Root Health – the key to improving yield

White paper, 2011

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Executive summary

New agronomic strategies to address the next green revolution will focus on roots and soil. Seed treatment will play a key role in the solution to protect and ensure healthy roots, thus increasing crop performance

The global population is steadily increasing. With this population growth, demand also increases on arable land, water, energy, and biological resources to provide an adequate supply of food while maintaining the integrity of our ecosystem. The first "green revolution" has significantly impacted agricultural practices. A next green revolution may follow, focused on finding still unexplored solutions.

Worldwide, research increasingly points to Root Health as the key for future crop productivity improvements. Because they are out of sight, roots are often out of mind. It has been estimated that 80% of all plant problems start with soil/root problems. Increased use of agronomic practices such as no-till and irrigation can increase prevalence of soil-borne diseases, which compromise Root Health. These diseases impact plant physiological processes and inhibit plant development, which in turn negatively affects yield. It is important to have a thorough understanding of how soil-borne pathogens do their damage in order to devise good control strategies.

One new strategy that has proven successful is the use of seed treatment fungicides to protect plants from these yield-reducing diseases, enabling the plants to grow to their maximum genetic potential. Sedaxane is the first Syngenta molecule developed specifically as a seed treatment – with the optimal combination of systemic movement and soil mobility. This compound falls into the new SDHI class of fungicides. Syngenta will commercialize sedaxane-based fungicide seed treatment offers under the umbrella tradename VIBRANCE™. It has unique antifungal activity against seed- and soil-borne diseases such as smuts and bunts, snow molds, *Rhizoctonia* and many others.

Industry experts and scientists recognize that protecting plant root systems and ensuring healthy roots can hold the key to the next green revolution. Through focus on Root Health and with the exciting new sedaxane technology, we are taking the next step.

The challenge - growing more from less

Continued increase in world population puts pressure on natural resources, requiring new research directions aimed at producing more from less

According to the latest estimates, approximately 6.6 billion humans now inhabit the earth. The human population has grown nearly ten-fold over the past three centuries and has increased by a factor of four in the last century. With an estimated one-quarter million people being added to the world population each day, the need for food will reach unprecedented levels. Reports from the Food and Agricultural Organization of the United Nations, many other international organizations, and scientific research confirm this serious food supply problem. Whether food supply can keep pace with an expanding human population is an old question. In 1798, Thomas R. Malthus predicted that population growth would outstrip food supply, causing great human suffering. In the early 1960's, most nations were self-sufficient in food, but alarm about the rapidly growing population caused many to echo Malthus' prediction.

With the ever increasing world population, there is also increased pressure on arable land, water, energy, and biological resources to provide an adequate supply of food while maintaining the integrity of our ecosystem. It has been estimated that the per capita availability of world grains, which make up 80% of the world's food, has been declining for the past 15 years (Kendall and Pimentel, 1994). At present, fertile cropland is being lost at an alarming rate. For instance, nearly one-third of the world's cropland (1.5 billion hectares) has been abandoned during the past 40 years because erosion has made it unproductive (Pimentel et al., 1995).

In addition, the rising demand for biofuel is limiting the amount of land available for food production, thereby placing further constraints on food security.

Increased demand for food led to the so-called green revolution which brought remarkable increases in crop production (Gewin, 2010). In the 1960's, the efforts of agricultural scientists to develop new high-yield crop varieties began to be realized in many areas of the world.

Technology drives sustainable solutions to unlock the potential of plants

Even with this first green revolution success, modern agriculture is challenged to further lead the way to sustainable solutions that are specific to crops, localities, available resources and cultures. Today's technologies unlock the potential of plants to help farmers grow more using less water and land. Insecticides, fungicides and herbicides, for example, protect crops from insects, diseases and competition from weeds. Modern science can identify key natural traits of a plant to breed improved varieties with the highest possible yield. In other instances, genetic modification can be used to achieve traits, such as disease resistance or herbicide tolerance.

