working draft

Restoring Our Heritage Of Wheat

John Barleycorn by Mary Azarian

Join generations of farmers who saved their own seed to create the food that we eat today.
It takes a community to grow a loaf of bread!

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Introduction

Modern wheat is the most widely grown crop on the planet, yet 'green revolution' wheats cannot feed a growing planet[1] as we face unprecedented climate change, nor meet criteria of burgeoning local food movements. Modern wheat is bred by industrial breeders for mega-farms dependent on agrochemicals. Nutrition is neglected. Flavor is forgotten. Genetically diverse landrace[2] wheats, selected by traditional farmers over millenia, give robust stable yields in organic systems and have rich, delicious flavor. As climate challenges present new stresses, greater biodiversity introduces dynamic resiliency for stable wheat production to meet local and global food needs.

'Northeast Organic Wheat', funded by NESARE, brings together a multi-state team of farmers and bakers to develop wheat varieties adapted to the Northeast. We are trialing landrace wheats, involving farmers in on-farm selection and integrating small grains into ecological cropping systems. After three years of trials, we have observed that European landrace wheats from climates similar to our consistently yield higher in organic soils than the modern commercially available varieties.

The Problem with Conventional Fertility

Conventional systems are maintained in a state of nutrient saturation, inherently leaky from a chronic surplus of nitrogen and phosphorus.[3] Although conventional wheat has high protein, the synthetic fertilizers decrease the soil-plant agro-ecosystem, depressing beneficial soil biota such as earthworms and myccorhizae. Modern wheat is dwarfed to not lodge under intensive agrochemicals. Stunted root systems limit nutrient uptake functions.[4] The quality of grain protein from synthetic nitrogen differs from the slow-release of nutrients in organic soils, and may be related to the burgeoning of allergies to wheat gluten[i] Good nutrient management combined with organic-adapted varieties is the foundation for producing stable yields with quality protein.

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[1]The diet of three billion people worldwide, who depend on wheat as a primary source of micronutrients, is nutrient deficient. Although wheat **yield** has increased through 'green revolution' breeding, concentrations of minerals, ie copper, iron, magnesium, manganese, phosphorus, selenium and zinc except calcium have **decreased**. S. Jones, WSU

[2]A 'landrace' is a population of plants or animals that has evolved over generations of natural and human selection to be well adapted to local conditions. Landrace populations, domesticated by traditional farmers in their centers of origin, carry wide genetic diversity. The diverse traits of landrace wheats enable us to save seeds of the plants with the traits we seek, and to develop new varieties best adapted to our farms.

[3]Nutrients in Agroecosystems L. E. Drinkwater1* S. S. Snapp2 1 Cornell University. Ithaca, NY 14853, 2 Dept of Horticulture, 440A Plant Soil Sciences . MSU, East Lansing, MI 48824-1325, snapp@msu.edu

[4] SongYN, Zhang FS,Marschner P, Fan FL, Bao XG, Sun JH, Guo TW, Li L (2007b) Effect of intercropping on crop yield and chemical and microbiological properties in rhizosphere of wheat Biol Fertil Soils. 43:565–574.

Organic Wheat Production combines two dynamics aspects:

1. **Nutrient Cycling:** integrating cover cropping, manure, compost and mineral inputs in reduced tillage three- year rotations, and

2. **Whole Farm Biodiversity:** evolving varieties, genepools and mixtures better adapted for organic nutrient uptake.

1. Nutrient Cycling: Integrating Wheat in Ecological Cropping Systems

Manure, compost and legume cover crops provide fertility in organic production systems. Wheat thrives best in rotations of 'cover crop – wheat – vegetables' enhanced by intercropping.[5] Building soil organic matter not only enhances nutrient availability, but improves water-holding capacity, increases the cations exchange capacity and prevents soil-borne diseases.

The nutrient budget for wheat begins by estimating the nitrogen required to optimize yield in a whole farm rotation. Hard red wheat needs about 75 lbs of nitrogen per acre, *or about* 2.0 lb of nitrogen per bushel of wheat to be produced. Soil organic matter can supply an estimated 20 lb pounds of nitrogen per acre for each 1% organic matter. Thus a 2.5% organic matter soil could supply 50 lb N. Human-grade wheat requires 12% protein and markets for up to twice that of lower protein animal feed grade.[6]

Balancing Nitrogen

Enhancing the life processes that regulate the cycling of nutrients by cover cropping and building soil organic matter reduces the need for adding nitrogen in the spring[7]. Adding too much nitrogen may cause lodging and decreases water use efficiency, resulting in serious yield reduction in dry seasons. Excessive nitrogen causes susceptibility to cold injury and to mites, an imbalance between vegetative and kernel development causing soft grains of poor quality. On the other hand, too little nitrogen not only reduces grain quality but weakens plant vigor, causing poor grain set, disease or insect susceptibility that contributes to low yield. [8] In cereals, powdery mildew, a severe disease in New England's cool, moist climate, may be encouraged by excessive nitrogen[9].

