_{cb} values indicates there is large day-to-day uncertainty in crop coefficients applied to vineyards.

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Session 5

Decision Support Approaches and Technologies for Improving Resource-Utilization Efficiency

Chaired by Victor Alchanatis

SPATIALLY VARIABLE PRESCRIPTION OF WATER AND NUTRIENTS DRIVEN BY HISTORICAL AND ON-THE-GO ACQUIRED DATA.

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Thermal crop sensing technologies have potential as tools for monitoring and mapping crop water status, improving water use efficiency and precisely managing irrigation. Leaf Water Potential (LWP) measurements by pressure bomb in the boll-filling stage of cotton is currently used as an effective tool for irrigation management. Nevertheless, these measurements do not express the variability in the field. Estimation of LWP from thermal images could address this problem. In previous studies, a regression model for assessing LWP in cotton plants based on crop water stress index calculated using ground and airborne thermal imagery was developed and validated. In this study we applied this model and compared between thermal-based irrigation management and today's common practice. The experimental results show that there is no significant differences between the methods and that cotton can be irrigate efficiently using LWP values that are derived from remotely sensed thermal images. The thermal-based method resulted to similar seasonal water application amounts as the commercial practice, and achieved yields that were slightly higher but with no statistically significant difference from commercial practice (n=6, p=0.01). For its assimilation the cost effectiveness of the thermal-based irrigation management should be examined in commercial scales. Future study should focus on the applicability of this approach for variable rate irrigation.

Nitrogen management is important both from a production and environmental standpoints. Common nitrogen management in irrigated fields is based on a uniform N application. This practice does not account for spatial and temporal variability of plant response to environmental conditions. This practice leads to: unnecessary over-applying N rates, high leaching rates, ground water contamination by $N\text{-}NO_3$, reduction in yield quality. Hyperspectral sensing provides the means to remotely estimate and map nutrients in crops canopy. Two major characteristics of hyper-spectral imaging : Their unique spectral properties, namely the narrow-band widths and the plethora of the bands, as opposed to wider and limited number of bands in other broad-band spectral sensing systems; their spatial attribute as opposed to point measurements of other spectral systems. Most available hyperspectral data processing techniques focus on analyzing only their spectral data. In other words, hyperspectral image are usually not treated as images, but as unordered listings of spectral measurements with no particular spatial arrangement. Estimation of leaf nitrogen across the whole field may enable better evaluation of fertilization needs. Spatial delineation of homogenous zones enables variable rate N application according to prescription maps prepared in advanced and combined with soil characteristics.

IMPROVING IRRIGATION AT THE FARM LEVEL: AN OVERVIEW OF THE EU FP7 PROJECT FIGARO

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Increasing water demand, caused by global population growth coupled with global warming exacerbating current drought conditions in Europe, has resulted in dwindling fresh water resources. The misuse of the available fresh water resources across Europe threatens sustainable agricultural development and overall economic growth. These considerations have led the European Union to fund the Project FIGARO (Flexible and precIse IrriGation plAtform to Improve FaRm scale water prOductivity) as part of its FP7 Program. The overall Project's goal is to improve the use of irrigation water via the development and implementation of irrigation strategies that take into account, in real-time, soil water availability, local weather forecasts, crop physiological status and water needs. The main product of the FIGARO project, which is entering its fourth and final year, is a computational platform which manages all the flow of data and combines information from sensors, static databases, dynamic databases and models in order to analyze user-supplied irrigation strategies and/or compute sub-optimal irrigation schedules.

The talk will focus on the Decision Support System component of the FIGARO platform and will discuss three approaches which were developed for computing optimal and sub-optimal irrigation schedules. The first approach consists of full optimization of the irrigation schedule assuming perfect weather forecasts. Although this assumption is not realistic, this approach is useful in the sense that it yields a benchmark result to which the other approaches can be compared. In the second approach the irrigation events are not optimized directly, but the optimization is performed using as decision variables soil moisture levels at which irrigation events are triggered. These "threshold levels" are defined relative to soil moisture levels at which water stress starts to affect the crop development (according to the crop model), and remain constant on periods of time defined according to crop developmental stages. As a result, the number of decision variables is small (four or five), which makes the procedure very efficient and stable computation-wise. The last approach can be viewed as a combination of the two previous ones: the optimization includes irrigation event(s) for the immediate future (4-7 days) and irrigation thresholds for the rest of the season. In this manner the number of decision variables remains acceptably small while the overly rigid strategy based on fixed thresholds is relaxed for the near future. Since the computation time is small (less than one minute), the procedure can be executed in real-time when new information is available, for instance when weather forecasts are updated.

Intuitively, the (in)accuracy of the weather forecasts is expected to have a major effect on the overall performance of the optimization procedure. This relation between inaccurate weather forecasts and overall performance will be discussed in details via a number of simulation examples with maize, cotton, tomato and potato at various locations throughout Europe. Throughout these examples we will also discuss the advantages of using local weather forecasts compared to large-scale forecasts such as the Global Forecast System.

Evaluating the Role of Water Availability in Determining the Yield/Plant Population Density Relationship in Rain-fed or Sprinkler-Irrigation Crop Production

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The relationship between crop areal yield, Y_a (kg/m^2) and plant population density (*PPD*), (pl/m^2), or its single-plant yield counterpart (Y_p=Y_a/*PPD*; kg/pl) was of considerable agronomic interest for at least a century. Probably, the basic reason for wishing to quantify *Y*(*PPD*) is to evaluate such characteristics as optimum plant population density and potential maximum yield; in addition, this knowledge can facilitate comparison between cropping practices. Thirty-eight yield/plant-population-density (*Y-PPD*) data sets were collected from the literature and analyzed statistically to yield, inter alia, a single "universal" relationship that realistically describes the *Y-PPD* data obtained with various plants in various agricultural and environmental conditions. The present analysis aims to facilitate evaluation of the dependence of water availability to plant-root systems on: plant-population density, plant-arrangement geometry, active-root-system size, and soil texture. The outlined evaluation of the relative water uptake rate/plant-population-density (*RWUR-PPD*) relationship can quantify the roles of water availability and competition among neighboring root systems in determining the *Y-PPD* relationship in rain-fed or sprinkler-irrigation crop production. In particular, this methodology quantifies the effects of root system size, soil capillary length and planting rectangularity, on the *Y-PPD* relationship. The proposed evaluation is based on a simplified, coupled source/sink description of steady water flow and uptake. The description of the plant root system is simplified as a discrete, localized point sink that extracts water at a prescribed suction. Sprinkler-irrigation or rain is assumed to wet the soil uniformly, and the *RWUR*, representing the role of water availability in determining *Y*(*PPD*), depends on a minimal number of three parameters that represent the soil capillary length, the size of the plant root system, and the plant population density. The secondary effect of the plant arrangement geometry also can be quantified by inclusion of an additional rectangularity parameter. Overall, the proposed *RWUR* evaluation shows, in reasonable qualitative agreement with experimental findings, that the *Y-PPD* relationship increases with increasing root system radius and soil capillary length, and with decreasing rectangularity. *RWUR* evaluation shows that competition between neighboring plants for water increases approximately linearly with the product of (root-system radius) × (soil capillary length). Plant roots and shoots compete also for resources other than water, e.g., nutrients and oxygen in the soil, atmospheric carbon dioxide, and solar radiation. Thus, the agronomically important *Y-PPD* relationship depends on genetic, agricultural, and environmental factors that affect availability of other resources differently from their effects on water availability; and these differences render it virtually impossible to define and quantify the roles of the various essential resources and the effects of diverse factors in determining the *Y-PPD* relationship. This is why practical agronomists use empirical mathematical expressions to describe *Y-PPD*. The outline of the lecture is as follows. Firstly, we report on a literature survey and summarize the main findings of the reported experimental studies. Next, we outline the methodology of evaluating the effect of plant density (and rectangularity) on rain-water or sprinklers-water availability to plants, and illustrate the corresponding effects of root system size, soil capillary length, and rectangularity. Finally, we discuss the correspondence between these expected effects on the *RWUR*, on the one hand, and, on the other hand, the experimental *Y-PPD* findings.

APPLICATION OF MID-INFRARED AND RAMAN SPECTROSCOPY IN THE CHARACTERIZATION OF SOIL ORGANIC MATTER

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As an important composition of soils, soil organic matter (SOM) plays a vital role in soil fertility, food production and agro-ecosystem balance. SOM is a heterogeneous mixture of organic residue from plants and animals in the soil. Over 90% of the N and S, and 75% of P are contained in the organic matter of the topsoil. As the major reservoir of terrestrial carbon, certain amounts of organic matter are stored in agriculture soils for both the preservation of soil fertility and the improvement of the soil structure. Therefore, qualification of SOM in farmland soil including composition and structure has been much concerned.

The routine laboratory-based analysis techniques, involved in the characterization of SOM, are time and labor consuming, and face challenges in seeking structure information since soil pretreatments such as extraction are usually used. Thus, instrumental analysis method with non- or minimum-pretreatment of soil is necessary for the better understanding of SOM, and molecular spectroscopy such as infrared spectroscopy and Roman spectroscopy provide options for this purpose.

Fourier transform mid-infrared photoacoustic spectroscopy (FTIR-PAS) is based on the absorption of electromagnetic radiation by using analyte molecules, which is useful to highly absorbing soil sample without pre-treatment. Raman spectroscopy (RS) is a technology stemming from the inelastic scattering of light, and the advantages include not only being nondestructive, cost-efficient, easy for sample preparation, but also has unique independence from water interference compared to infrared spectroscopy. With these methods, the skeletal vibrations of both aliphatic and aromatic fractions of SOM could be captured by Raman spectroscopy while infrared spectroscopy more likely reflects functional group vibrations, which may be combined to further characterize SOM.

Four typical farmland soils, i.e., black soil from north China, Fluvo-aquic soil from middle China, paddy soil from east China, and red soil from south China were used in this study, and the FTIR-PAS spectra and RS spectra were recorded. For the soil FTIR-

PAS spectra, three clear absorptions occurred in the wavenumber range of 1,200–900, 1,800–1,400, and 3,800–3,000 cm^{-1}. 3,800–3,000 cm^{-1} was assigned to O-H and N-H vibrations, which was interference by O-H from water; 1,200–900 cm^{-1} was assigned to C-O vibrations, but Si-O vibrations showed much contribution; 1,800–1,300 cm^{-1} was assigned to C=C and C=O vibration, which mainly resulted from SOM, and thus can be used to qualify SOM content. For different soils, the band intensity for black soil was strongest, followed by the paddy soil and red soil, and it is the weakest for the Fluvo-aquic soil. Furthermore, for each soil type, the band intensity was stronger for the soil with higher content of SOM. For the soil RS spectra, only a strong band in the wavenumber range of 1,800–1,300 cm^{-1} was observed. The band intensity was strongest for red soils, followed by the Fluvo-Aquic soil and paddy soil, and it was weakest for black soil; for the Fluvo-aquic and red soil, the band intensity was stronger for the soil with lower content of SOM, while for the black soil and paddy soil it was stronger for the soil with higher content of SOM.

The quantitative results of SOM with FTIR-PAS spectra in the range of 1,800–1,300cm^{-1} greatly matched the results from chemical analysis, but more details about the structure information of SOM was not directly available due to the strong interferences among functional groups. FTIR-PAS spectra showed that the SOM content in Fluvo-aquic was lowest, but the aromaticity was strongest; for black soil, the SOM content was highest, but the aromaticity was weakest. For the low SOM content soils, i. e., Fluvo-aquic and red soil, the soil with low SOM content showed higher aromaticity; however, for the high SOM content soils, i. e., black soil and paddy soil, the soil with low high content showed higher aromaticity. These results should be decided by soil hydrothermal condition, such as for red soil, with rich hydrothermal condition, the dissolvable carbon was even higher than that in black soil though the SOM content was significantly lower, in this case, liable soil carbon was easy to lose from SOM, while aromatic was left, which resulted in high aromaticity.

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Session 6

Bridging Gaps: Sharing and Disseminating Knowhow and Technology

Chaired by Alon Ben-Gal

SOCIO-ECONOMIC BARRIERS TO INCREASING THE EFFICIENCY OF WATER AND NUTRIENT USE IN DEVELOPING COUNTRIES : UNDERSTANDING SMALLHOLDER FARMERS.

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Smallholder agriculture dominates production in the developing world. Increasing smallholder productivity and incomes in the face of climate change, growing water scarcity, and environmental pollution is one of the greatest challenges of sustainable development. Achieving this goal will require dramatic improvement in the efficiency of water and nitrogen use .

While existing, proven technologies such as drip or sprinkler irrigation or soil health tests can help, their adoption remains low. This talk will first present a conceptual framework highlighting a range of hypothesized factors that may be responsible for low adoption, and then review an empirical research program that utilizes experimental and quasi-experimental designs, in the field, in several locations in India and Africa, to identify the actual bottlenecks and test policies that can help overcome them.

We consider two kinds of potential causes of low adoption. The first includes the absence of incentives for efficient use of natural resources. The second is concerned with market or institutional failures prevailing in developing countries (Greenstone and Jack, 2013)

There are two types of incentives for conservation and efficient use. The first is regulation, or pricing. But prices of natural resources are often severely distorted by lack of regulations or by heavy subsidies. For example, the absence of pricing of electricity for pumping is thought by many to be the main driver of groundwater depletion in India. Similarly, the subsidized costs of nitrogen fertilizer are thought to be related to the inefficiently high levels of usage. The second is scarcity, which could lead to efficiency even when prices are absent. But in some cases, it takes time for scarcity to manifest itself. For example, in the short term, declines in groundwater depth can be compensated for partially through greater use of power or the drilling of deeper wells .

The second kinds of potential barriers are more "economic" in nature, and include poor access to credit and insurance products, small scale of operation and incomplete information. While they can impede the adoption of any kind of technology, they may be exacerbated in the case of resource saving technologies, because these often involve large upfront costs and may therefore require time to become profitable, and are also often neglected by the private sector innovation and an already malfunctioning extension system .

I will review a number of field studies that attempt to test the importance of these various factors. In the context of groundwater depletion in India, I will begin by describing a field study that introduced, for the first time, voluntary metering and marginal “reverse” pricing of power usage for pumping groundwater in the state of Gujarat. Farmers were invited to install meters in order to receive compensation for every unit of power they voluntarily “save” from a pre-specified benchmark. This introduces a marginal opportunity cost on groundwater pumping for participating farmers. Contrary to prevailing priors, and while farmers’ interest in participating was high, the pilot experiment (which includes about 100 well owners) found no evidence of reduced usage of power for pumping, suggesting that the role of pricing may not be as prominent as is often thought. A second field study sought to understand whether scarcity drives a shift to more efficient use of water. We exploited a natural experiment, also in Gujarat, in which the rate of groundwater depletion varied across villages because of geological factors. While geologically “disadvantaged” farmers had shrunk their cultivated area, we found evidence for only very most improvements in water use efficiency. In contrast, we found that the main response in these villages was migration of young males to cities. A third study examines the rapid diffusion of drip irrigation in Gujarat, India. Using detailed electricity billing information, we are able to show that following drip adoption, power usage increases in the short-term, the opposite of the expected result, and we explain the result in terms of an effect echoing the familiar “rebound effect” from the energy efficiency literature .

Moving to economic barriers, I will describe a large scale ongoing impact evaluation of a drip irrigation program in Senegal which attempts to overcome the diseconomies of small scale cultivation by installing drip irrigation to groups of women farmers. The evaluation will seek to understand whether groups are able to avoid free-riding and work collectively to realize the benefits of larger scales. I will also describe results, again from the diffusion of drip irrigation in Gujarat, which show that learning from earlier adopting farmers plays a very large role in adoption decisions, highlighting the importance of good information. I will also show evidence that price plays another important role in adoption decisions, by examining the impacts of varying subsidy levels. Moving from water to soil, I will describe preliminary results from a field study that attempted to simulate and evaluate the impacts of the distribution of soil health cards in Bihar, India. We tested the soils and reported the resulting fertilizer recommendations to about 500 randomly chosen farmers. We did not find evidence for an impact on fertilizer usage patterns. Moreover, through the use of auctioning, we are able to show that the main driver was not an inability to understand the contents of the cards, but rather a lack of trust in the credibility of the information. This highlights the limitations of the public extension systems and the need for more proactive and prolonged interaction and training in order to shift cultivation practices to be more resource efficient .