These trends and developments have impacted crop production practices. They continue to drive significant new research directions, such as the examples listed below, in order to produce more from less:

- There is an increase in the use of Precision Agriculture (use of GIS, variable dose rate application, variable seed rates, etc.)
- The focus is shifting towards crop enhancement, so that crops are able to better withstand environmental extremes and utilize resources more efficiently
- Due to increased environmental awareness, there is a shift towards more sustainable production methods, such as no-till/reduced tillage and carbon management (mainly in cereals, canola/OSR, and corn)
- Multiple cropping, intercropping
- Increased use of transplanting (mainly sugar beet)
- Technologies such as induced resistance and biological control have gained additional attention as alternatives to conventional disease and pest control in crops
- Hybrid crops (such as canola/OSR, cereals, corn, sunflowers and soybean)

Experts increasingly recognize Root Health as a key to meeting the demands for future crop productivity improvements

To meet growing food supply needs and effectively respond to the increasing demand on limited natural resources, new strategies are required to increase yield. Worldwide, more and more research is pointing to Root Health as the key for future crop productivity improvements. "The strategies of the past aren't working now to meet increased food needs. Roots are the key to the second green revolution," says Jonathan Lynch, a plant nutritionist at Pennsylvania State University. This is echoed by Peter Gregory, chief executive of the Scottish Crop Research Institute in Dundee, UK. "We've gone quite a long way over the past 40 years without worrying about roots at all, but the economic and environmental consequences of inefficient nutrient applications are now apparent."

The clear link between Root Health and increased yield was also explored further at the Global Root Health Forum organized by Syngenta in 2011, where keynote speaker David Wright (North Central Soybean Research Program, USA) said "future yield increases will come from improving Root Health, but this is an area with great opportunity for research." Mark Westgate (Iowa State University, USA) added, "maximizing seed yields starts and ends with a healthy root system," thereby emphasizing the importance of Root Health in relation to increased yields.

The root cause of the problem: invisible pathogens compromise Root Health

Because they are out of sight, roots are often out of mind. They are widely overlooked for their significance in plant health

Roots have two main functions: 1) to anchor the plant to the soil and 2) to provide a large surface area – increased by the presence of root hairs – to facilitate the uptake and absorption of water and nutrients. The structure and growth habits of roots have a pronounced effect on the size and vigor of the plants, adaptation to certain soils and response to cultural practices.

Because they are out of sight, roots are often out of mind. They are widely overlooked for their significance in plant health. It has been estimated that 80% of all plant problems start with soil/root problems. The roots of most plants are prone to attack by pathogenic fungi and nematodes, but the effects of such organisms may go unnoticed unless the attack is sufficiently severe to cause crop failure or unless there is some base-line with which to compare production (Rovira, 1990). Often these effects are only noticeable at the end of the season when growers are faced with often fairly significant yield losses. Furthermore, unless specific analyses are conducted, these problems are often misdiagnosed, resulting in further losses for growers.

Soil is a dynamic, living natural terrestrial ecosystem and is home to a multitude of different types of living organisms, including bacteria, fungi, nematodes and a variety of others. The balance of the different populations of organisms is a highly delicate one. Subtle changes in chemical and biological composition due to – among others – farming practices, fertilizer and pesticide use can result in the domination of pathogenic organisms in this complex ecosystem. When such domination happens, it often results in significant crop losses which can be exacerbated by stress conditions such as drought, excess soil moisture, cold, increased salinity, etc.

Rhizoctonia is one example of a serious disease threat to cereals that is increasing because of changes in agricultural practices

Due to increased awareness of sustainable agriculture, practices such as no-till (or minimum-till) have been increasingly adopted for their environmental and economic advantages. No-till systems offer many benefits that intensive tillage systems cannot match, such as among others: reduced labor requirements, fuel savings, improved long-term productivity, reduced soil erosion, greater soil moisture retention and decreased soil compaction. Yet because these practices leave the soil undisturbed with a layer of organic matter on top, they may also increase prevalence of soil-borne diseases. This increase compromises Root Health. No-till practices may also physically, biologically and structurally alter the local field environment by affecting soil temperature and moisture, competition among microorganisms and soil disturbance (Rothrock, 1992). They have changed the disease spectrum, making broad-spectrum protection more important. *Rhizoctonia*, in particular, is a serious threat to cereal and rotation crops because plants are weakened early, tillering is affected and there are multiple groups/races which could be involved.