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5 Don't even think about growing wheat in the same field year after year!
6 Masoud Hashemi and Ruth Hazzard, UMass Cooperative Extension
7 for winter wheat.
8 Masoud Hashemi, UMass Cooperative Extension
9 Schafer, J.F. 1987. **Rusts, smuts and powdery mildew**. In: *Wheat and Wheat Improvement,* 2nd ed. American Society of Agronomy, Madison, Wisconsin, pp 542-584

Three Year 'Cover Crop – Wheat – Vegetable' Rotation

Year 1	Year 2 early spring	Year 2 mid-summer	Year 2 late summer	Year 3
Spring: Incorporate compost, manure, amendments Cover crop. Fall: Till in and plant grains in early Sept	Undersow with clover, mustard, etc.	Harvest wheat.	Plant late vegetables and/or fall cover crop.	Rotate different families of vegetables. Intercrop legumes. Repeat year 1.

Soil Test: Test your soil to correct nutrient or pH imbalances. Wheat prefers a pH between 6 and 6.5. If lime is limiting, minerals will not be available to plants.

Timing

Winter wheats yield better than spring types in mid-New England, and compete better with weeds. All of the wheats grown in colonial Massachusetts were winter types from France and England where only winter wheat is cultivated. Wheat originally was planted in fall and harvested in summer in the Fertile Crescent and only evolved as a spring crop to survive the harsh cold climates of Northern Europe. Not only do winter wheats develop extensive root systems for stable nutrient uptake, but their well-established root systems enable rapid spring growth that out-competes most weeds. Fertility management for fall-planted wheat starts the spring before by incorporating manure, compost and minerals for the spring-planted cover crops that will be tilled under in late summer before fall wheat planting. Early to mid-September is the optimal wheat planting period. The complex soil ecology nourished by tilled in cover crops provides slow-release nutrients for winter wheats. In the early spring under-sow frost-planted clover or mustard into the wheat field. Rotating mustards before wheat and incorporating mustard seed meal helps reduce fusarium[10].

Spacing

The number of tillers the wheat plant puts out is determined earlier than most farmers think. As young seedlings interact with the soil environment, they will generate more tillers if there is ample root space and soil nutrients. Tillering takes place even before flag leaf is visible. Stress such as drought or nitrogen deficiency at this vulnerable stage results in significant and irreversible loss of grain yield. Heritage varieties can grow up to 25 or more strong tillers, each with a seed head when provided with ample nutrients and root space when planted with 8 to 12 inches all around each seed. Seeds should be planted at a depth of 1.5 and 2 inches deep.

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[10] **Suppression of soil-borne cereal pathogens and inhibition of wheat germination by mustard seed meal. J.A. Kirkegaard1, P.T.W. Wong2, J.M. Desmarchelier3 and M. Sarwar1**1CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT 2601 2NSWA Biological & Chemical Research Institute, PMB 10, Rydalmere, NSW 2116 3CSIRO Division of Entomology, GPO Box 1700, Canberra, ACT 2601

Reduced Tillage

Mycorrhizal symbiosis with wheat plant roots contributes a significant function to plant nutrient acquisition especially in organic conditions[ii]. Decreased tillage increases mycorrhizal fungal networks intact for better nutrient uptake, enhancing nutrient concentration in grains.[11]

Intercropping

harnesses ecological principles of diversity, species interaction and natural bio-controls to foster beneficial soil-plant interactions, resulting in greater yield stability than monocropping. Intercropping wheat with legumes draws on wider pools of N and P, enhancing niche complementarity. Synergies can be intensified by planting complex plant communities within livestock rotations, mimicking the ecological diversity of niches in natural systems.

Mixtures

'Looking at the field of ripening grains, Vavilov realized that it was not a uniform wheat cultivar, but a panoply of intermixed strains of grain that formed a resilient polyculture. It was necessary to collect hundreds of seedheads for a representative sample of the vast biodiversity in a single field.'

Gary Nabhan. Where Our Food Comes From. Island Press 2009

[11] Tillage Intensity, Mycorrhizal and Nonmycorrhizal Fungi, and Nutrient Concentrations in Maize, Wheat, and Canola. Ahmad Mozafara, Thomas Ankenb, Richard Ruha and Emmanuel Frossarda a Institute of Plant Sciences, Swiss Federal Inst. of Technology (ETH), Eschikon Experiment Station, Lindau, CH-8315 Switzerland b Swiss Federal Research Station (FAT), Tänikon, CH-8356 Switzerland. ahmad.mozafar@ipw.agrl.ethz.ch

Yusef explained, 'Each plant is different. I like the taste of this one to save for seed', as he plucked a handful of seed to munch and offered me a taste, 'The plants with big heads have deep roots to reach down for the water. They're good ones. ' The seedheads were the size of small corn cobs!