INTEGRATED WATER, SOIL AND NUTRIENT MANAGEMENT FOR EFFICIENT AND SUSTAINABLE FOOD PRODUCTION IN SUB SAHARAN AFRICA- SUCCESSES, CHALLENGES AND OPPORTUNITIES

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The challenge for agriculture in Sub Saharan countries of Africa (SSA) over the coming decades will be to meet the growing demand for food in a sustainable way. Declining soil fertility and mismanagement of plant nutrients as well as water have increasingly made achievement of food security difficult. As long as agriculture remains a soil-based and rain fed industry, major rises in output are unlikely to be attained without adequate and balanced supply of nutrients and water. Soils in Africa are typically highly variable in fertility and in how they respond to inputs. A large percentage of soil resources in SSA exhibit low nutrient levels with a high inclination towards nutrient loss due to their fragile nature. Highly weathered soils in the tropics have also been observed to have multiple nutrient deficiencies and nutrient balances are generally negative. Soil nutrient depletion and likely degradation as well as poor water management have been considered serious threats to agricultural productivity and have been identified as major causes of decreased crop yields and per capita food production in SSA. The use of fertilizer and irrigation has achieved significant strides in improving crop productivity in many agro ecological zones in SSA. Balanced fertilization of soils and watering of plants through synchronized supply of adequate nutrients and water to growing crops as well as increasing soil organic matter content over the long term are major gains realized through application of fertilizer and water resources. Some countries have made significant strides in this area but a considerable number still practice the conventional methods which have been blamed for the declining productivity. Constraints that limit utilization of integrated soil nutrient and water management systems have been noted with the observation that more committed research activity and better adoption of developed technologies would lead to promotion and establishment of the gains of procuring and utilizing nutrient and water resources for improvement of crop productivity and increase of food security SSA. This paper reviews Integrated Nutrient and Water Management approaches in Sub Saharan Africa. The key components of these approaches are described; the roles and responsibilities of various actors described; and successes, challenges and opportunities for improving the management of water, plant nutrients and soil fertility presented.

SUCCESSFUL LARGE-SCALE IMPLEMENTATION OF DRIP IRRIGATION IN SMALL HOLDERS PLOTS IN INDIA – ECONOMICS AND IMPACT ASSESSMENT

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Rising demand for irrigation water amid concerns of growing water scarcity has brought into renewed focus the need for improving irrigation application efficiency and raising crop water productivity. The capacity of large countries like India to efficiently develop and manage finite water resources is likely to be a key determinant for global food security in the 21st century. Therefore, drip irrigation technologies are aggressively promoted in India by national and state Governments by providing different kinds of financial, institutional and technical support systems. The drivers for promotion of these technologies are primarily to save water and avert water scarcity, as a strategy to increase income and reduce poverty, and to enhance the food and nutritional security in rural households. Despite the reported significant economic advantages and the concerted support of the Government and other stakeholders, the current drip irrigated area in India (2.1 million ha) remains an insignificant proportion of its potential (27 million ha). This study offers findings regarding the Special Purpose Vehicle, TSMIP (Telangana State Micro-irrigation Project) initiated as a mega-project of US$ 350 million in India, aiming at bringing 0.5 million ha under drip irrigation.

The farmers in TSMIP noted about ten advantages of drip irrigation technologies. Water & power savings, yield gains, higher profits and area expansion were consistently mentioned by the majority of the farmers as the most important merits of drip irrigation technologies. This shows that the adoption of drip irrigation technologies by farmers has complex physical, biological and social ramifications. About 93.5% of the farmers in TSMIP have indicated that they will continue using the drip irrigation technology. As we anticipated, the ownership, depth of wells and horse power of the pump had a strong effect on the probability of adoption of drip irrigation owing to high degree of control over the water source, motivation to efficiently use available limited water in the well. Further, higher share of horticulture crops *viz.*, fruits & vegetables and cash crops *viz.*, cotton & sugarcane, in the cropping scheme had a positive influence on drip irrigation adoption probability as compared to staple food crops such as cereals and pulses indicating that they are not sufficiently benefiting from innovations in drip irrigation technology.

Findings show that for all crops studied (Fruits, Vegetables and Sugarcane) the use of drip resulted in significant yield improvement (20.8 to 59.8%) over traditional furrow/basin irrigation, with mango and sugarcane productivity found to be significantly higher (+58%) compared to the other crops. Higher field application efficiency under drip resulted in significant savings in water (49.2 to 54.2%) contributing to marked increase in water productivity (12.5 to 167.9 kg/m^3). Overall average water saving of 52.1% suggested that area under irrigation can be doubled by adoption of drip in fruits, vegetables and field crops. Reduced hours of pumping in drip irrigated crops enabled substantial saving in energy (557 to 1537 kWh/ha/year) contributing to low electricity consumption consequently low production costs in drip irrigated crops. Fertigation of crops through drip system enhanced fertilizer use efficiency (26.0 to 289.9 kg/kg fertilizer applied in different crops) by 27.6 to 107% over soil application in different crops.

Results of the economic analysis clearly showed that the adoption of drip technology is economically viable for all the crops. The NPV under drip irrigation system, for different crops varied from a highest value of US$ 7579 in papaya to a lowest of US$ 524 in egg plant. The study also indicates that farmers recovered the entire capital cost of the drip system from the income within 3 to 7 years in perennial fruit crops and < 1 year in vegetables, banana, papaya and sugarcane, even without any subsidy. The findings particularly for vegetables (Tomato, Egg plant, Chillies) and fruit crops like banana & papaya, and sugarcane clearly discard the common misapprehension that the capital cost recovery of drip investment takes more time. The breakeven point for yield unit and selling price in all crops studied was attained at lower level due to adoption of drip irrigation in comparison to conventional surface furrow/basin irrigation of crops. Preliminary findings regarding adoption of drip irrigation in aerobic rice both in experimental and farmers fields also showed promising results with respect to yield improvement and water saving. The technology found to maximize the synergistic interactions of improved seeds, water and fertilizer – the three components of the Green

Revolution besides ensuring the congruence of sustainability, productivity, profitability and equity.

SHARING KNOWHOW AND EXPERIENCES FOR SECURING SUSTAINABLE IRRIGATION WITH TREATED WASTEWATER: A USAID R&D PROJECT IN THE MIDDLE EAST NORTH AFRICA REGION

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The increase in water scarcity in 2050 in the MENA (Middle East North Africa) region is projected by the World Bank to reach ~60% of the water needed for all sectors (World Bank Report, 2011). The largest part, about 70%, is for agriculture and food production. It is recognized that treated wastewater must be used for irrigation in order to compensate for the reduction in available potable water. USAID is supporting regional cooperation among members of a MENA Network of Water Research Centers (MENA-NWC) in R&D projects whose aim is to sustain agriculture for food production by using reclaimed wastewater whose quality is high enough to enable unrestricted irrigation and reduce negative environmental consequences.

The project "Upgrading Treatment Processes to Improve Effluent Quality for Irrigation"[i] is conducted by a joint group from the Technion's Grand Water Research Institute (GWRI) the National Center for Agricultural Research (NCARE) in Jordan and Al-Quds University (AQU) in East Jerusalem, Palestinian Authority. It is a combined effort by Palestinian, Jordanian and Israeli researchers and extension practitioners to upgrade the quality of secondary urban wastewater to tertiary quality by membrane and special treatment technologies and use the upgraded effluents for irrigation and plant nutrients supply while maintaining cost feasibility and reducing environmental damages. Special focus is placed on regional collaboration in preparing guidelines and tools for disseminating the knowledge and experience to decision makes, professional specialists and end users.

The project combines three components, conducted by three expert teams:

1. Testing new membranes and systems for treatment of secondary to tertiary effluents towards near zero liquid discharge (NZLD), increase efficiency of treatment and alleviates the problem of brine disposal, while reducing salinity of the final product;
2. Investigating effects of irrigation with effluents of different qualities. Special efforts are on sustainable provision of nutrient demand while conforming with regulations

that aim at protecting crop quality and food health and minimizing negative environmental impacts;

3. Development of a management platform that combines information from the above two components and from additional professional sources in a Decision Support System (DSS) that aids in identifying optimal system configuration and design. The DSS is to be used by experts to plan and operate the system, to engage practitioners, and to inform Decision Makers of the technical and management consequences and of the imperative to raise the quality of treated wastewater above secondary for irrigation of crops.

Extension Services are engaged in the project with the objective of bringing in field experience and ensuring that the results are transferrable to the field.

Emphasis will be placed in the presentation on the activities and interactions between the teams, with focus on the importance of knowhow dissemination and increasing awareness to the importance of high quality treated wastewater for sustainable irrigation and food production.

World Bank Report. 2011. Middle-East and Northern Africa Water Outlook April 2011. **http://www.futurewater.nl/wp-content/uploads/2011/04/Final_Report_v11.pdf**

[1] The Project is managed for USID by DAI (http://dai.com/#who-we-are) under FABRI (Further Advancing the Blue Revolution Initiative) (http://dai.com/our-work/projects/middle-east-and-north-africa%E2%80%94further-advancing-blue-revolution-initiative-fabri)

Session 7

Indicators and Benchmarks for Sustainable Food Production and Resource Conservation

Chaired by Fusuo Zhang

MITIGATING NITROGEN EMISSIONS TO IMPROVE CROP PRODUCTION: AN INTEGRATED APPROACH

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There is growing awareness of the environmental and human health consequences resulting from the loss of reactive N (Nr) from farming systems. With the introduction of the Nr Cascade concept there is now greater clarity about the potential for multiple effects of reactive N in both natural and managed (including human) ecosystems (Galloway et al. 2003). There is also for the farmers the economic imperative to conserve N to lower production costs. Release of reactive N from farms is regulated in many countries by various conventions on surface water, ground water, air quality, climate change and ecological species diversity. In Canada, gaseous losses (especially NH_3) comprise about 2/3 of N losses from agriculture to the environment (Clair et al. 2014).

Robust emission factors and models are needed to enable assessment of emissions from farm activities, to quantify the effectiveness of mitigation techniques, and to enable reliable upscaling of emission estimates which is needed for development of sound public policies. A further consideration is that estimates of gaseous losses may be used to infer other N losses such as into waterbodies. There are several accepted methodologies for measuring emissions of NH_3 and N_2O (less so for N_2) but all techniques are subject to limitations. It is also a concern that there is not always clear experimental evidence showing that mitigating emission increases N use efficiency, so pollution swapping may be unwittingly promoted. While researchers often contrive their experiments to isolate N use efficiency, in practice efficient use of N cannot be divorced from the challenge of judicious use of all other inputs (e.g. phosphorous, water, pesticides, energy, labour). Mitigating N emissions must also take into account the whole farm, especially where there are livestock, since any benefits in the field are net of earlier losses such as from housing and manure stores. Further, regional nutrient imbalances must also be addressed. For example, with the high cost of returning wastes from regions of high human and animal densities to croplands, there is often a preference for cheaper approaches such as composting, simultaneous nitrification-denitrification (SNdN) reactors and landfills which blow off N into the atmosphere.

Integrated agronomic studies can help to mitigate emissions and improve farm efficiency. In a long term field study we estimated N recovery from mineral fertilizer and liquid dairy manure and were able to infer loss pathways for the contrasting N sources (Bittman et al. 2014). We reduced ammonia emission and enhanced N recovery from dairy slurry with simple solid-liquid separation (by settling) due to enhanced soil infiltration of the thin slurry fraction (Bittman et al. 2011). We observed changes in N_2O emission patterns but generally not overall amounts. Since the solid (sludge) fraction that was removed is rich in P, the separation technique also reduced excessive phosphorous loading. A strategy was developed to precision inject the sludge into corn as a replacement for starter commercial P fertilizer (Bittman et al. 2012). Precision injection increased P uptake and lowered the potential for ammonia emissions but increased the risk of both nitrate leaching and N_2O emissions. Our current studies are directed at reducing this presumptive pollution swapping.

There is an interesting enigma associated with livestock grazing. Grazing greatly reduces ammonia losses because it limits the exposure of NH_x to the atmosphere compared to confinement rearing, and is recognized as a Category I abatement measure by the UNECE (Bittman et al 2014). However, efficient N use is not possible on pasture due to spatial and temporal variability compared to strategic spreading of stored manure. The contradictory information shows that there is still much to understand about managing reactive N.

Future advances in mitigating N losses will be aided by partnerships of researchers, industry specialists and farmers (participatory research). An example is the recent breakthrough technology in Denmark for practical acidification of liquid manure in order to vastly reduce NH_3 (and methane) emissions from manure in buildings, storages and fields (Birkmose and Vestergaard 2013).

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AN EASY-TO-USE NITROGEN USE EFFICIENCY INDICATOR FOR AGRICULTURAL AND FOOD SYSTEMS

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There is a need for communications about resource use efficiency and for measures to increase the use efficiency of nutrients in relation to food production. This holds especially for nitrogen. Nitrogen (N) is essential for life and a main nutrient element. It is needed in relatively large quantities for the production of amino acids (protein), nucleic acids and chlorophyll in plants. However, excess N pollution is a threat to the environment and potentially also to our health.

The ambition of the EU Nitrogen Expert Panel is to contribute to improving efficient nitrogen use in food production. Here, we propose an easy-to-use indicator framework for 'nitrogen use efficiency' (NUE), applicable to agriculture and food production–consumption systems. It is based on the mass balance principle, i.e. using N input and N output data for its calculation: NUE = N output / N input. NUE values have to be interpreted in relation to productivity (N output) and N surplus (i.e., the difference between N input and harvested N output).

For estimating NUE and communicating the results, data and information are required about (i) the total N inputs into a system and the N output in harvested products, (ii) the nature of the system (e.g. farm, crop system, livestock housing system, food processing and distribution system) and its boundaries, (iii) the time span of the analyses, and (iv) possible changes in the stock of N in the system. The NUE indicator is easily presented via a two-dimensional input – output diagram. This allows the presentation of NUE, N output and N surplus in a coherent manner, together with possible reference or target values.

We show that the NUE concept is applicable to N fertilization trials, farms and crop production systems at national level. Changes in NUE over time due to the effects of technical progress, market changes and policy measures can be presented easily in the two-dimensional input – output diagram. The concept allows to examine differences in NUE between farms, between specific systems, between countries, and between years. NUE may serve also as an indicator for 'sustainable intensification' of food production. For proper comparisons, a clear and approved protocol is needed for uniform data and information collection, processing and reporting. Also, the proposed reference values need further underpinning.

Nitrogen use efficiency impacts many of the recently approved Sustainable Development Goals (SDGs) for the post-2015 era, for which concrete targets, pathways and indicators need to be developed at country scale and below. The proposed NUE indicator is suitable for setting realistic targets and monitoring of progress in that context, particularly in relation to SDG 2 (Food and nutrition security), SDG 12 (Sustainable consumption and production), SDG 14 (Marine ecosystems) and SDG 15 (Terrestrial ecosystems).

REDUCING NITROUS OXIDE EMISSIONS WHILE SUPPORTING SUBTROPICAL CEREAL PRODUCTION IN OXISOLS

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By 2050 the world's population is forecast to be over a third larger than at present and cereal demand is predicted to increase by 60%. Pronounced intensification of cereal production is expected to take place in Oxisol-dominated tropical and subtropical regions (Smith *et al.*, 2007), identifying the need for more nitrogen (N) to be supplied to these agroecosystems. It is established however that boosting food production though an increased use of synthetic N fertilisers will result in sharp increases in greenhouse gas emissions, especially N_2O. It is therefore critical to identify alternative N management strategies aimed at supporting future intensification of tropical and subtropical agricultural systems without provoking an increase of N_2O emissions from these agroecosystems.

A unique dataset of high-frequency observations and N recovery data referring to multiple cropping seasons, crop rotations and N fertiliser strategies was gathered in this study using a fully automated greenhouse gas measuring system, ^{15}N-tracer techniques and a process-based biogeochemical model. The aim was to define profitable, agronomically viable and environmentally sustainable N management strategies to support future intensification of cereal production on subtropical Oxisols. This aim was achieved by way of the following three research objectives: i) evaluating the use of urea coated with the DMPP nitrification inhibitor to limit N_2O emissions and increase grain yields compared to conventional urea; ii) evaluating whether the introduction of a legume phase in a cereal-based crop rotation can reduce the reliance of cereal crops on synthetic N fertilisers and minimise N_2O emissions during the cereal cropping phase and iii) use model simulations to test the hypotheses underlining the first two objectives and assess the sustainability of the N management practices investigated under a broader spectrum of environmental conditions.