Increased understanding of how pathogens create damage will lead to better control strategies for currently difficult-to-detect soil-borne diseases

Problem pathogens within the soil have been clustered into two main groups by Wayne Pedersen (Emeritus Plant Pathologist, University of Illinois, USA):

- The "killers" such as *Phytophthora* and *Pythium* are generally quite aggressive and, once infection has taken place, plants can die off rapidly depending on the environmental conditions. These effects can be quite devastating. Fields can be almost entirely destroyed within a short period of time. In general, awareness of diseases caused by these pathogens is high.
- The effect of the "nibblers" such as *Rhizoctonia* and *Fusarium* is less obvious, particularly under less favourable conditions. But even under conducive conditions, nibblers can result in a 20 – 30% yield reduction. In general, awareness of these diseases is low, mostly due to the subtle nature of these infections, showing few or no symptoms.

Rhizoctonia root rot affects plants in a wide range of regions, but is often unnoticed or misdiagnosed. It is mainly a disease of no-till cereals, but can cause losses in a range of other crops such as canola/oilseed rape (OSR), potatoes, cotton and sugar beet. This pathogen is difficult to control because it has a wide host range (different anastomosis groups) and can survive and grow in the soil without a live host plant. The effects of many of these pathogens are often linked to more than just the observed disease. Field observations have linked *Rhizoctonia* infections to reduced nodulation, wilting of leaves and decreased abiotic stress tolerance, especially in drought conditions. Stressed plants are less resistant to pathogens. This combination of factors impacts plant physiological processes and inhibits plant development, which in turn negatively effects yield.

It is important to have a thorough understanding of how these pathogens do their damage in order to devise good control strategies. Due to the multi-host range of many of these pathogens, crop rotation is not always an option, although it can in some cases have a positive effect. Cultural practices such as adequate nutrition to ensure rapid initial growth, adjusted sowing times (where possible), light cultivation etc. can help reduce inoculum and help the young plants "escape" infection.

A new strategy that has recently proven successful is protecting plants from these yield-reducing diseases by enabling development of healthier, stronger root systems through seed treatment – thereby helping the plants grow to their maximum genetic potential. The success of this strategy makes it more clear that maximizing yield starts and ends with a healthy root system.

The solution - boosting plant performance through Root Health

Stronger, healthier roots can better uptake water and nutrients, which leads to better crop development at all critical stages

Recently, there has been a shift in focus to the importance of roots for plant performance. According to the Food and Agriculture Organization (FAO), top ranked stresses in agriculture include water, soil salinity and soil acidity. These factors all relate to roots and Root Health. Syngenta is at the forefront in supporting a worldwide research platform on Root Health. In February 2011, the company organized a Global Root Health Forum bringing together nearly 100 research experts from public and private organizations to discuss and exchange their findings on Root Health.

Stronger, healthier roots can better uptake water and nutrients, two of the most critical resources a plant needs. This leads to better crop development at critical early stages and under a wide range of conditions. More robust root systems help produce stronger stems and foliage that better withstand environmental stress, especially in challenging climates. They protect the genetic potential of the crop and, ultimately, lead to improved yield consistency.

Over the past several years, Syngenta scientists around the globe have been busy analyzing the interactions between roots, diseases, moisture efficiency and nutrient utilization. They have learned that a simple act like effectively protecting crop roots from disease can have an enormous impact by unlocking greater potential within the root systems.

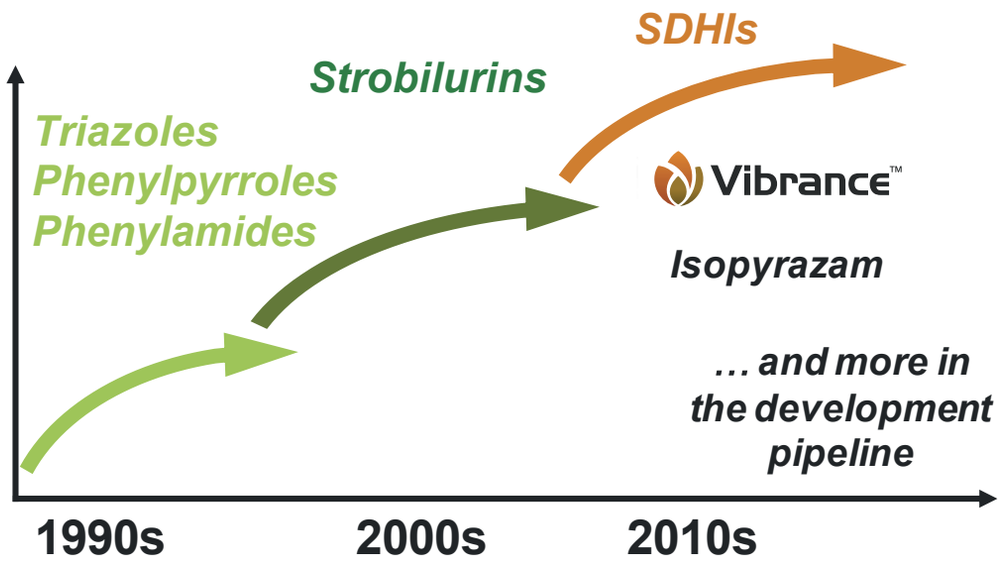
Strategies to ensure stronger, healthier roots include seed treatment to protect root systems against soil-borne diseases. At Syngenta, this research direction has resulted in a new active ingredient designed specifically as a seed-applied fungicide

Researchers at Syngenta are applying this knowledge through new seed treatment advancements. They have developed a new, proprietary fungicide that, through its new mode of action, creates unmatched broad spectrum disease protection. Field trials on all major crops under a range of conditions confirm that this leads to a stronger, healthier root system that helps produce better plant emergence and stronger crops. As a result, researchers are finding that crops are better able to withstand the stresses of the growing season to deliver higher yields and quality. It is the first time in the company`s history that Syngenta has developed a new active ingredient, sedaxane, specifically designed for seed treatment.

Fungicides have been used for a long time, starting from inorganic compounds such as sulfur and organic compounds such as Carboxamides. Seed treatment traditionally focused on seed-borne diseases such as smuts and bunts; however, over the past two decades fungicides and seed treatment technology has advanced at rapid pace.

Fludioxonil (in the Phenylpyrolle class of fungicides) was introduced in the 1990's by Ciba-Geigy, a Syngenta legacy company, to control soil-borne *Fusarium*,

Microdochium and others. Later, metalaxyl (a Phenylamide) was the first ingredient to control *Pythium*. Additional development of active ingredient difenoconazole (a Triazole) helped control powdery mildew among other diseases and azoxystrobin (a Strobilurin) controlled a wide range of key diseases such as ringspot, alternaria and white blister.



Evolution of the major fungicide classes

Syngenta has expanded the leading Root Health expertise of its legacy companies to help growers achieve greater yield stability across their fields with a comprehensive portfolio of products against the important diseases and pests.

VIBRANCE™ - the new addition to Syngenta's portfolio of Root Health enhancing products

Sedaxane is the new active ingredient that Syngenta has developed specifically as a seed treatment that offers long-lasting root protection for a broad spectrum of diseases. It will be commercialized under the trademark VIBRANCE

Sedaxane is a new Syngenta molecule and the first Syngenta fungicide developed specifically as a seed treatment, with the optimal combination of systemic movement and soil mobility. It has particular activity against smuts and bunts as well as snow mold in cereals. It also provides excellent long-lasting *Rhizoctonia* activity in many crops.

Sedaxane belongs to the chemical class of Pyrazole-Carboxamides. These compounds inhibit fungal metabolism by binding to the Succinate Dehydrogenase enzyme and fall into the new SDHI class of fungicides (succinate dehydrogenase inhibitors).

Syngenta will commercialize proprietary sedaxane-based fungicide seed treatment offers under the umbrella trademark VIBRANCE.

This compound penetrates from the seed into the surrounding soil and forms a protective cloud around the seed, developing roots and the lower stem. It has ideal soil mobility in a wide range of soil types from highly organic to sandy soil. Sedaxane is taken up by the entire root system.

Due to the new mode of action, it is possible to devise a proactive approach to resistance management. This means that offers based with the seed treatment VIBRANCE™ add another element to the tool kit to prevent build-up of resistance by high risk pathogens such as *Michrodochium nivale* (snow mold).