The results of this study indicate that in subtropical Oxisol-based cereal cropping systems there is significant scope for limiting N_2O losses and improving the fertiliser N use efficiency, especially during the summer cropping season. The warm and humid soil conditions of subtropical summers, associated with the higher N fertiliser rates applied to summer crops, were conducive for greater nitrification and denitrification rates

compared to winter. Among the N management strategies tested, the application of DMPP urea was the most effective in minimising N_2O losses during a summer crop.
The slower nitrification rates of DMPP urea enabled a better match between the NO_3^- released by the fertiliser and plant N uptake, resulting in almost no accumulation of NO_3^- in the topsoil and therefore effectively limiting denitrification. As a result, the use of DMPP urea on average abated N_2O emissions by 65% compared to the same N rate with conventional urea. However, the enhanced synchrony of DMPP urea was limited to the top soil and DMPP did not increase crop productivity compared to conventional urea. The high clay content of the soil prevented fertiliser N losses via deep leaching, while the low soil C and the short-lived periods of soil saturation limited N_2 emissions. Consequently, a good synchrony between fertiliser N supply and plant uptake was achieved with conventional urea and DMPP had limited scope to increase the N use efficiency of the urea-based fertiliser.
The introduction of a legume phase in a cereal-based crop rotation showed multiple environmental and agronomic advantages. Planting the cereal crop shortly after incorporating legume residues ensured the synchrony between the crop N uptake and the mineral N progressively released by the decomposition of the residues. This practice avoided the accumulation of relevant amounts of N in the soil that would have been available to nitrifying and denitrifying microorganisms, and N_2O emissions were primarily a function of the N fertiliser rate applied. As a result, decreasing the synthetic N rates applied to the cereal in the legume crop rotation led on average to a 35% reduction of N_2O losses. Concurrently, the incorporation of legume residues provided enough readily available N to support crop development and grain yields were not affected by the reduction of synthetic N.
Overall, the results of this study reveal that the use of DMPP urea in subtropical Oxisols cannot be regarded as an economically viable standard farming practice to reduce N_2O emissions unless governmental incentive policies are established. Conversely, introducing a legume phase in cereal-based crop rotations can be effective N management practice under the environmental and agronomical perspective. If properly implemented, this strategy enables to significantly reduce N_2O emissions, achieve high yields, reduce the costs associated with N fertilisation and provides greater flexibility to the farmer in terms of timing and rate of fertiliser application.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., 2007. Agriculture. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

ASSESSING THE ENVIRONMENTAL BURDENS AND IMPLICATIONS TO FOOD SECURITY OF LIVESTOCK CONSUMPTION IN THE USA

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Livestock exert enormous regional to global impacts on air and water quality, ocean health, and greenhouse gas (GHG) emissions, and are the largest land user globally. In this work we quantify land, irrigation water, GHGs and reactive nitrogen (Nr) costs due to feed consumption by major animal-based categories (beef, poultry, dairy, eggs and pork), and compare them to costs of plant-based alternatives. The quantitative knowledge for such an undertaking is currently incomplete, hampered by divergent methodologies that afford no general comparison of the relative impacts. We introduce a novel methodology that portraits the environmental burdens associated with current production and consumption of animal-based products. Our results for the U.S reveal resource demands per consumed kcal of eggs, poultry, dairy and pork are similar but strikingly lower than beef's by an order of magnitude. Analysis of three staple plant foods show three- to sixfold lower land, GHG, and Nr requirements than those of the nonbeef animal-derived calories, whereas irrigation are comparable. We also assess current individual feed-to-food energy and protein conversion efficiency of all major animal products and calculate potential food availability gains upon replacing inefficient animal based food with more efficient substitutes.

Symposium Posters

Graduate Students and Post-Docs

IN SITU MODIFICATION OF DESALINATION MEMBRANES FOR IMPROVED PERFORMANCE

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Nanofiltration (NF) and reverse osmosis (RO) membrane processes are widely used today for desalination and water treatment. The most common RO and NF membranes are thin-film composite (TFC) membranes with a polyamide top layer, which appear to have an exceptionally favorable combination of high permeability, good salt rejection, robustness and durability. However, it still has a few drawbacks such as poor selectivity towards small-uncharged solutes and small organic micropollutants, this poor selectivity is believed to result mainly from the non-uniformity and defects on the top active layer, which are structurally looser and more weakly exclude the solutes.

Another important drawback is the polyamide tendency to fouling and biofouling, which leads to an increase in mass transfer resistance and a decrease in water flux, therefore considered a major obstacle to the widespread use of TFC polyamide RO and NF membranes.

Based on promising results obtained previously in our group, (Bernstein *et al.* 2012; Ben-David *et al.* 2010) this study systematically examines improvement of polyamide membranes performance using surface grafting. A facile method for carrying out such modification is concentration polarization-enhanced redox graft polymerization. In this way the polymerization is carried out while filtering the solution of monomers and initiators through the membrane. The selectivity of the grafted layer can be tuned towards model pollutants through the use of optimal monomers along with sealing less selective and more permeable areas “defects” inherently present in the original active layer.

Main focus was on the monomer glycidyl methacrylate (GMA) for improving selectivity of uncharged solutes such as boric acid and representative endocrine-disrupting contaminants (EDCs). The other monomer used was 3-(Methacryloylamino) propyl/ethyl] dimethyl (3-sulfopropyl) ammonium hydroxide (SPP/SPE), a zwitterionic monomer, for improving fouling resistance.

Optimization of monomer and initiator concentrations and degree of grafting was carried out to ensure that salt rejection was not affected and flux only slightly reduced, yet substantial beneficial changes in surface chemistry and overall selectivity were produced. In addition, from dead end experiments it was showed that GMA and SPP combination achieved enhancement in the rejection of EDCs model compounds as well as boric acid (up to 35% improvement), with a moderate loss of flux.

Accelerated fouling tests were conducted to evaluate the performance of modified membranes in cross flow cells. Short term tests containing humic acid as a model of organic foulant resulted in unchanged salt rejection, enhanced boron rejection and fouling resistance of the modified membranes.

To assess the full potential for improving, tuning and/or restoring modified membranes in real feed conditions and for long-term performance stability tests; up-scaling optimal modification procedure to commercial RO modules is currently underway.

Bernstein, R., Belfer, S., & Freger, V., 2012, Improving performance of spiral wound RO elements by in situ concentration polarization-enhanced radical graft polymerization, Journal of Membrane Science, 405-406: 79-84.

Ben-David, A., Bernstein, R., Oren, Y., Belfer, S., Dosoretz, C., & Freger, V., 2010, Facile surface modification of nanofiltration membranes to target the removal of endocrine-disrupting compounds, Journal of Membrane Science, 357(1): 152-159.

RAPID MPN-QPCR SCREENING FOR PATHOGENS IN AIR, SOIL, WATER, AND AGRICULTURAL PRODUCE

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A sensitive, accurate, high-throughput, cost-effective, and rapid alternative for screening multiple viable bacterial pathogens in the environment was developed. A variety of environmental sample types, including aerosols, soil, vegetable surfaces and wastewater were first enriched with a general pre-enrichment broth in a dilution series, Then, enumerated by most probable number (MPN) estimation using quantitative PCR for rapid screening of amplicon presence. Soil and aerosols were extensively tested with experimentally spiked and non-spiked environmental samples, as these sample types are prone to large experimental variation. A battery of spiking experiments (1-1000 cells in serial dilutions) was also performed for vegetable surfaces (modelled by tomato) and wastewater. Limit of detection (determined by concomitant spiking studies with *Salmonella enterica* and/or *Pseudomonas aeruginosa*) in sand, sand/clay mix and clay soil samples was 1–3 colony forming units (CFU) g^{-1}; on vegetable surfaces, 5 CFU per tomato; in treated wastewater, 5 CFU L^{-1}; and in aerosols, >300 CFU m^{-2} or m^{-3} h^{-1}. Our method accurately identified *S. enterica* in non-spiked environmental soil samples within a day, while traditional methods took 4-5 days and required sorting through biochemically and morphologically similar species. Likewise, our method successfully identified *P. aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus,* and *Escherichia coli* in aerosols generated by a domestic water treatment system. The obtained results suggest that the developed method presents a broad approach for the rapid, efficient, and reliable detection of relatively low densities of multiple pathogenic organisms in challenging environmental samples.

AQUACULTURE WASTEWATER FOR CROP PRODUCTION: EVALUATING THE PERFORMANCE OF A MARINE AQUAPONIC SYSTEM PRODUCING TWO SPECIES OF SALTWATER VEGETABLES.

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The desire to develop more sustainable and economically viable land-based aquaculture systems has led to increased research on incorporating plants into recirculating aquaculture systems. Fish are only able to assimilate 25-30% of the nutrients supplied in fish feed; the remaining 70-75% are a potential pollutant if not treated properly (Shpigel et al., 2013). Alternatively, agricultural products can be used as a biofilter to remove the excess nutrients in aquaculture effluents while simultaneously providing a secondary product. Aquaponics, the combination of recirculating aquaculture and hydroponic plant growth has become more prevalent in the last 20 years as a sustainable method to produce fish and vegetables simultaneously. Current aquaponics research has largely focused on freshwater fish and plant species. Less research is available on production of marine fish in aquaponic systems, due to limited land-based production of marine fish species and the selection of appropriate edible plant species that grow in saltwater.

A full-scale marine aquaponic system was constructed during the summer of 2014 at Mote Aquaculture Research Park located in Sarasota, FL. The aquaculture system consisted of: a swirl separator, uplfow media filter, a moving bed bioreactor, 61.4 m^2 of hydroponic growing area, and a sand filter. On September 2014, the system was stocked with red drum (*Sciaenops ocellatus*) and two species of saltwater vegetables, sea purslane (*Sesuvium portulacastrum*) and saltwort (*Batis maritima*). Approximately 7-10 cm long cuttings of the two saltwater plant species were planted in net pots packed with coconut fiber and supported on polystyrene rafts floating in the raceways. Two to three cuttings per pot were added to obtain a total planting density of 47 plants/m^2 and a functional density of 19.5 net pots/m^2. Water quality parameters were measured regularly over a 9 month period. The parameters measured included: total ammonia nitrogen (TAN), nitrite (NO_2^-), nitrate (NO_3^-), total nitrogen (TN), total phosphorus

(TP), chemical oxygen demand (COD), total suspended solids (TSS), and volatile suspended solids (VSS). Dried plant samples were also collected 8 times and analyzed for nitrogen and phosphorus content. A mass balance was completed to determine the quantity of nutrients removed through plant growth.

The marine aquaponic system successfully produced both red drum and saltwater vegetables. As the main focus of the system was to produce red drum, initially nitrate levels increased due to insufficient plant biomass. In order to reduce nitrate levels, the sand drying beds were submerged to provide additional denitrification. Nutrient uptake by plants ranged from 0.06 to 0.87 g $N/m^2/d$ and 0.01 to 0.14 g $P/m^2/d$. It was estimated 0.55 kg/m^2 of plant biomass could be harvested every 28 days. During the study, the sea purslane grew rapidly and showed no signs of nutrient deficiencies. The saltwort did not perform as well and showed signs of nutritional deficiencies (slow growth, chlorosis) particularly during the first three months of operation. Red drum (*Sciaenops ocellatus*) were initially stocked at an average weight of 0.047 kg and grew to a harvestable size of 0.91 kg in approximately 12 months. A mass balance indicated that plants contributed to less than 10% of nitrogen and phosphorus removal and passive denitrification was the dominant nitrogen removal process. Based on the mass balance it was estimated the area of plant production could be increased to 711 m^2 of growing area without experiencing nitrogen limitation. After one year of operation the system has produced and harvested over 366 kg of saltwater vegetables and 500 kg of red drum.

Shpigel M., Ben-Ezra D., Shauli L., Sagi M., Ventura Y., Samocha T. and Lee J.J., 2013 Constructed wetland with Salicornia as a biofilter for mariculture effluents. Aquaculture 412-413: 52-63.

THE INFLUENCE OF SOLUBLE ORGANIC MATTER ON GYPSUM PRECIPITATION – IMPLICATION ON SOIL SALINIZATION

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Gypsum, having quite a low solubility, is not regarded as a salinity agent. However, in a previous study we observed severe salinization in gypsum-containing soils (up to 30% gypsum) from the Hula Valley altered wetland. The salinity severity of these soils, as indicated by the paste extract electrical conductivity (EC), well correlated to the concentrations of Ca^{+2} and SO^{-}_{4} in the paste extracts. Moreover, the paste extracts of the saline soils (EC > 3.5 dS/m) were in equilibrium with gypsum, while those of the other soils were under-saturated with respect to gypsum. In soils controlled by gypsum, EC was closely related to the Ca/SO_4 concentration ratio (r^2 = 0.91), in accordance with a geochemical model that relates EC to Ca/SO_4 in a gypsum equilibrated systems. The Ca/SO_4 ratio was found to increase with decreasing extract water content. Extrapolating this trend to field decreased moisture levels during evapotranspiration suggest increased Ca/SO_4 ratio and increased gypsum-originated EC. Thus, gypsum contribution to soil salinization might be higher than commonly assumed.

The above effect of decreased water content resulted from evapotranspiration on EC, as a consequence of increasing Ca/SO_4 assumes equilibrium with gypsum. However, soil's dissolved organic matter (DOM) possesses kinetic effect on gypsum precipitation that may aggravate gypsum-related soil salinization at time of soil drying. In an agricultural field the soil water content in the root zone is constantly changing. As the soil is wetted, gypsum dissolves. As the soil dries, DOM may hinder gypsum precipitation, leaving the soil solution supersaturated with respect to gypsum, and consequently intensify soil salinization. This mechanism is expected to have a large influence on the osmotic potential of the soil solution in the active rhizosphere while the solution is being concentrated in the field.

This process was examined in pure systems by adding various types of DOM (water-soluble OM from Hula peat, citrate and Ca-saturated citrate) at equal concentrations (100 mg C/L) to gypsum-oversaturated solutions (75 mM), and comparing to a gypsum-saturated solution with no DOM. The influence of DOM on gypsum precipitation was studied during a 1-week period by examining Ca and S concentrations and the solutions' gypsum-saturation states. In addition, the influence of three levels of the peat DOM (0, 10 and 100 mg C/L) on solution composition and precipitate characteristics was examined during a 2-week period.

The addition of peat DOM significantly hindered gypsum precipitation, keeping the solution highly oversaturated with respect to gypsum for a long time. This hindrance was reflected by two- to threefold higher Ca^{+2} and SO^{-}_{4} concentrations and a slower decrease in concentrations compared to solutions with no DOM. Ca-saturated citrate solutions did not differ from the citrate solutions, indicating that the gypsum-hindrance mechanism is related to interactions between the DOM and the gypsum crystals, and not to Ca–DOM complexation. The decrease in soluble C concentrations during the experiment indicated DOM sorption to the precipitated gypsum crystals. DOM sorption decreased the gypsum precipitation rate and changed the morphology of the crystals precipitated in the presence of DOM. The morphology of the gypsum crystals formed in the presence of OM showed hindered growth in the main growth direction (111 plan on c axis) and accelerated growth in a secondary direction (b axis, 010 and 110 plans), leading to the development of wider crystals.

The mechanism of gypsum-precipitation hindrance by the soluble OM resulted in high Ca^{+2} and SO^{-}_{4} concentrations for long periods of time, comparable to irrigation cycles in the field. Thus, gypsum oversaturation due to DOM presence may even exacerbate the contribution of gypsum to soil salinization.

A Global Model Of Smallholder Agriculture Exposure To Climate Change Impacts

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In this research, we are constructing a global model of smallholder agriculture exposure to climate change impacts. Much of the literature in agricultural development and international food security focuses on the impacts of climate changes on smallholders and ways in which they can adapt to climate change, however the premise underlying this body of work has not been systematically tested or quantified. Given rapid demographic shifts and urbanization in many developing counties, it remains unclear how many smallholders will experience significant climate change impacts, and to which extent small farmers will be involved in food production when climate change's major effects on temperature and precipitation come into effect. We are working on a quantitative analysis of these exposure measures that should significantly contribute the recent debate spurred by an influential paper that argues a focus on smallholders by the development community is misguided (Collier and Dercon, 2014).

By combining spatially disaggregated climate change projections with country level demographic and urbanization projections, extrapolations of yield growth and crop models we are constructing estimates of future smallholder exposure to climate change under a range of different socio-economic scenarios. The model and scenarios are calibrated through empirical analysis of several cross-sectional and longitudinal household level data sets that attempt to estimate the sensitivity of farms of different sizes to weather fluctuations.

Collier, P., & Dercon, S. ,2014, African Agriculture in 50Years: Smallholders in a Rapidly Changing World?. World Development, 63, 92-101.

DETERIORATION OF PEA (*PISUM SATIVUM* L) RHIZOSPHERIC SOIL HEALTH UNDER ELEVATED ULTRAVIOLET-B IRRADIATION IN THE INDO-GANGETIC PLAINS OF INDIA

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Sun is the primary source of energy for all surface phenomena and life on Earth. Ultraviolet-B (UV-B, 315-280 nm) radiation is a natural constituent of solar light coming to Earth's surface due to thinning of stratospheric ozone (O_3) layer. Many studies performed previously have shown harmful effects of UV-B on various morphological, biochemical and physiological responses of plants. After the successful implementation of Montreal protocol this problem is now resolved up to some extent, as O_3 concentration is not showing a decreasing trend in the stratosphere. However, under recent climate changing scenarios, presence of water vapors in the stratosphere can be dangerous for O_3 layer as suggested by recent reports (Anderson et al., 2012). Beside this, four new ozone depleting substances (previously not included under Montreal protocol) i.e. CFC-112a (CF_2ClCCl_3), CFC-112 ($CFCl_2CFCl_2$), CFC-113a (CF_3CCl_3) and HCFC-133a (CF_3CH_2Cl) have been detected in the atmosphere (Laube et al., 2014). This may led to more penetration of UV-B causing adverse effects on growth, physiology and yield of many agricultural crops in future also.

UV-B radiation is unable to penetrate into the soil so it is apparent that its effect are not direct on symbiotic process, however changes that occur in host plants due to UV-B, is responsible for changes in symbiotic associations. Therefore, experiment was designed with two UV-B radiation levels, i.e., ambient (A) and elevated (E; A+7.2 kJ m^{-2} day^{-1}) and using two pea cultivars (HUP-2 and HUDP-15) to investigate the effects of elevated UV-B radiation on microbial biomass C, N and various soil enzyme activities in rhizosphere under natural field conditions. Plants were exposed to supplemental UV-B for 3 hour daily over the middle of photoperiod. Under elevated UV-B exposure, both the cultivars developed cupping of leaves and development of light purple patches, which later turned in to chlorotic and necrotic patches. Maximum leaf injury noticed was 21 and 13 % for HUP-2 and HUDP-15 under elevated UV-B. Compared to ambient, elevated UV-B radiation negatively affected total biomass by 29 and 19 % in cv. HUP-2 and HUDP-15. Flavonoid content was increased significantly by 32 and 36.5% and phenol content by 18 and 25 % in the roots of cv. HUP-2 and HUDP-15, respectively. In the present study, significant reductions in number of root nodules were also observed in both the cultivars. Under elevated UV-B, microbial biomass C, N and various soil enzyme activities of rhizospheric zone were negatively affected. Contrary to this, increase in microbial biomass C, N and soil enzyme activities have been noticed in nonrhizospheric zone. The above findings are well correlated with the changes in composition and amount of root exudates induced due to supplemental UV-B radiation, which are affecting the dynamics of soil microbial biomass. Elevated UV-B exposure affected overall plant growth negatively including nodulation. In the rhizosphere, exposure of elevated UV-B reduced the microbial biomass and activities of most of the soil enzymes associated with nutrient release and decomposition of common complex molecules which led to shifting of microbial population towards non-rhizosphere. Activities of key soil enzymes indicated that under elevated UV-B, non-rhizospheric soil became healthier than the rhizospheric soil.

Thus, UV-B is a serious concern, as it is not only harmful for above ground vegetation but also responsible for the damage to below ground microbial world, leading to deterioration of rhizospheric soil health. Ultimately, this will create more stress to the agriculturally important fields and crops, resulting in severe yield losses at present and also in future.

Anderson JA, Wilmouth DM, Smith JB, Sayres DS (2012) Increased risk of ozone loss from convectively injected water vapor. Science 337:835-839. doi:10.1126/science.1222978.

Laube JC, Newland MJ, Hogan C, Brenninkmeijer CAM, Fraser PJ, Martinerie P, Oram DE, Reeves CE, Rockmann T, Schwander J, Witrant E, Sturges WT (2014) Newly detected ozone-depleting substances in the atmosphere. Nat Geosci 7:266-269. doi:10.1038/ngeo2109.

SIMULATIONS LOW NITROGEN AND HIGH IRRADIANCE IMPAIR PLANT PERFORMANCE

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Stress combination cannot be directly extrapolated from the response of plants to single stress applied individually (Mittler, 2006). Light is the prime driving force for photosynthesis, and the relation between plant photosynthesis and light is complex. By its nature, the photosynthetic process occurs in the chloroplast, a green organelle located in plants leaves. Light absorbed by chlorophyll molecules in the photosynthetic antenna, which orbits the photosynthetic reaction centers, is vital for photosynthesis. However, excessive absorbed light energy urges the creation of reactive oxygen species (ROS) that may harm the photosynthetic machinery.

Nitrogen (N) availability is a limiting factor for plant growth in both natural and agricultural soil, and low soil nitrogen is common throughout the world. Nitrate is the main oxidized nitrogen form plant utilize. Under circumstances where CO_2 supply is limited nitrate can serve as alternative electron acceptor in the chloroplastic liner electron chain. Studies conducted in Arabidopsis plants response to low nitrogen stress were mostly preformed at far below light saturation conditions (100 to 200 µmol photons m^{-2} s^{-1}), so in fact, those conditions scarcely stimulate photoinhibation faced by nitrogen deficient plants under field conditions. This may lead to incorrect evaluation of plant photo-damage under any abiotic stress (Mittler and Blumwald, 2010). Our results suggest a unique interaction between the stress combination high light and nitrogen deficient in Arabidopsis plants. Growth, photosynthetic potential and leaf pigment content alter significantly under light with decreasing nitrogen availability.

The objective of this study is to provide clearer image of nitrogen deficit plant performance under varied light intensities.

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Mittler R, Blumwald E (2010) Genetic engineering for modern agriculture: challenges and perspectives. Annu Rev Plant Biol 61: 443–62.

N_2O EMISSIONS UNDER PROPOSED IRRIGATION AND FERTIGATION BEST MANAGEMENT PRACTICES FOR ALMOND

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Nitrous oxide (N_2O) is a potent greenhouse gas (GHG) that has approximately 300 times the radiative forcing potential of carbon dioxide (CO_2) and accounts for up to 70% of GHG emissions for agricultural related activities. Nitrogen (N) fertilizer is the primary source of N_2O production from agriculture, approximately 0.9% of all applied N is lost as N_2O (Bouwman et al., 2002). In California there are approximately 0.5 million ha of nut crops which are, mainly, almonds, pistachios and walnuts. Almonds specifically, and the other nut crops, are considered to be N intensive with up to 426 kg ha^{-1} of N applied annually. Therefore, nut orchards represent a major potential contributor of GHG emissions. More the 90% of California almond orchards are irrigated and fertilized (fertigation) using micro-irrigation systems which consist of either above ground drip or micro-sprinkler emitters.

Surface N_2O emissions are affected mainly by water content, carbon availability, mineral N availability (NH_4^+ and NO_3^-), and microbial activity which in turn are controlled by the spatial distribution of water and fertilizer N in the soil. Due to the dissimilar nature of water application from different emitters we should expect differing N_2O emission patterns (Alsina et al., 2013). The disparate patterns are likely to influence the process of upscaling emission measurements from the flux chamber scale, which is usually cm^2, to the orchard scale which is m^2 or ha. Typically, the upscaling process is performed using a weighted mean average for a certain orchard area (planted row, berm, driveway) where the measurement is assumed to represent the selected landscape scale (orchard) area. The size and shape of the represented area might be affected by variability in emissions patterns.

Best management practices (BMPs) for California almond orchards involve splitting the annual amount of N (N-rate) into 3-4 applications to optimize N uptake by the trees. A potential N_2O mitigation strategy could include the use of smaller and more frequent N applications (Venterea et al., 2012) which can be facilitated by the practice of high frequency fertigation.

We conducted field experiments to investigate both the effect of irrigation method and fertigation management on N_2O emissions from almond orchards using the above proposed BMPs. The experiments consisted of a detailed measuring scheme around drip and micro-sprinkler emitters to determine soil surface emission patterns and thus better evaluate cumulative N_2O emissions at the orchard scale. Three proposed BMPs for fertigation management strategies (Advanced grower practice, pump & fertigate, which consists of AGP while subtracting well water N from the N rate and a High frequency low [N]) were evaluated during a whole season.

Results showed that N_2O fluxes were higher from the wetted area of drip emitters than around micro sprinklers due to higher NH_4^+ concentrations. Emissions were highest close to the drip emitter and decreased with distance from it while highest emissions were measured at a distance of 150 cm from the micro-sprinkler. This resulted in a simple upscaling function for N_2O emissions around drip emitters, which require a single measurement of N_2O flux. Weighted average scheme was adopted around micro sprinkler but it requires more measurements to estimate emissions accurately. Reducing N rate decreased N_2O emissions linearly without lessening almond yield. Applying the same N rate in more frequent fertigation events reduced N_2O emissions even further by almost 50% also without affecting almond yields. This reduction was attributed to the decrease in soil NH_4^+ concentration.

Our results strongly indicate that mitigation of N_2O emissions from almond orchards might be achieved by moving to higher frequency of fertigation without reducing seasonal N rate to avoid yield loss and by irrigating with micro sprinklers. Although, other setups for drip irrigation can be explored in order to reduce N_2O emissions such as subsurface drip.

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LIMITING OF NITRITE OXIDATION IN FIXED BED NITRIFICATION REACTOR IN TWO STAGES ANAMMOX PROCESS.

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The anaerobic ammonium oxidation (ANAMMOX), an autotrophic denitrification process, is widely accepted as a promising process for nitrogen removal from wastewater with high ammonium concentration and low C/N ratio. The ANAMMOX process is more cost effective than the conventional nitrification–denitrification system due to lower sludge production and no requirement for aeration (Mumtazah et al. 2014).

During the ANAMMOX process planctomycete-like bacteria combines ammonium and nitrite to produce nitrogen gas under the anoxic condition (Pathak et al., 2007). The noticeable advantage of ANAMMOX is that it allows over 50% of oxygen to be saved with no organic carbon source needed. In wastewater treatment ANAMMOX need to be combined with a precedent partial nitritation stage by ammonia oxidizing bacteria (AOB), namely the oxidation of NH_4^+ to NO_2^- (around one-half of NH_4^+ is oxidized to NO_2^- the other half is not) (Zhiwei at el. 2011). There are several strategies to enable the occurrence of the first step of the aerobic nitrification, while inhibiting (minimizing) the activity of the nitrite oxidizing bacteria (NOB), such as temperature control, pH control, oxygen concentration, short HRT.

The online control of ammonium oxidation based on DO, ammonium or conductivity sensors was reported as a useful method to achieve sustained partial nitritation. It has been shown that terminating aeration prior to the completion of NH_4^+ oxidation (i.e., NH_4^+ remaining in the effluent) is a key factor leading to sustained nitritation (Fux et al., 2002; Peng et al., 2004).

However, there are few reports on nitritation process control in a biofilm system that has been widely accepted as a wastewater treatment process for its higher biomass, smaller reactor volume, and less sludge production (Jang et al., 2005). Biofilm is also beneficial to slowly growing microorganisms, such as AOB species. Thus, it is necessary to develop a strategy for the maintenance of partial nitritation in a biofilm system. The key to achieve partial nitritation relies on the knowledge of the abundance of AOB over NOB and how AOB respond to different operational conditions.

This study have explored the stability of partial nitritation in a continuous fixed bed-up flow biofilm reactor with recycle and external aeration. The reactor has been operated for at least 100 days with limiting DO concentrations which were controlled by recirculation rate. The reactor was fed with synthetic medium consisting on tap water supplemented with ammonium chloride (50 mg/L as N) and sodium bicarbonate to save alkalinity and low concentration of phosphate (Dawas-Massalha et al., 2014).

A successful control of nitritation was achieved in which 50% of ammonia was not oxidized the other 50% of the ammonia was oxidized and accumulated as nitrite (~45%) with very low nitrate accumulation (~5%) in the effluent. In addition, the biofilm microstructure evolution and the dynamic changes of AOB and NOB associated with the operating conditions were examined using PCR and DGGE technology. In parallel an ANAMMOX reactor to be fed by the nitritation effluent was established, and the efficiency of the ANAMMOX process was investigated too.

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MODELLING OF MILLIMETRE-WAVE RADIATION INTERACTION WITH HIGH-SPATIAL-RESOLUTION LAYERED SOIL SUBSTANCES

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Structural changes in the top soil layer strongly affect its water permeability. This has agricultural, ecological and engineering-related implications. Many of the underlying processes are still not fully understood or detected. Millimetre waves have been experimentally found optimal for the purpose of remotely sensing the processes involved. Modelling of the interaction of electromagnetic radiation with soil substances has been widely covered in the literature. This presentation suggests a methodology for modelling specifically the interaction of millimetre-wave radiation with high-spatial-resolution layered soil substances with varying levels of moisture contents. Applying the proposed model should lead to better understanding of the processes and serve as a reference for their measurement.

Soil-water interaction is governed by processes occurring in the soil surface. Such processes include the formation of a structural crust in the top soil, resulting in decreased water permeability (Shainberg & Shalhevet, 1984; Goldshleger et al., 2002; Ben-Dor et al., 2004). This leads in turn to increased runoff, flooding and erosion and decreases of water availability to soil and roots. A crust layer is a result of structural changes of the soil surface and has typical thicknesses in the range of 0.1-2 mm. In order to sense the variations in the crust layer and underlying layers, a range resolution of the same order of magnitude as that of the layer thickness is required. This, together with a sufficient penetration depth, is obtained by the use of the millimetre-wave spectral range. Millimetre-wave reflectometry has been successfully used for the evaluation of soil moisture content under varied irrigation regimes and surface conditions by remote sensing. Empirical models were constructed based on the experimental results (Eliran *et al.*, 2012, 2013, 2014). A particularly advantageous frequency is 94 GHz. Atmospheric attenuation in this spectral window is 0.4 dB/km, much lower than in the rest of the millimetre-wave range.

The current study is aimed at constructing a theoretical model explaining the experimental results of millimetre-wave reflectometry measurements of soils under varied irrigation regimes. The model will enable the simulation and prediction of similar experiments. Models, rigorous and approximated, for the scattering of electromagnetic radiation by soil substances, both dry and moist, are found in the literature (Elfouhaily and Gu´erin, 2004). Still, no single model fully describes the interaction of millmetre waves with soil substances and soil water under the complete range of typical conditions including both surface and volume scattering and including structural crust layers and the micro-profiling of soil moisture content. We present a methodology of combining several models from the literature to fully describe, simulate and predict the relevant phenomena, namely the structural changes involved in crusting processes as well as a micro-profile of the soil moisture under various surface conditions and irrigation regimes.

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REAL-TIME MONITORING OF N-SPECIES ISOTOPES BY FOURIER TRANSFORM INFRARED (FTIR) SPECTROSCOPY – A NOVEL TOOL TO INVESTIGATE SHORT-TERM ISOTOPE DYNAMICS AND N_2O FORMATION IN SOIL

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Transformations and flows of N-species from agricultural systems may adversely affect the environment via gaseous emissions of N_2O, which enhance the greenhouse effect and indirectly damage the ozone layer or nitrate leaching to water resources [1]. Soil microbial processes, commonly occurring simultaneously, are considered responsible for up to 70% of N_2O emissions into the atmosphere. A better understanding and quantification of the pathways leading to N_2O formation is essential to the development of mitigation approaches. To this date, this knowledge is not yet sufficient. Effective tracing of N-transformations is possible using stable isotopes of N and O. The problem with this approach is that the appearance of a particular species may depend on several parallel processes, which may bias the decipherment [2]. Commonly used tool for investigating the processes and quantifying the contributions of the different sources of N emissions is the IRMS (Isotope Ratio Mass Spectrometry). The method allows determination of the isotope ratios in reactants and product species, but cannot be used online. In addition, it requires time-consuming preparation steps, which may also increase the risk of isotope exchange within samples before analysis [3, 4].

The present research focuses on the alternative measurement of isotopic N-species, using FTIR spectroscopy, which allows direct or almost on line measurements of changes in the isotopic composition of species. Practically, it is a non-destructive technique that requires minimal samples preparation and allows measurement of concentrations of products and intermediate. Spectra in mid-IR range, combined with advanced methods for signal processing, can be used to quantify isotopic composition, because the isotopic enrichment induces small shifts in energy absorption bands [3]. The uniqueness of the work is the use of an innovative system for investigating the N-dynamics via Long Path Attenuated Reflectance FTIR (LP-ATR-FTIR). The system is based on two types of measuring cells, connected together allowing tracking simultaneous changes in N-species, both of mineral N in solution/soil phase (ATR crystal measuring directly changes in moist soil) and changes in gaseous phase isotopologues and/or isotopomers via the Long Path (LP) component. Real-time tracking using isotopic enrichment methods, offers a more precise approach for tracing changes in concomitantly occurring reactions (e.g. nitrification, de-nitrification, mineralization). These in turn allow investigation and quantification of N-transformations mechanisms and pathways that affect gas phase composition and formation of N_2O isotopologues/isotopomers and mineral N-species in the soil and its solution phase [4, 5].