Impact of Rhizoctonia on roots and enhanced protection from offers based with the seed treatment VIBRANCE

Check

Offer with VIBRANCE

Source: Syngenta Switzerland (Stein), 2010, Rhizotrones trials, 83 days after seeding

In vivo spectrum of VIBRANCE on cereals

Seed-borne fungi	Activity	Foliar & soil-borne fungi	Activity
Ustilago nuda		*Septoria nodorum*	
Tilletia caries		*Puccinia recondita*	
Microdochium nivale		*Erysiphe graminis*	
Pyrenophora graminea		*Rhizoctonia* spp.	
Cochliobolus sativus		*Typhula incarnata*	
Fusarium spp.*		*Gaeumannomyces graminis*	

In vivo spectrum of VIBRANCE on other crops

Seed-borne fungi	Activity	Foliar & soil-borne fungi	Activity
Rhizoctonia spp. - many crops		*Sphacelotheca* - corn	
Sclerotium spp. - peanut, SB		*Phakopsora* - soya	
Phoma spp. - SB, canola		*Helminthosporium* - rice	
Macrophomina - Soya		*H. solani* - potato	
Fusarium spp. - many crops		*Colletotrichum* - onion	

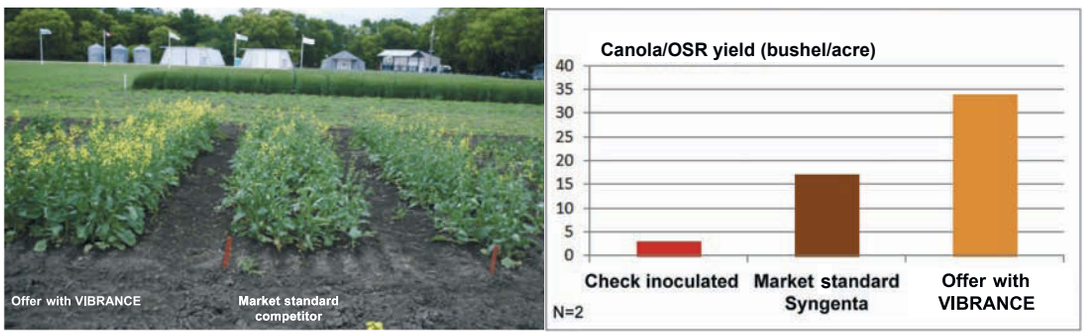
* when combined with fludioxonil

excellent | good | some effect | no activity

Source: Syngenta

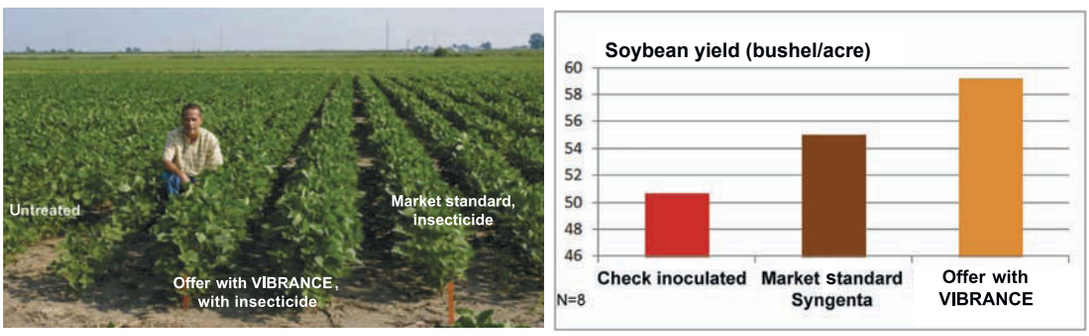
Outstanding *Rhizoctonia* activity was observed in many crops. Tested rates are in general between 2.5 and 20g/100 kg seed. It is important to note that *Rhizoctonia* is a highly variable pathogen and many trials are needed per crop to confirm rates. Overall, the trials conducted to date support the view that sedaxane is highly active on many crops, often better than current market standards.

Performance of offers based with the seed treatment VIBRANCE™ against Rhizoctonia solani on canola/OSR in artificially-infected trials in Canada