The study examines impacts of the environmental conditions and farming management impacts, such as the thickness of the soil layer, aeration conditions, moisture content and fertilization or manuring, on N-transformations and formation rates. We focus on identifying and quantifying N_2O emissions and their sources (nitrification, de-nitrification and possibly nitrifier de-nitrification) and at the same time determine gross rates of mineralization and nitrification. Efforts also made to determine the composition and function of microbial populations that affect the main changes under different conditions. All these are expected to provide deeper understanding and quantification of pathways contributing formation of the undesired species and allow improved mitigation management approaches.

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SUPERFUND CYCLING: THE FATE OF HEXAVALENT CHROMIUM IN THE SUBSURFACE ENVIRONMENT

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In order to understand the long-term bioavailability of inorganic pollutants such as chromium(Cr) it is essential to quantify their cycling, stability, and sorption state. In the environment nontoxic Cr(III) is the preferred species, however, manganese(IV) oxides and industrial activity can transform nontoxic Cr(III) into carcinogenic Cr(VI). Mn oxides can also help immobilize chromium as surface precipitates, resulting in surface passivation of the manganese oxides and a reduction in redox capacity. This process has profound implications to reduce the formation of chromate, sequester free chromium, and minimize the risk of environmental contamination. Despite the significance of Cr in the environment, the current understanding of these reactions is very limited. Our research seeks to address these deficiencies by elucidating the mechanisms of chromium oxidation and release on manganese surfaces. We utilized synchrotron-based X-ray absorption fine structure spectroscopy (XAFS) to differentiate chromium phases in-situ which are essential to understanding their long term environmental stability. Additional studies focused on Cr(VI) desorption from contaminated soils from an active EPA Superfund Site to validate our findings.

LONG TERM PHOTOSYNTHETIC RESPONSE TO ELEVATED CO_2 UNDER DIFFERENT N FERTIGATION REGIMES

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Increased atmospheric CO_2 affects photosynthesis in C3 plants. In the short term, increased CO_2 causes increased levels of photosynthesis. Over time, however, the level of photosynthesis decreases in a process called CO_2 acclimation. CO2 acclimation is characterized by a decrease in photosynthesis increase in leaf starch concentrations, a decrease in leaf N concentration, and a decrease in Rubisco expression and concentration. Two major hypotheses to explain this phenomenon have been discussed in the literature. 1) CO_2 assimilation competes with NO_3 assimilation in the leaves, meaning that increased CO_2 availability decreases the rate of NO_3 assimilation causing N deficiency and a decrease in the rate of photosynthesis over time (Bloom et al. 2002). 2) Elevated CO_2 alters the sink/source relationship in the plant, causing a buildup in photosynthates and triggering a feedback mechanism that decreases the rate of photosynthesis over time (Ainsworth et al. 2004).

According to either hypothesis, increased N availability may affect the degree of CO_2 acclimation. In order to study the effects of N availability on CO_2 acclimation, tomato plants were grown in greenhouse chambers (2x2x3 m) in 3 different levels of CO_2 and 5 different levels of N. Physiological indicators of CO_2 acclimation, including gas exchange, leaf starch concentration, leaf N concentration, Rubisco expression and relative growth rate were measured. This experiment was repeated 5 times over the course of 2 years. Over the course of these experiments, we have shown that CO_2 acclimation does in fact take place, and that the physiological indicators of CO_2 acclimation are in fact most of the physiological indicators, CO_2 and N caused opposite reactions. Increases in CO_2 in the growth conditions lead to increases in leaf starch, and decreases in leaf N concentration, Rubisco expression, and photosynthesis (when measured at a standard CO_2 concentration). Increased N has the opposite effect on these indicators. However, despite the antagonistic effects of CO_2 and N on CO_2 acclimation indicators, in most of the measurements there was no significant interaction effect.

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MAPPING SOIL ORGANIC MATTER BY KRIGING COMBINED WITH CLUSTERING OF SELF-ORGANIZING MAP

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Using spatial correlations between soil organic matter (SOM) and its primary influencing factors improves the mapping accuracy of SOM content, which is essential for ensuring sustainable soil utilization and gaining a better understanding of precision agriculture. Because of the complex nonlinear relationships between SOM and its primary influencing factors (topography, soil type, soil texture, and land use), it is difficult to analyze or visualize the results by linear statistical methods. Moreover, not all studies have systematically and comprehensively applied the complicated relationships to improve the accuracy of SOM mapping.

The objectives of the present study are to examine whether kriging combined with clustering of self-organizing map (KCSOM) can improve the mapping accuracy of SOM. Before mapping SOM content based on the influencing factors, ANOVA was used to prove the effects of different factors on the tested SOM content. Considering topography, soil type, soil texture, and land use as the primary factors affecting spatial distribution of SOM, the delineation of Pinggu District (suburban Beijing) was clustered into seven groups based on a self-organizing map. The spatial variation of SOM was categorized into two types: between-cluster (i.e., cluster effect) and within-cluster (i.e., residual). Further, the spatial distribution of SOM was obtained by integrating the variation components of soil cluster effect and residual. Then, KCSOM was proposed by considering the variation components of topography, soil texture, soil type, and land use. To verify the validity of the model, it was compared with four other interpolators: ordinary kriging (OK), kriging combined with soil texture (KST), kriging combined with soil type map delineation (KSMD), and kriging combined with land use (KLU). The results showed that spatial distributions of SOM using KCSOM eliminated the smoothing effect of OK and provided greater details. The mean error (ME), root mean squared error (RMSE), and relative improvement (RI) of KCSOM were 0.004, 2.01, and 30.92%, respectively. The decrease in the estimation imprecision (DIP) of KCSOM

relative to OK was 77.04%. The accuracy of mapping SOM with KCSOM was greater than that with the other methods (OK, KSMD, KST, and KLU), as indicated by ME, RMSE, RI, and DIP values.

The reasons why KCSOM shows better performance than the other methods (such as KSMD, KST, KLU, and OK) can be summarized as follows. First, compared with OK, KCSOM eliminates the smoothing effect and can effectively avoided underestimation of the higher values of the interpolation surface and overestimation of the lower values. The KCSOM taking into consideration clusters, reflects good performance when there are abrupt boundaries of clusters. Second, KSMD, KST, and KLU taking into account an influencing factor (such as soil type, soil texture or land use) as auxiliary information for mapping SOM content were greater improvement than that of the OK. This is consistent with previous studies that the influencing factors can improve accuracy of the mapping SOM content (Shi et al. 2011; Liu et al. 2006). Finally, self-organizing map has the ability to learn complex relationships between SOM and its influencing factors. Thus, the influencing factors (slope, elevation, land use type, soil type, and soil texture) can be combined for mapping SOM content. When the influencing factors were used as input, and clusters were used as output for self-organizing map, KCSOM showed significant improvement for mapping SOM content. The method (KSMD, KST, or KLU) considering an influencing factor as auxiliary information, may not systematically and comprehensively analyze the relationships between the influencing factors and SOM content to be mapped, and hence shows poor performance for the SOM content mapping compared with KCSOM. It was concluded that KCSOM can serve as an effective method for mapping SOM content with high accuracy.

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REMOTE SENSING OF PESTICIDE DRIFT: A TOOL FOR ESTIMATING AND REDUCING AIR POLLUTION IN AGRICULTURE

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The use of pesticides is important to ensure food security around the world. Unfortunately, acute and chronic exposures to pesticides may result in adverse effects on human health. Exposure to pesticide can be by oral consumption of produce tainted by pesticides as well as by contact with contaminated surface, or inhalation of airborne pesticide drift from field.

Measurement of pesticide drift in real time is very challenging. The active ingredient is diluted with water up to a concentration of ~0.1%v. The sprayed solution is exposed to constantly changing meteorological conditions which alter pesticide's properties, e.g. size distribution of spray droplets. Additionally, the active ingredient can evaporate and be present simultaneously in condense and gas phases. These facts, together with the large variety of pesticides commonly used, make it extremely difficult to monitor pesticide drift in real time in the field

This study examines detection, quantification, and identification of pesticide spray drift using ground based remote sensing. The spectral measurements were done using Open Path Fourier Transfer Infra-Red (OP-FTIR) spectroscopy. Many materials have a distinctive spectral signature in the OP-FTIR measuring range (500-5000cm^{-1}) which makes this technique ideal for detecting and identifying pesticides drift.

The experiments were conducted in a research farm (Matityahu research station) with several types of orchards and sprayers. The experiments were divided into two main setups: (1) Measurements at a height of 1.5 meters "on the fence" of an orchard to establish the ability of the OP-FTIR to identify the active ingredient in the drift cloud, (2) Measurements at different heights in order to create a vertical profile of the drift. Water sensitive papers were placed along the line of sight of the device to measure the droplets size distribution, which was required in order to estimate the water load.

During the experiments of the first experimental setup the OP-FTIR was able to detect Impulse (fungicide) and Bogiron (fungicide) during spraying operation in fallow field, young and mature apple orchards. Additionally, the water load in each spraying event was quantified to allow an estimation of the drift magnitude.

During the experiments of the second experimental setup, the OP-FTIR was able to detect spray drift generated by three different sprayers. The spray drift was quantified in various heights (3, 4, 5, and 6m) and this profile provided insight about the pattern generated by each sprayer. These measurements were also useful to compare the environmental footprint of the three sprayers in the specific meteorological conditions which were prevailed at the site on that day.

This work demonstrates the potential of the OP-FTIR for detecting and quantifying clouds of pesticides in real time. Moreover, the OP-FTIR has proven to be a useful tool for assessing pesticide exposure and spraying efficiency.

PERIPHYTON- BASED BIOFILTER: A NOVELE IN SUSTAINABLE LAND-BASED MARICULTURE.

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While seafood supplies from wild fisheries worldwide are steadily declining, it is estimated aquaculture production to increase by 50 million tones by the year 2050 to meet future demands (Tacon and Forster, 2001).

Effluent treatment and high-protein feed incur much of land-based aquaculture operation costs, and influence systems sustainability. Conventional technologies applied to remove toxic nitrogen compounds are generally costly, and lead to incomplete utilization of natural resources (Midilli et al. 2012). The use of fishmeal and fish oil as prime constituents in commercial feed implying negative protein balance, hence, other sustainable and economic alternatives are required.

Periphyton is a widespread plant-based ecosystem that is promising as both biofilter and fish feed. Yet, applicability in mariculture has scarcely been considered. Periphyton community consist of autotrophic and heterotrophic aquatic organisms that develops as a natural film on different wet surfaces when exposed to elevated levels of nutrient supply and light (Axler & Reuter 1996; Azim et al. 2005). The use of periphyton in tilapia pond-culture suggested reducing the consumption of commercial aqua-feed by nearly 50%, while maintaining both fish growth and water quality (Milstein et al. 2008).

The current study has examined the performances of a novel, marine, periphyton- based biofilter fed with effluents from semi intensive mullet production, towards application in mariculture. Growth rate, yield and nutrients uptake efficiency of the periphyton were examined in several setups during two seasons. Metagenomics analyses, microscopy and chlorophyll profiling assessed community composition and dynamics during studies.

The periphyton grew at rates of 2.7 and 5.6 g (dry weight) m^{-2} d^{-1} at autumn and spring, respectively. Multi-comparison analyses showed a correlation between the growth of periphyton biomass and the uptake of nutrients (total ammonia nitrogen-TAN and phosphorus). TAN uptake rate by the periphyton ranged between 0.013 and 0.44 g m^{-2} h^{-1}. Doubling the substrate area for Periphyton in the biofilter significantly increased both the production of biomass the efficiency of TAN uptake by the biofilter. The periphyton's community consisted of diatoms, cyanobacteria, heterotrophic bacteria, protozoa, nematodes and macroalgae. Microalgae, mostly cyanobacteria in the summer and diatoms in the autumn, dominated young periphyton.

Silicate enrichment of the effluent at a 1:5 ratio (w:w, Si:TAN) postponed the appearance of macroalgae by 14 days while higher levels of silicate enrichment reduced macroalgae' s chlorophyll b fraction to below 5% of total chlorophyll for at least 35 days. Silicate enrichment also increased both dominance and diversity of diatoms in the periphyton. While protein levels in the produced biomass ranged between 30-45% in dw, silicate enrichment increased lipids and ash content in the produced biomass while reducing levels of carbohydrates.

Results from current study support the potential of marine periphyton as relatively cheap, efficient and sustainable biofilter for nitrogen removal from mariculture effluent.

The use of marine periphyton as natural nutritious food for marine fingerlings and the co-production of fish and periphyton in land- based system will be examined in future research.

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EFFECT OF FERTILIZER pH ON THE FUNCTIONAL DIVERSITY OF MICROBIAL COMMUNITIES IN INOCULATED FOC SOIL

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Banana *Fusarium* wilt, also called Banana Panama disease, a typical soil-borne pathogenic fungus of the vascular tissue disease of Banana caused by FOC (*Fusarium oxysporum f. sp. Cubense*; Wang, 1989). It is a kind of strong pathogenicity, long living period and destructive disease that is the most difficult to be controlled in Banana plots when pH is below 6.0, fertility is low and the content of sand is high (Hong et al.2006). In many China farmlands, large amounts of acid fertilizers or physiological acid fertilizers are applied in Banana plots (e.g., ammonium based fertilizer, potassium sulfate, potassium chloride, and the like). This practice results in soil acidification (Stevens et al.2009). And even worse, the growth of actinomycetes and bacteria was inhibited, while FOC proliferated rapidly in acidified soil; thus causing the loss of diversity and changes of family structures of indigenous soil microbes (Wanget al. 2011). The incidence of the soil spread diseases would be reduced by a variety of microbes (Cai et al. 2003). It was reported that soil acidification is one of the main reasons of rapid spreading of Banana *Fusarium* wilt throughout national Banana orchards (Fan and Li, 2014). The occurrence of Banana Panama disease and conventional (acidifying) fertilizers application finally led to reduced microbial activity and soil microbial diversity destruction. Some of the microbial communities accumulated and some other were reduced due to conventional fertilizers application, aggravating the development of Banana *Fusarium* wilt at early stage (Zhang et al. 2007). The BIOLOG technique can be used to investigate the metabolic functional diversity of soil microbes and for analysis of utilization ratio of carbon sources by soil microbes (BIOLOG EcoPlate, Mafham et al. 2002; Garland and Mills, 1991). In this research, BIOLOG EcoPlate was used to study the effect of fertilizer pH on the functional diversity of microbial community in FOC inoculated soil, providing theoretical basis for the application of alkaline fertilizer.

The results of this research showed that the activity and diversity of soil microbial communities in the acid soil were reduced when the soil was inoculated by FOC. These, were also improved significantly by applying the alkaline fertilizers compared with the conventional ones (non-alkaline). The regulation of soil pH is one of the best methods to improve the activity and increase the number and diversity of soil microbial community (Wang et al. 2011). This is also an important measure to reduce incidence of the Banana *Fusarium* (Groenewald, 2006). Accordingly, we propose to avoid using large amounts of non-alkaline fertilizer for long periods. Alternatively, alkaline fertilizers can be used as a new source which has a potential to regulate soil pH and improve the activity and diversity of soil microbes, and it might be the optimal measure to prevent or control the FOC during Banana growth.

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FATE OF PATHOGENS IN WASTEWATER IRRIGATED SOIL

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Using treated wastewater (TWW) for irrigation could alleviate freshwater scarcity and provide food security in arid environments. However, TWW irrigation could present a considerable health risk especially when used for vegetables that are eaten raw. The overall goal of this project was to challenge the restrictions imposed on the use of secondary TWW for irrigation of vegetables. We predicted that TWW irrigated soil could be a vehicle to fecal indicators and pathogens on route to the crops. To test our prediction we set a field experiment where cucumber (*Cucumissativus*) was irrigated with secondary TWW. We compared pathogen and indicator levels in five replicate plots irrigated by surface or sub-surface drip irrigation and tested the effect of plastic cover in combination with the different irrigation practices. Human pathogens including obligate and opportunistic bacteria (*Salmonella enterica*, *Shigella spp.*, *Escherichia coli* O157/H7, *Pseudomonas aeruginosa* and *Staphylococcus aureus*) and indicators (*E. coli*, fecal coliforms and *Enterococci*) were monitored throughout the field trail using a combination of cultivation-based and molecular techniques. In addition, we attempted to track the source of fecal contamination in the crops by using Bacteriodetes spp. Our results indicate that bacterial contamination on and in the cucumber (corresponding to surface and tissue) are not linked to the irrigation regime. In fact, no differences were detected between cucumbers irrigated with fresh water or TWW; even though the cucumber surface was contaminated with fecal coliforms the source of the contamination could not be tracked to humans. Moreover, we have rarely found pathogens in the irrigated soil regardless of the treatment used, and could not detect an advantage to the use of plastic ground cover. The results indicate that surface or subsurface drip irrigation with secondary TWW did not enrich the soil or crop with human pathogens or indicators. We suggest that testing for pathogens and indicators in soil, in addition to the water and crop, should be considered mandatory as contamination might be independent of the irrigation water source.

HOW DO GROSS AND NET NITROGEN MINERALIZATION RELATE TO SOIL ORGANIC MATTER QUANTITY AND QUALITY?

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Nitrogen mineralization is a critical source of N for crop nutrition as well as N pollution. As N mineralization is the result of the breakdown of organic N by soil heterotrophic bacteria, the quantity and quality of soil organic matter influence rates of both gross N mineralization and net N mineralization. The relationships between soil organic matter properties and net N mineralization has been widely investigated due to the potential utility of net N mineralization predictions for crop N fertilization recommendations (Schomberg et al. 2009, Ros et al. 2011). In contrast, relatively few investigations of the relationships between gross N mineralization and soil organic matter properties have been performed, likely due to the difficulty and expense of measuring gross N mineralization. However, as a fundamental N cycling process, additional information about gross N mineralization will improve understanding of overall N cycling and may suggest opportunities to improve agricultural N management. Additionally, fluorescence properties of extracted soil organic matter that are now easily obtained by fluorescence spectroscopy may be related to net and gross N mineralization rates and could provide an easy to measure predictor of N mineralization. Identification and verification of easily measureable predictors of gross N mineralization and net N mineralization could enable insights into N mineralization dynamics without requiring the time and resource intensive measurement of gross N mineralization.

Utilizing soils from a range of agricultural systems in the Midwest US and Israel, we measured gross N mineralization with the ^{15}N pool dilution method and potentially mineralizable N with a 7-day anaerobic incubation. We compared the measures of N mineralization with soil organic matter measurements including particulate organic matter C and N, cold water extractable C and N, and hot water extractable C and N, as well as a fluorescence index, β:α freshness index, and humification index of cold and hot water extractable organic matter.

Our results revealed a number of significant correlations between gross N mineralization, net N mineralization, and soil organic matter properties that were consistent across the examined soils. Gross N mineralization and net N mineralization were positively correlated with hot water extractable organic C and N and particulate organic matter C and N, while gross N mineralization was negatively correlated with hot water extactable organic C:N and positively correlated with the hot water extract humification index. This research suggests that several measures of labile soil organic matter could be useful for predicting both gross N mineralization and net N mineralization, and that the humification index of hot water extracted organic matter may be a useful predictor of gross N mineralization

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IMPACT OF TREATED WASTEWATER ON GROWTH, RESPIRATION, AND HYDRAULIC CONDUCTIVITY OF CITRUS ROOT SYSTEMS IN LIGHT AND HEAVY SOILS

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Roots interact with soil properties and irrigation water quality leading to changes in root growth, structure, and function. We studied these interactions in an orchard and in lysimeters with clay and sandy loam soils. Minirhizotron imaging and manual sampling showed that root growth was three times lower in the clay relative to sandy loam soil. Treated waste water (TWW) led to a large reduction in root growth with clay (45-55 %) but not sandy loam soil (<20%). TWW increased salt uptake, membrane leakage, and proline content, and decreased root viability, carbohydrate content, and osmotic potentials in the fine roots, especially in clay. These results are evidence that TWW challenges and damages the root system. Phenology and physiology of root orders were studied in lysimeters. Soil type influenced diameter, specific root area, tissue density and cortex area similarly in all root orders, while TWW influenced these only in clay soil. Respiration rates were similar in both soils and root hydraulic conductivity was severely reduced in clay soil. TWW increased respiration rate and reduced hydraulic conductivity of all root orders in clay but only of the lower root orders in sandy loam soil. Loss of hydraulic conductivity increased with root order in clay and clay irrigated with TWW. Respiration and hydraulic properties of all root orders were significantly affected by Na amended TWW in sandy loam soil. These changes in root order morphology, anatomy, physiology, and hydraulic properties indicate rapid and major modifications of root systems in response to differences in soil type and water quality.

MODELING NITROGEN PROCESSES IN A LAYERED SOIL

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Nitrogen biochemical processes in soils have great environmental importance for both greenhouse gas emissions and groundwater contamination. The N-cycle processes in soil, and primarily those of nitrification and denitrification, are microbially mediated.

Nitrification is a two-step process in which two different species of bacteria are involved: ammonia oxidizing bacteria (AOB) and nitrite oxidizing bacteria (NOB). During this process ammonium is reduced first to nitrite (AOB) and then to nitrate (NOB). The Nitrifying bacteria need a supply of oxygen, ammonium, CO_2 and nutrients. The AOB has an important role as they perform the first step of the process, which can be the rate limiting. Denitrification is a process in which nitrate is reduced to the main products of N_2O and N_2, which is driven by heterotrophic bacteria in anoxic conditions. The ability to denitrify is widespread among the bacteria without systematic affiliation. Therefore the concentration of oxygen can be seen as rate controlling factor for both processes.

The soil is a heterogeneous medium and so are the associated microbial processes. Soil heterogeneity can be a result of burrows, cracks, roots, aggregates and layering of the soil. One simple type of soil heterogeneity is due to layering, with textural interfaces between layers. These interfaces are the transition zone between two layers of different hydraulic properties. Under flow conditions these interfaces may create different environmental conditions that can affect the microbial activity. Those different environments can lead to enhanced (or depleted) biological activity. As agricultural soils are very heterogeneous, it is important to determine the relations between the physical heterogeneity and the biogeochemical processes.

The hypothesis that stands behind this research is that the physical heterogeneity of the soil, such as layering, is leading to different oxygen concentrations and therefore will affect the biochemical processes in soil, and especially around the interface.

To verify this hypothesis a model of the water flow, multi-solute transport and microbial N turnover in the soil was developed for different scenarios of soil layering. The objective was to determine the differences of nitrogen processes comparing homogenous and layered soil, and comparing near- and far from- transition zones. The processes were modeled using COMSOL Multyphysics® (version 4.3.2.189). Water flow in the soil was modeled by Richards' 2D equation where the dependent variable was the matric head. Nitrogen species in the soil where modeled by the advection dispersion equation (ADE). Nitrogen species undergo advection, dispersion and microbial decomposition in the soil. The microbial decomposition was modeled initially using first order kinetics, assuming constant turnover rate in the whole domain. Two types of soils where simulated in different configurations: first one soil type (loam and clay). Then combinations of the soils mentioned, creating layers. First order reaction gives a simple solution for nitrogen processes in the soil, but it’s insufficient in this case, since we want to examine the influence of the changing environmental state variables as water content (and oxygen) on the nitrogen processes around the interfaces. For this reason the reaction term was modified to Monod kinetics, taking into account dissolved oxygen concentration. The results of the two simulations, first order and Monod, were compared and analyzed.

THE EFFECTS OF TREATED WASTEWATER IRRIGATION ON SOIL WETTABILITY AND THE SPATIAL DISTRIBUTION OF WATER AND SOLUTES

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Treated waste water ('TWW'/"effluents") is commonly used for irrigation of agricultural fields, due to a continuous shortage of fresh water, and today the majority of orchards in Israel are irrigated with TWW. This practice is highly attractive since it combines water supply required for agricultural production and the recycling of nutrients and contributes to overall long-term sustainability. However, in the past few years there had been an increasing amount of evidence regarding the negative effects of long-term irrigation with TWW on the soil, the trees and the crop (both quality and quantity). Many research studies have been conducted with the attempt of identifying the source of these negative effects. Following previous studies published by Wallach's research group regarding the effect of prolonged TWW irrigation on soil wettability, this study aims at investigating the outcome of soil wettability decrease and the development of water repellency on the spatial and temporal variability of water and solutes in the soil profile of a commercial TWW irrigated citrus orchard in Sitriya, Israel. The first stage of this study, which included the characterization of the soil's wettability have showed that wettability was severely affected in plots irrigated with TWW. In light of these findings, it was decided to examine the integrated impact of the TWW on soil properties by mapping the soil's spatial and temporal water content distribution, using an electric resistivity tomography device (ERT). This technique provides an undisturbed examination of the soil's profile, which assists in locating preferential flow paths. This examination has demonstrated that the decrease in soil wettability induces a non-uniform water content distribution in the form of preferential flow pathways with high water content, and with drier soil between them. Further to aforementioned revelations, the next step was to sample the soil in these flow paths and in between them in order to measure the salinity and other different solute concentrations. In addition, moisture content, salinity and matric potential were continuously monitored within the preferential flow paths and in between them by

different sensors. Preliminary results have shown that indeed the spatial distribution of water content and solutes is highly heterogeneous in the horizontal dimension. Observed concentrations measured in the preferential flow paths were significantly different than those that were measured between them. Further research will include additional soil sampling and continuous monitoring in order to statistically verify the preliminary results. The validation of this study's hypothesis may help pave the path to finding ways to reclaim the agricultural fields that had been negatively affected by irrigation with TWW, with the use of different materials which lower the hydrophobicity levels of the soil and neutralize the negative effects. This reclamation will increase the water use efficiency, reduce the negative effects of TWW on the soil and trees and prevent the potential pollution of groundwater by dissolved agrochemicals.

MODELLING OF MULTICOMPONENT SOLUTE TRANSPORT FOR LYSIMETER DESIGN

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Drainage lysimeters are commonly used for evaluating water and solute balances in environmental and agricultural research. In situ monitoring of salts, fertilizers, and other contaminants leaching into deep layers of the soil profile can provide information for improved decision making with respect to efficient and sustainable irrigation practices. However, conditions at the bottom of a lysimeter may limit or otherwise influence water flow and solute transport and thus water drainage and salt leaching into the underlying soil profile (Ben-Gal and Shani, 2002; Flury et al., 1999). There are nowadays three main types of lysimeters with respect to bottom conditions: with free drainage, suction controlled, and highly conductive drainage extensions. There have been studies comparing solute transport in free-drainage lysimeters and under field conditions (Flury et al., 1999). While the effects of the bottom conditions created by the highly conductive drainage extensions on water flow as a function of soil hydraulic properties are well understood (Ben-Gal and Shani, 2002), their effects on the composition of drainage water need to be further explored.

Models can be cost-effective tools for estimating, assessing, and preventing environmental damage by agricultural activities. However, model accuracy and reliability are highly influenced by the quality of their parameterization, often determined by calibration and validation (Skaggs et al., 2014). Models such as HYDRUS-1D (Šimůnek et al., 2008) coupled with UNSATCHEM (Suarez and Šimůnek, 1997) have often been used to assess the implications and risks arising from various agricultural practices, such as irrigation with low quality water in arid and semi-arid regions (Gonçalves et al., 2006; Ramos et al., 2011). However, the use of one-dimensional models to represent highly three-dimensional patterns created under drip irrigation is likely to lead to erroneous conclusions (Warrick and Lazarovitch, 2007).

In this study, solute transport experiments involving drip irrigation were performed in lysimeters. Irrigation water quality alternated between desalinated and brackish waters. Lysimeter drainage and soil solution samples were collected every 2-3 days for chemical analysis of major ions. Their concentrations were subsequently used to calibrate the variably-saturated water flow model HYDRUS (2D/3D) coupled with the reactive transport model UNSATCHEM. Overall, the calibrated numerical model successfully simulated the major ion composition and total salinity of experimentally collected drainage and soil solutions.

The calibrated model was then used to evaluate functioning of lysimeters with different lower boundary designs. Seasonal leaching fractions, determined using drainage water fluxes, chloride concentrations, and overall salinity of drainage water, were evaluated for either hypothetical steady-state conditions or transient conditions based on real evapotranspiration data. By considering the complex multidimensionality of flow and transport patterns in lysimeters resulting from imposed boundary conditions (e.g., drippers and drainage outlet designs), the modeling approach presented in this study offers an opportunity to improve our understanding of spatial distributions of water contents, water fluxes, and dissolved, precipitated, and adsorbed solute concentrations. The model indicates that, in the long term, after the system achieves steady-state or apparent steady-state conditions, the effects of different lower boundary conditions on flow and transport patterns are small. However, if the transient response of a lysimeter is of interest, the effects of different drainage outlet designs need to be taken into account. The model can be used to study whether lysimeters represent field conditions and to analyze design criteria, particularly regarding the choice of the bottom boundary condition.

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Ion Exchange Resins For Improved Prediction Of Nitrogen Mineralization And Nitrification Rates In Soils

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Ion Exchange resins (IERs) became common for studying N fluxes in agro-ecosystems. Soil mineral N is adsorbed rapidly by IERs so that they may serve as stronger sinks for mineral N than microbial sinks.

Our main research hypothesis is that sensible use of IERs by uniform mixing of IER beads in soil should minimize diffusion constrains and better indicate plant roots activity. This is expected to provide an effective solution for estimating more realistic, close to gross mineralization and nitrification rates, in soils for acquiring deeper understanding of processes controlling soil N availability and for estimating N roots uptake.

Our results show that nitrate denitrification losses are significantly reduced by uniformly distributing anion exchange resins (AERs) beads (Cl^- loaded) in soil, under anaerobic conditions. Accordingly, higher nitrification rates were measured in soils mixed with AERs compared to soils without AERs even under aerobic, optimal conditions for nitrification. Under the lower loads of mineral N (i.e. ~40 – 80 mgN/kg soil), positive net-accumulation of mineral N was higher in the AER treatments. Mixed bed anionic and cationic IERs (H^+/ OH^- loaded) treatments provided higher mineralization rates than the AER treatments. This is related, both to: N adsorption on IERs thus protecting the N mineral species from loss processes and to higher availability of soil organic matter as indicated by TOC measurements of soil water extracts.

It is anticipated that the above methods should provide improved mineralization and nitrification prediction under plant growth in soils. In future experiments, N mineralization and nitrification rates with IERs will be compared to N balance and uptake by plants in pot experiments.

EFFECT OF FOLIAR APPLIED FZ ON PHYSIOLOGICAL CHARACTERISTICS OF SOYBEAN WITH DRIP IRRIGATION UNDER WATER DEFICIT

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This study was undertaken to investigate the underlying mechanism asserted by FZ (a newly developed antitranspirant, alkaline oil extracted from the desert plant sparsifolia was compounded into zinc, boron and other trace elements and nitrogen, phosphorus and potassium) on soybean physiology under two levels of water supply. This was done by evaluating its effect on stomatal opening, enzyme activity, gas exchange at the leaf scale, yield and water consumption. The study was carried out under field conditions in 2013 in an arid region of northwest China. Treatments were plants treated with FZ and untreated plants (control) under mild and severe water deficit. Results showed that there was no significant effect of foliar applied FZ on soybean under severe water deficit, while significant effect on gas exchange and yield under mild water deficit. All parameters, of treated plants under severe water stress, were not statistically different from controls. Under mild water deficit there was an increase of 40% and 20%, 21%, 24% on superoxide dismutase (SOD) and peroxidase (POD), photosynthesis(Pn), yield, respectively; while no significant effect on stomatal opening confirmed by scanning biological microscope, and, in turn, no effect of stomatal conductance to water vapor(g_s), transpiration(E) and water consumption. Finally, water use efficiency increased by 21% under mild water deficit. Overall, these results prove that the underlying mechanism of FZ differs from that showed by the commercial film antitranspirants (like Vapor Gard). In fact, the efficacy of the latter is based on the formation of a thin antitranspirant film over the leaf and not on the physiological regulation of the leaf. The use of FZ would be an effective tool to improve water use efficiency in soybean production under arid and semi-arid conditions.

IDENTIFYING CONTAMINANTS AND MAJOR SPECIES IN SOILS USING SPECTRAL INDUCED POLARIZATION

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As soil and groundwater resources become scarcer and more vulnerable there is a pressing need to manage their usage. Therefore, a great need exists to develop tools and approaches for monitoring and characterizing the variety of processes in the subsurface, preferably in a useful noninvasive manner. Geophysical methods can fulfill that need, specifically the spectral induced polarization (SIP) method. SIP measures the frequency dependent electrical conductivity and soil's polarization by applying AC field. Its response is a complex function of pore solution volume and chemistry, microgeometry and surface chemical properties. Hence, it is greatly affected by the presence of pollutants. The interactions of pollutants with the soil phases influence the soil's electrical properties, which are reflected in the SIP signature.