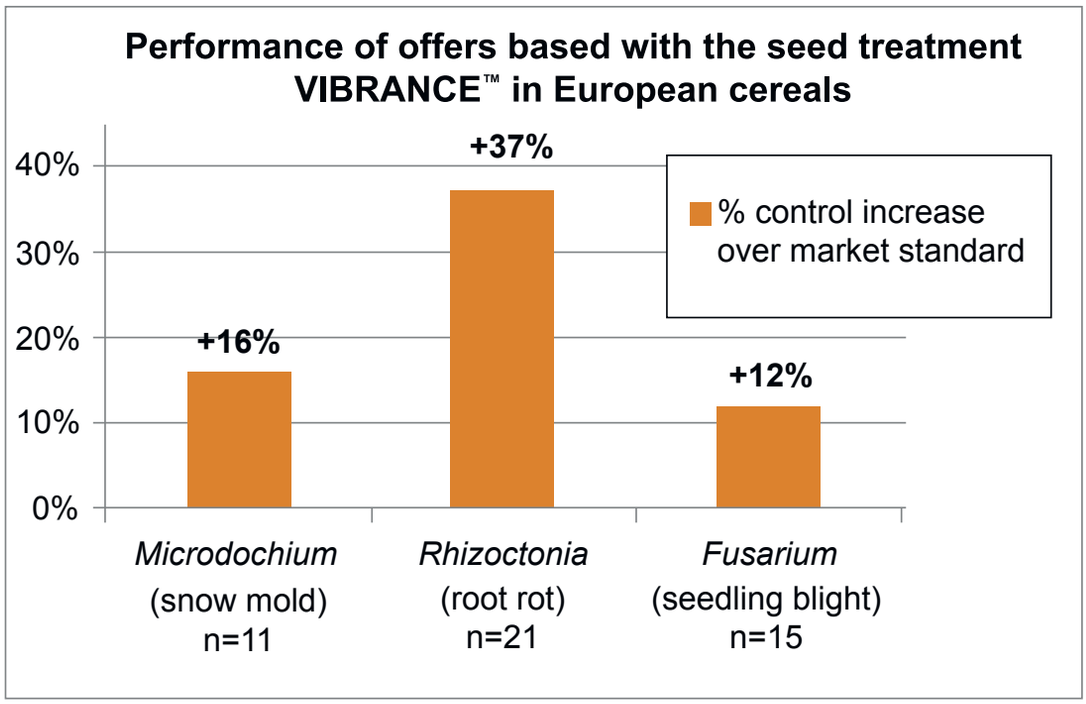
Source: Syngenta, Canada

Performance of offers based with the seed treatment VIBRANCE against Rhizoctonia solani on soybean in artificially-infected trials in the USA



Source: Syngenta, USA

Broad spectrum protection offers based with the seed treatment VIBRANCE will provide the next level of protection against many difficult-to-control diseases



Source: Syngenta, Europe field trials, 2009-2010

Root Health – the long-term opportunity to improve yield

Experts see significant, long-term opportunities for research that will result in new solutions underneath the soil line. Now is the time to take a holistic view of the plant, including the roots

Industry experts and scientists have recognized that roots hold the key to the next green revolution. However, they also recognize that this is just the beginning and that there is still a great deal of work to be done before the industry will have an in-depth understanding of the complex world underneath the soil line. As one participant succinctly concluded at the Global Root Health Forum, "We are at the beginning of our knowledge. We know the pathogens, but not the interactions and disease complexes."

Despite increased awareness within the scientific community, Root Health remains a relatively low priority for the grower. Yet if we are to take the next step in maximizing yields, now is the time to look beyond soil pathogens and take a holistic view of the plant, including the roots. This means integrating solutions such as seed treatment with agronomic practices and carefully selected genetics. By reaching the root zone directly, new seed treatment technologies such as VIBRANCE ensure strong, healthy plants with robust root systems. These healthy roots, in turn, will help maximize yield, underpinning a good return on investment.

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References

Gewin, V. 2010. An underground revolution. *Nature* 466: 552 - 553.

Kendall, H.W., and Pimentel, D. 1994. Constraints on the expansion of the global food supply. *Ambio* 23: 198-205.

Pimentel, D., C. Harvey, P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Sphpritz, L. Fitton, R. Saffouri, and Blair, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science* 267: 1117-1123.

Rothrock, C. S. 1992. Tillage systems and plant disease. *Soil Science* 154:308-315.

Rovira, A.D. 1990. The impact of soil and crop management practices on soil-borne root diseases and wheat yields. *Soil Use and Management* 6(4): 195 - 200.

Find more

About Root Health, seed treatment and VIBRANCE™

http://insidemob.mobi/vibrance

Global Root Health Network

Or contact Christian Schlatter, Global Seedcare Asset Manager, christian.schlatter@syngenta.com

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