In this study, we examine SIP as a tool for identifying and quantifying the presence of organic and inorganic components in the soil. Several experiments were performed. First, the influence of a free-phase organic pollutant on the SIP signature was examined on an unsaturated 'Hamra' soil. Next, we used Loess soil to investigate the SIP effect of several different organic pollutants and their mixtures, in order to examine the ability to distinguish them by the SIP method. Third, the soil solution and adsorbed phase inorganic composition influence on the SIP signature was examined.

Adding free-phase NAPL (Decane) to the soil causes a decrease of the imaginary part of the complex conductivity as well as the relaxation frequency. We suggest that membrane polarization, which is related to the diffuse layer and pore space, as the main polarization mechanism responsible for these results. Furthermore, we suggest that altering the characteristic pore throat length controls the SIP response when a free-phase compound is added to the system.

The same trend of decreasing polarization was observed when calcium rich soil was contaminated with other organic compounds on top of Decane. However, the real part of the conductivity (related to dissipation processes) had a clear decrease when Decane was added, as opposed to no significant change in previous experiments. The calcium rich environment had apparently contributed, in our perspective, to the formation of different surface interactions of the organic compounds (polar or charged with different functional groups) in the presence of Decane. Additionally, we present an artificial neural network classification with preliminary satisfying ability to indicate the existence of a specific contaminant.

A clear influence is observed for the inorganic chemical composition of the soil solution and the adsorbed phase has on the soil's electrical signature. Coherent changes exist in the relaxation time and chargeability when the chemical composition of the soil was changed. It seems that divalent cations had a unique influence on the electrical signature: addition of divalent cation to the porous media causes an instantaneous shift in the relaxation frequency, while the polarization magnitude is affected in a more gradual way. Three types of data driven models to potentially predict inorganic species are introduced. Dominant species were fairly well predicted, as seen from Figure 1 below for adsorbed concentrations of major cations.

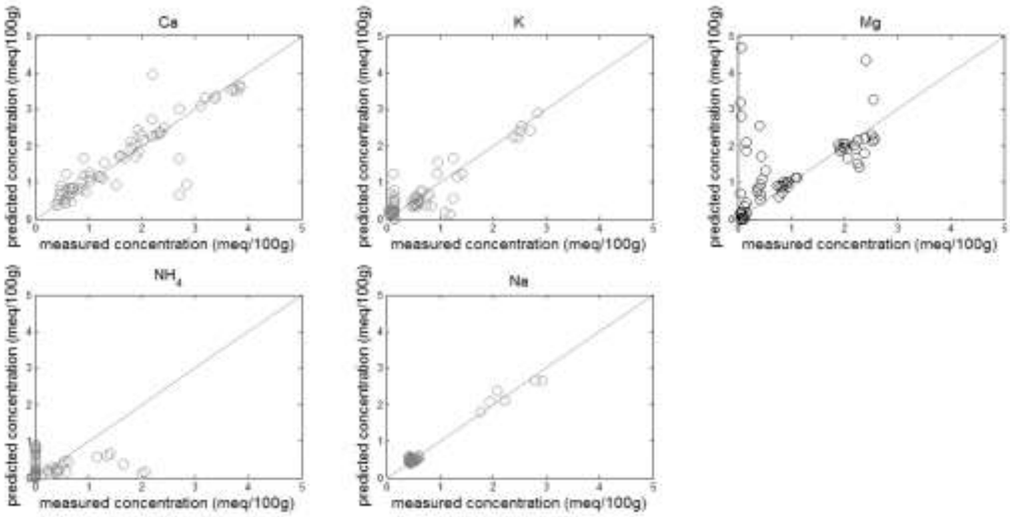

Figure ***Error! No text of specified style in document.*** *- Prediction of the cations concentrations with artificial neural network. The Root mean squred error (RMSE) is 0.288 meq/100g and the relative squred error (RSE) is 0.401.*

REDUCTION IN STRESS RESPONSE SIGNALING ENABLES GROWTH UNDER STRESS CONDITIONS- A POTENTIAL MECHANISMS OF CYTOKININ–INDUCED STRESS TOLERANCE.

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Cytokinins regulate plant senescence, cell divisions and other various development processes. Previous work showed that leaf senescence could be delayed and drought resistance is showed in transgenic plants expressing isopentenyl transferase (IPT), an enzyme that catalyzes the rate-limiting step in cytokinin synthesis.

Our objectives are engineering abiotic stress tolerant nicotiana tabacum plants via controlled cytokinins overproduction by linking cytokinin biosynthesis to a stress related promoter.

We developed transgenic tobacco with moderate IPT activity under stresses, using methallothionine gene promoter from Arabidopsis - Pmet:IPT. This plants show extreme drought tolerance and tolerance against salt stress.

Previous works showed increased antioxidant genes expression. Our results show that indeed, antioxidant genes as Catalase were upregulated in Pmet:IPT under drought stress. When we tested the expression of MAPK genes, known to be part of stress signal transduction, we saw that WIPK (a MAPK) expression was downregulated. Thus, we tried to see whether the activity of stress-signal kinases is changing due to salt stress. In BY-2 cells (tobacco cell suspension) 2 such kinases (SIPK and NtOSAK) were less activated during salt stress.

Expression of drought-induced gene, NtERD10 was downregulated in Pmet:IPT under salt stress. To confirm these results in the whole plant, we made RNA-Seq analysis of Arabidopsis. Stress-induced genes were not upregulated under salt stress in presence of BAP.

Na accumulated significantly less in leaves of transgenic Pmet:IPT under 300mM NaCl stress, while K accumulated more in the transgenic plants leaves both under regular and stress conditions.

SELF-RELIANCE?! ASSESSING ISRAEL'S NATIOANL FOOD SECURITY COMPONENTS THROUGH-OUT THE YEARS

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Recent years global economic crisis, rising food prices, climate change and other social, and environmental processes, has increased the interest in sustainable food systems and food security at different scales.

National Food security is the ability of a country to provide a stable supply of its population's food needs and demands. This could be achieved through local production or by import. Local food production is a key component in the national food system and contributes to the national food security.

Israel's food system has changed over the years as a result of social, economic and environmental factors and constraints. Food supply and agriculture production have been shaped and planned mostly according to economic feasibly. However, the need to examine the sustainability of Israel's food system and its food production self-reliance should be part of a national food security and sustainable development strategies.

This research presents an analysis of Israel's food system over the last 5 decades: focusing on the changing local food system, the inputs of required natural resources (land, water, energy), and the growing gap between domestic nutritional supply and demand. It will then raise questions regarding the promotion of sustainable food systems and food security policies.

RELEASE DYNAMICS OF DISSOLVED ORGANIC MATTER IN SOIL AMENDED WITH BIOSOLIDS

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There are knowledge gaps regarding the fate and transport of dissolved organic carbon (DOC) and total nitrogen (TN) in agricultural soils, in particular, in biosolids amended ones. Currently, most studies that addressed the above issues (directly or indirectly) are engaged with soils under cover of naturally occurring forests at relatively humid regions rather than agricultural soils in semi-arid or arid regions. The main objective of this study is to quantify the effect of water flow interruptions on DOC and TN release dynamics from biosolids amended soils. The release dynamics were examined for sand and loess soils sampled from agricultural fields located at the Negev Desert of Israel. Each one of the soils were mixed with 5% (w/w) composted biosolid (Compost-Or, LTD). The mixtures were packed into a Plexiglass column (I.D. 5.2 cm, L=20 cm) and a flow-through experiments were conducted at 1 ml/min flow rate in a continuous or interrupted manner (3day interruption after each 2PV leaching) for a total of 12 PVs. In addition to the flow interruptions, the effect of soil sterilization was examined. The leachates were collected in time intervals equivalent to about 0.12 pore volume. The DOC, TN concentrations and UV-VIS characteristics were analyzed for each fraction. The results showed that the smaller and less aromatic molecules were leached at the initial phase. In general, sterilization treatments provided evidence that the major processes affecting the release of DOC and TN form the biosolid examined, are of chemical and/or physical nature rather than biological ones. In addition, about 2% of the TN and 20% of the DOC were leached following 12PV, implying that composted biosolids can act as a long-term slow release nitrogen fertilizer. The result of this study demonstrates the importance of the biosolids and soil properties combination, which need to be taken into account when applying any organic amendment to agricultural fields. High amounts of DOC may increase microbial activity, and consequently increasing the competition between microorganisms and plant. In addition, it may enhance the transport of contaminants to groundwater via the vadose zone.

HYDRAULIC PROPERTIES OF UNSATURATED BIOFILM-AFFECTED SOILS

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Soil biofilms are abundant in agricultural soils and play a significant role in the rhizosphere, promoting soil fertility and productivity and altering flow and transport patterns in the vicinity of root veins. As such, understanding the way biofilms and other biological materials affect the soil-water-plant-atmosphere continuum is of global importance. While it was shown, by numerous works, that biofilms in saturated systems can cause significant reduction of the hydraulic conductivity, only a few studies dealt with flow under unsaturated conditions, such as those prevailing in the rhizosphere. Further, knowledge of how biofilms affect water and nutrient retention is lacking. We use here direct measurements of soil hydraulic properties of soil batches inoculated with real biofilms to investigate and quantify the effect of biofilms on hydraulic properties of unsaturated soils. We show that biofilms can significantly alter the soil hydraulic properties under unsaturated conditions.

Measurements of the soil hydraulic conductivity function and water retention curve were performed by using the evaporation method under refrigeration conditions (to minimize biofilm growth during the experiment). Data were analyzed by the simplified evaporation method and were fitted to standard relations of unsaturated hydraulic properties. The results show that the hydraulic properties of biofilm-affected soils significantly differ from those of clean soils. It was found that the hydraulic conductivity of biofilm-affected soils is reduced by up to a half order of magnitude compared to the hydraulic conductivity of clean soil. As the amount of biofilm in soil increases, the hydraulic conductivity decreases. The differences in the water retention curves were less pronounced. While no significant difference was observed in the wet and intermediate ranges of the curves, the soil water retention in the dry range increased when increasing the biofilm amount. Fitting to standard relations revealed that the experimental curves are best described by relations of bimodal pore size distribution, suggesting that the biofilm phase has a significant role in both retention and conductivity.

BERRY, IT'S HOT OUTSIDE! PREVENTING OVER-EXPOSURE OF CLUSTERS TO RADIATION AND HIGH TEMPERATURES

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Ongoing expansion of viticulture from traditional temperate regions into arid regions poses climatic challenges such as high solar radiation, high temperatures, and low water availability, all known to be detrimental to berry quality. These challenges are magnified further in view of climate change and water scarcity issues. Practical techniques to control the effect of elevated radiation and temperatures on fruit quality are still lacking. An agro-technique that can potentially improve the berry microclimate is comprised of photo-selective shading nets installed directly around the clusters, maintaining the above canopy exposed. While shading nets have been used extensively in other fruit crops, their use in wine grapes to reduce radiation is limited. Our aim was to study the effect of shading nets application on the micrometeorological conditions surrounding berry clusters and the response of the berries to this modification towards improving yield quality.

Our research was conducted at a commercial vineyard in the Negev desert, Israel (30.6080° N, 34.8030° E; 800 a.m.s.l). Three experimental rows were selected from 10-year-old Cabernet Sauvignon vines planted in a north-east to south-west direction, with rows angled 30° to the east. Application of shading nets was performed immediately prior to véraison, parallel to the removal of all basal leaves covering the cluster zone on both sides of the canopy for uniformity of exposure between treatments. The following treatments were applied: fully exposed clusters, grey shading net with 30% radiation block, grey shading net with 60% radiation block, red shading net with 30% radiation block, and blue shading net with 30% radiation block.

Air temperature, relative humidity, incoming shortwave radiation, and wind speed and direction were measured continuously from véraison to harvest in the vineyard, along with ambient air temperature and relative humidity in the direct vicinity of the clusters. Two weeks prior to harvest thermal images of clusters in all five treatments were acquired hourly for a course of 24 hours. Representative clusters on the east and west sides of the vine row were identified, and thermal images were taken from three view angles (north, south and east or west). Solar radiation reaching the cluster zone was measured from véraison to harvest for each treatment using five pyranometers positioned to face all directions (up, north, south, east, and west) and positioned under the shading nets on the east side of the vine row at the same distance from the vine as the clusters. The pyranometer set was moved between treatments approximately every three days so that each treatment was monitored at three time points during the course of the measurement period. Fruit size, weight, and maturity indices were measured for each treatment every week throughout the growing season to monitor berry development.

Relative humidity and air temperature in the vicinity of the clusters was not affected by the presence of the shading nets, likely due to the overall low relative humidity in the region, implying that this technique of shading application is not expected to increase berry rot. The diurnal pattern of berry surface temperature was modified by the presence of the shading nets with increased temperature homogeneity correlated to decreased radiation transmittance. Increased homogeneity is beneficial and contributes to an improved wine product, implying this approach may potentially improve yield quality. Differences in both instantaneous berry-surface temperature and seasonal thermal energy accumulation were found between east and west facing clusters, indicating the significance of cluster exposure relative to direct solar radiation.

Significant differences in the quantity and quality of solar radiation transmittance received onto clusters was observed between treatments. Color and density properties of the shading nets affected the radiation transmittance with the colored nets manipulating the spectra of radiation reaching clusters. Significant effect on the maximum berry temperature and the thermal dynamics of diurnal berry warming and cooling was observed between treatments. Studies have shown that differences in berry thermal dynamics can influence the accumulation of berry secondary metabolites, thus affecting berry ripening, composition, and quality. Our results indicate the promising role of shading net application in mitigating microclimatic challenges in arid vineyards.

Insights From Soil Redox Measurements Concerning The Effects Of Treated Wastewater On Avocado Plants Grown In Clay Soils

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Treated wastewater (TW) has become a common source of water for agriculture in much of the world, due to the widely accepted perception that it does not damage agricultural production. However, recent findings challenge this perception: a marked decrease in yield appeared in citrus and avocado trees irrigated with TW compared with fresh water (FW) irrigated trees, with up to 40% less yield in Hass-avocado. These detrimental effects appeared predominantly in orchards cultivated in clay soils, and the damage did not seem to be linked to any of the known hazards associated with the use of TW, namely: boron, chloride or sodium toxicities in the leaves (Lahav et al., 2013). TW characteristically has a high sodium adsorption ratio (SAR) and a high level of organic material, the combined effect of these two may lead to severe lack of oxygen in the soil as previously reported in TW irrigated avocado (Assouline and Narkis, 2013). The association of the damage to clay soils rather than sandy soils led us to hypothesized that the damage is linked to the lack of oxygen and to changes in soil reduction-oxidation (redox) state, which are a known cause of damage to plants in soils with low oxygen levels (Husson, 2013). An extensive study was carried out in the Akko Experimental Station, where avocado plots have been irrigated with either TW or FW since 1995. The site was selected because of previously reported yield loss in the TW-irrigated plots; the soil is a grumusol with ~60% clay. Continuous redox potential and pH measurements were carried out at a depth of 25 cm. Soil solution composition was sampled periodically *in-situ* using Rhizone samplers. Mineral composition was sampled biannually in tree leaves, xylem tissue and roots.

In both TW and FW plots the fluctuations in redox values in dry periods were small, and the pe+pH values indicated oxic conditions (pe+pH>14). Decreases in soil water tension following irrigation or rain were followed by drops in pe+pH values in accordance with decreases in soil oxygen levels. Minimum pe+pH values in the TW irrigated plots were significantly lower than in FW-irrigated plots, more so during the irrigation season than in the rain season. A linear correlation appeared between irrigation volume and reduction severity in TW-irrigated plots, but not in the FW plots, indicating a direct link to the irrigation regime in TW-irrigated plots. The minimum pe+pH values measured in the TW plots are indicative of suboxic conditions (9<pe+pH<14) which are suitable for Fe and Mn reductive–dissolution (Sposito, 1989). In contrast to these findings, Fe and Mn levels in the soil solution and in the tree organs were not elevated in the TW plots. A possible explanation for these contradicting findings may be the short duration of the reducing conditions; another may be that the measured redox potential partly reflects conditions in smaller soil pores which are less available for both plant nutrient uptake and for our sampling.

Root and xylem tissue samples showed few-fold greater Na concentrations in TW irrigated plants compared with FW irrigated plants, although no difference was observable in leaf Na between the two treatments. The physiological blockage of Na at the lower tree parts leading to Na accumulation in the root and xylem was previously recognized by Kadman (1964), however its implications were not well recognized – leaf samples in avocado do not represent the plant Na uptake – leading to a possible "hidden" Na toxicity in the lower plant parts. The elevated Na concentrations in the TW-irrigated roots were accompanied by significantly lower K concentrations compared with FW-irrigated plant roots. Hypoxia is known to disrupt Na/K relations in plants (Legget, 1961) we therefore suggest that the suboxic conditions in the root zone of TW-irrigated plants contributed to the elevated Na uptake and the lower root K content reported here. Our findings indicate that soil redox conditions *per-se* do not seem to be the direct cause of damage to avocado trees irrigated with TW. We suggest that poor aeration, as was found in TW-compared to FW-irrigated clay soils in this study is leading to elevated Na and decreased K levels in avocado root and xylem. Thus, the detrimental effect of TW on the avocado trees is physiological and it is caused by the low oxygen levels in the soil. We conclude that management practices that will allow better soil aeration will allow sustainable use of TW which is an essential resource in the world today.

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MAIZE WATER UPTAKE FROM DIFFERENT LAYERS AND ROOT-ZONES UNDER ALTERNATE FURROW IRRIGATION USING STABLE HYDROGEN AND OXYGEN ISOTOPES

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How to quantify the root water uptake from different soil layers under alternate furrow irrigation (AFI) condition accurately, is still of great challenge. In this study, the stable hydrogen and oxygen (δD and $\delta^{18}O$) isotopes of soil water, stem water, rainfall and irrigation water (groundwater) over a maize field under AFI condition were measured during 2013-2014. The root water uptake was estimated by the multi-source mass balance method (IsoSource model). Results show that $\delta^{18}O$ distribution varied significantly between the ridge (R) and furrow (F) near soil surface and between ridge surface and wet furrow under AFI. $\delta^{18}O$ in stem water had better response to soil water variation at wet side, and soil water in wet side was firstly absorbed by maize root and then transported to the dry side. Maize water uptake was mainly from the depths of 20-40 cm at the late jointing stage, 40-60 cm at the late heading stage and 40-80 cm at the filling stage, with relative contribution of 84, 80 and 66%, respectively. Maize water uptake from different soil zones varied remarkably at AFI. For example, at the filling stage, 16-52% of maize water uptake was from the depth of 60-80 cm below the ridge (dry side) before irrigation; 32-78 and 14-64% from the surface soil (0-20 cm) of wet furrow and the ridge at 1 d after irrigation; 14-60 and 8-54% from the depths of 20-40 cm below the ridge side and 40-60 cm below wet furrow at 3 d after irrigation, and 6-80 and 30-60% from the depths of 60-80 cm below the ridge and 40-60 cm below the ridge side at 7 d after irrigation. Thus, maize root water uptake was from deeper soil with the advance of growth stage, and it was mainly from the deeper soil in dry side and the shallow soil in wet side under AFI.

Symposium Posters

Researchers

NITROGEN FERTILIZER RATE EFFECTS ON SOIL ORGANIC CARBON IN IOWA CROP SYSTEMS

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Nitrogen fertilizer rate is a key factor affecting soil organic C (SOC) in corn-based cropping systems (Cassman, 1999). However, the effect of nitrogen fertilizer on SOC is highly debated (Robertson et al., 2013). Nitrogen fertilizer can increase SOC by increasing crop reside production (Brown et al., 2014). Nitrogen fertilizer may also decrease SOC by increasing SOC mineralization (Russell et al., 2009). We suggest that variability in the response of SOC to N fertilizer is due to the lack of an agronomic perspective. Although many studies examine the effect of N fertilizer on SOC, they do not empirically determine whether the N fertilizer input was agronomically insufficient, optimum or excessive. The objective of this study was to determine the change in SOC at N fertilizer rates that were empirically determined to be insufficient, optimum and excessive. Soil samples were collected to a depth of 15 cm in 1999 or 2000 and again after 14 to 16 years of corn N rate treatments ranging from 0 to 269 kg ha^{-1}. The soil samples were analyzed for total C and N concentrations. For continuous corn systems, the annual change in SOC increased from neutral or negative at 0 kg N ha^{-1} to slightly positive at the site-specific agronomic optimum N rate. For the corn-soybean systems, the annual change in SOC was neutral or negative and did not respond to N rate. The results indicate that adequately fertilized continuous corn systems accrue SOC, whereas adequately fertilized corn-soybean systems do not.

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DIDAS - A USER-FRIENDLY SOFTWARE PACKAGE FOR ASSISTING DRIP IRRIGATION DESIGN AND SCHEDULING

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The DIDAS software package, based on analytical solutions of linearized water flow and uptake problems, assists in drip-irrigation system design and irrigation scheduling. Water flow is described by superposition of solutions for positive sources (on-surface or subsurface emitters) and negative sinks (root systems). Steady water flow is assumed in the design module and unsteady flow in the irrigation scheduling module. The design tool, based on relative water uptake rate (RWUR) criterion, assesses the effects on water use efficiency of geometrical attributes: distances between emitters along drip lines; separation between drip lines; depth of subsurface emitters; and size and depth of root systems. Evaluation of the maximum possible RWUR assumes no plant-atmosphere resistance to water uptake, i.e., the roots are assumed to apply maximum suction and the water uptake rate depends only on the soil capability to conduct water from sources to sinks. The RWUR computations require only three parameters describing the soil texture, the root zone size, and the potential evaporation, in accounting also for evaporation from the soil surface. The optimizing tool for irrigation scheduling is based on a relative water uptake volume (RWUV) criterion. The computations of diurnal variations of water uptake rates and RWUV for a given irrigation scenario require additional information on the diurnal pattern of plant resistance to water uptake and on the soil hydraulic conductivity. DIDAS also contains a diurnal pattern module for evaluating diurnal water-uptake patterns; it assumes quasi-steady flow and accounts for the diurnal variations of plant-atmosphere resistance and evaporation in fine-tuning the design and in preliminary evaluation of scheduling scenarios. DIDAS was programmed in Delphi, runs on a PC under the Windows operating system, and requires no further software. The drip irrigation scenario is constructed via a few GUI windows, which contain also a library of the required soil input parameters, and a best-fitting procedure for determining them. The computed RWURs and RWUVs are displayed graphically and the tabulated output results can be exported to, e.g., Microsoft Excel for further

processing. An updated DIDAS version can be downloaded freely from http://app.agri.gov.il/didas. The present, second public release of DIDAS meets the major demands dictated by its development objectives. Short-term development goals include minor graphical improvements, addition of new drip irrigation configurations, and addition of a module for evaluating water uptake from drip irrigation in the presence of shallow groundwater. We also intend to extend DIDAS to sprinkler irrigation. Depending on feedback from DIDAS users we may consider also other development options; 590 people from 78 countries downloaded either the first or the second DIDAS versions 1.0.1 (and 1.1.1) from March 2014 through November 2015.

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SOIL NUTRIENTS PREDICTION BASED ON MID-INFRARED DIFFUSE REFLECTANCE SPECTROSCOPY AND FOURIER TRANSFORM MID-INFRARED PHOTOACOUSTIC SPECTROSCOPY

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The sustainable agriculture and the intensification of agricultural production require new techniques in agriculture to better use resources and optimize production processes, such as precision agriculture. The spectral-based methods are good tools and soil properties can be measured from a single scan when deal with numerous soil samples.

The diffuse reflectance (DRF) spectroscopy is based on the detection of the electromagnetic radiation (EMR) reflected at a characteristic wavelength without needing direct contact between sensor and soil. The energy that penetrates one or more particles is reflected in all directions. It can be used widely as reference for development and application of soil sensing techniques at different scales from field (proximal sensing) to orbital level (remote sensing) for many years, and also as support for assessment of statistical models in prediction of soil properties. Fourier transform infrared photoacoustic spectroscopy (FTIR-PAS) is based on the absorption of electromagnetic radiation by analyzed molecules. Nonradioactive relaxation processes induce local warming of the soil sample matrix. Pressure fluctuations are generated by thermal expansion, which can be detected by a very sensitive microphone. The resulting spectrum differs from both equivalent transmission and reflectance spectra because the technique detects nonradioactive transitions in the sample. It is used as quick and nondestructive tool to quantify calcium carbonate, soil identification, and formost, the soil depth-profiling at the micrometer scale.

The purpose of the study was to use the complementarity of two techniques to develop a spectral library for quantitative assessment of soil nutrients such as SOM, N, P and K for survey and management based on a Self-Adaptive PLS model. The results showed that both yechniques displayed good prediction capacity in soil nutrients. FTIR-PAS suggested better RPD in predicting of SOM, K and N, and DRF showed better value in predicting of P.

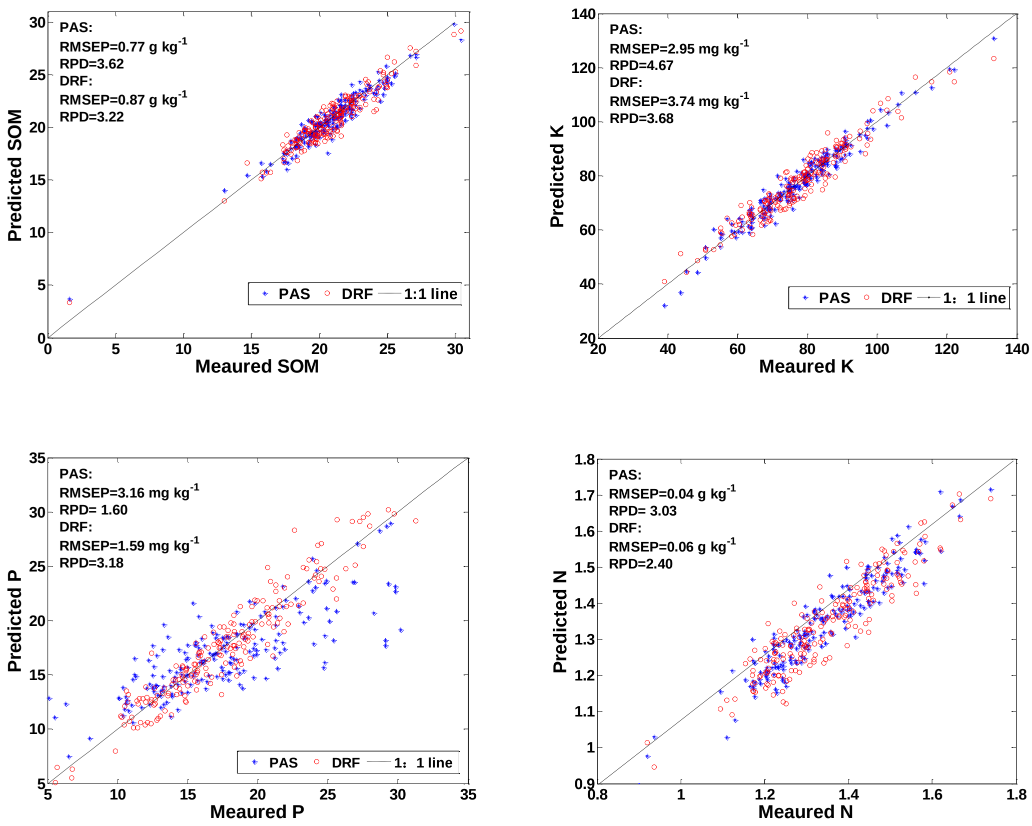

Fig. 1 Scatter plot of soil nutrients (SOM, K, P and N) measured value vs. predicted value by FTIR-PAS and DRF based on a Self-Adaptive PLS model

Application Of Coordination Complexes Of Fe^{III}–Ta In Modifying Aqueous Polyacrylate To Slow Nutrients Release Of Coated Fertilizer

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Waterborne polyacrylate are promising coatings for controlled release fertilizers. However, the nutrient release duration is too short for some crops with long growth periods. Waterborne acrylic emulsions were modified with coordination complexes of Fe^{III}–TA by simple blending of these two components. The effects of Fe^{III}–TA on water absorption, glass transition temperature, mechanical properties size and size distribution, zeta-potential as well as nutrient release profiles were investigated. Results showed that Fe^{III}–TA increased stress, hardness, particles size and size distribution, decreased water absorption and T_g. The preliminary solubility of nanocomposites coated urea was reduced from 27.7% to 8.7% and the 7 days' accumulative release percentage of nanocomposites coated urea was reduced from36.9% to 19.8%. Overall, our findings showed that simple blending of Fe^{III}–TA with acrylic emulsions produced excellent coating for coated controlled release fertilizer.

IMPROVEMENT OF THE PHOSPHORUS USE EFFICIENCY BY REDUCTION OF THE SOIL BUFFER FOR GREENHOUSE VEGETABLE CROPS

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Protected horticulture is characterised by high fertiliser inputs. The mineral uptake is proportional to the total yield, these high physical production levels involve high inputs of fertilisers. Compared to field vegetables, the annual fertiliser application is eight to ten times higher (Voogt, 2005). These high fertiliser applications and levels in the root environment increase the risk of nutrient leaching into ground- and surface waters. In reaction on the increasing pressure from applied EU regulations improved fertilisation management strategies are enforced. For soil-less greenhouse crops, re-use of drainage water is implemented successfully, however for soil-grown crops this is approach is not achievable. One of the strategies could be the reduction of the target values for available P in the soil pre-planting and throughout the growing season. This effectively reduces the risks of leaching and diminish the risks of P-saturation of soils.

A long term experiment was designed in two greenhouses, each significantly different in soil P-quantity (P-AL index), due to different historical P applications. In each greenhouse plots were installed with P application rates ranging in 5 steps from 0 till 350 kg P ha^{-1} yr^{-1} . In the lettuce trial 13 successive lettuce crops were grown in approx. three years. For chrysanthemum two other greenhouses were chosen, one with a soil deliberately low in P-quantity, during two years 8 crops were grown successively.

The different P-application rates resulted in large differences in available P (P-water) and P-index values on the long run, as well as lower P-levels in plant tissue. No significant effects on yield or crop performance was found in the long-term experiments with chrysanthemum and lettuce, not even in the zero P treatments, whereas the P-plant uptake was significantly reduced at the lowest and zero P treatment. It shows that the vast buffer of P build up by over-fertilisation in many years in most greenhouse soils could deliver sufficient P. Effectively the P-target value in the fertiliser recommendation system could be reduced, resulting in lower P-application rates and higher P-use efficiencies. Another outcome of this research is that the best assessment of the P-status in greenhouse soils likely is a combination of capacity assessment like weak acids extractions (Alt and Peters, 1992) and intensity assessment like a water extraction (Sonneveld et al, 1990).

Eventually, reduction in the P fertilisation, will contribute only to a certain extent to the reduction in nutrient emissions to the environment, since the leaching of P from greenhouse soils appears to be very limited. The P concentration in leachates (drainage water) is low, even at situations in greenhouses with high P.

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SAP FLOW OF MANGO AND GUAVA ORCHARDS IRRIGATED WITH TREATED WASTE WATER IN JERICHO CITY, PALESTINE

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As a waste water treatment plant (WWTP) has been newly constructed in Jericho under Japan-Palestine economic cooperation, it is timely for researchers from Japan and the National Agricultural Research Center (NARC) of Palestine to conduct a small-scale experiment to explore potentials of the use of this unconventional water resource for agriculture. The specific objective of this study, therefore, is to measure water requirements and find optimum trigger suction values for automatic irrigation system for tropical fruit trees using treated waste water in the study area.

Two treatments, differing in trigger suction value for automatic irrigation system, was settled, where each treatment will have 2 replicates in the land of Jericho WWTP. Four mango trees and four guava trees was transplanted in each treatment row in December, 2014. Previous cultivated plans were date palms. Irrigation method is drip irrigation with button emitter and controlled by tension-meter automatically. Meteorological factor to determine ETp is measured. Salinity level of treated water was 2mS/cm. The system is working successful on the whole.

Sap flow measurements with Heat Ratio Method (ICT SFM-1) on Mango and Guava stems were conducted in the plot and calibrated at Minami Kyushu University. The diurnal curve of sap flow on the Mango stem was indicated slight water stress condition in the plot and verified with water stress experiment. Non-reduced seasonal sap flow data obtained during very hot summer in Jericho, except the water transport trouble, indicates the possibility of the outdoor cultivation of tropical fruits using treated waste water. From the calibration results, it is important to consider the location of sensing point in the stem as seedling grows rapidly. It is also revealed that HRM has measuring upper limitation value around 27cm/h in the case of Guava seedling. Salinity tolerance is also evaluated for Guava and it is not sensitive up to 5000ppm.

Additionally, we examined the automatic irrigation system based on sap flow system against a potted mango plants applying saline water. Measured relatively high heat pulse velocity was utilized for the criteria of irrigation with three stages. The system was working well and it has a value to test in the real field.

Takeuchi S., 2012, Application of sap flow measurement in real-time soil moisture management and examination of supplemental irrigation using automatic drip system under high atmospheric demand conditions, Acta Horticulturae, 951,39-45.

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