Combining mixtures of different varieties with the same maturity period creates a natural buffer against diseases and pests, enhancing the populations' evolutionary capacity for resilience and complexity of flavor. A study on mixtures documented their potential to out-yield a monoculture[12]. Landrace wheats are typically composed of mixtures where one genotype dominates and others including natural hybrids occur. Traditional farmers typically combine diverse varieties together in proportions differing from farm to farm and village to village. This evolutionary process ensures yield stability over years, however lack of breeding knowledge or availability of quality varieties can limit substantial improvement of landraces on traditional farms in remote regions.

Disease Management

Organic strategies to control diseases integrate: crop rotation, on-farm selection of resistant plants, residue incorporation, staggering flowering times and seed treatments[13].

[12] Cultivar Mixtures, Cover Crops, and Intercropping with Organic Spring Wheat. University of Manitoba: http://www.umanitoba.ca/outreach/naturalagriculture/articles/wheatintercrop.html

[13]See: wheat.pw.usda.gov/ggpages/wheatpests.html, cropwatch.unl.edu/web/wheat/disease, greengenes.cit.cornell.edu/wpest.html, grain.jouy.inra/ggpages/wheatpests.html, pnw-ag.wsu.edu/smallgrains/Wheat%20Diseases.html, organicgrains.ncsu.edu/pestmanagement/wheatdiseases.htm

Common Wheat Diseases and Pests

Smut

Rust

Fusarium

Powdery Mildew

Hessian Fly

It is a great challenge to grow disease-free grains from farmer-saved seed. Great vigilance is needed. Farmers should only plant saved seed that is free of weed seed and disease with high germination vigor. Seed should be carefully cleaned for unwanted weed-seed and tested for germination after harvest (to know if the seed is worth saving) and again before planting. Seed quality can change during storage, so testing twice is smart. Fungicidal seed treatment control many seed-borne diseases but few are organic approved.

The safety of the grain for human consumption and the market value is dependent on disease-free grains. Test your grain to key quality parameters of protein, falling number and DON. *Growers who are unable to assure high quality in their saved seed should buy professionally grown seed*[14]!

Fusarium is the greatest pressure in the Northeast due to our typical rainy weather, susceptible cultivars and crop residues lift on the soil. When moisture is high at flowering and grain filling, tiny spores of Fusarium infect the spike. Grains contaminated with fusarium vomitoxin (aka DON) have reduced quality, flavor and yield. Flour mills will reject grain with more than 2 parts per million of DON. Growers recognize fusarium in the field by the bleached out white spikes that may ooze pinkish-orange spores. Infected heads have shriveled, lighter weight seeds. Prevention strategies integrate:

a. Crop Rotation – Fusarium can survive on crop residues of previously infected crops. A three year roration between cereal crops will assure complete decomposition of infected residues.

[14] Guide to Wheat & Flour Quality:http://www.wheatflourbook.org/doc.aspx?Id=201
Recommended Grain Testing Lab: ciilab.com

Even a single year non-host crop between cereals helps to reduce Fusarium potential.[15] Incorporate cover crops and diverse crops that are not hosts for fusarium and that build soil life.

b. Disease Suppressive Soil - Manage compost at lower temperatures with minimal turning over longer periods to encourage earthworm activity. Earthworm castings contain complex microbial communities that suppress fungal pathogens, and help decontaminate infected grain stalks that host fusarium. Apply disease-suppressive compost generously.

c. Residue Management - Avoid overwintering grain residues that can host fusarium. Contamination is common when wheat follows corn, especially if residues remain on the soil surface. Chopping and tilling residues enhances decomposition and decreases contamination.[16]

d. Stagger Planting Dates or plant varieties with different days to maturity to reduce risk of the entire crop being infected during flowering or grain fill, the vulnerable periods for infection.[17]

e. Post Harvest – Since Fusarium infected kernels are lighter than healthy kernels, they can be removed using a gravity table to separate out the light weight kernels A home-made gravity table can be fashioned simply by placing grain in a hand-held box and shaking it in small vigorous motions so the lighter seeds are vibrated to the lower section to be removed.

f. Fungicides - Jack Lazor, Butterworks Farm, VT, observes: 'Spraying the biodynamic silica prep on wheats reduces Fusarium.' Silica is used to supress fungal diseases, to stimulate leaf growth and to enhance ripening, however it may cause burning if the weather is very dry. Contact <jpibiodynamics.org> to order.

g . Grow and Breed Fusarium-Resistant Varieties - Growing resistant varieties is the most effective solution for organic growers. Where can we find fusarium resistant wheats? Progress

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[15] Dr. Gary Bergstrom, Cornell University, a plant pathologist and Fusarium specialist, our region's disease management expert - from his workshop and editorial contributions.

[16] Fusarium head blight and mycotoxins in cereals – potential strategies to control contamination under conservation tillage. Susanne Vogelgsang, Andreas Hecker and Hans-Rudolf Forrer. Research Station Agroscope Reckenholz-Tänikon ART, Reckenholzstrasse 191, 8046 Zurich, Switzerland, susanne.vogelgsang@art.admin.ch

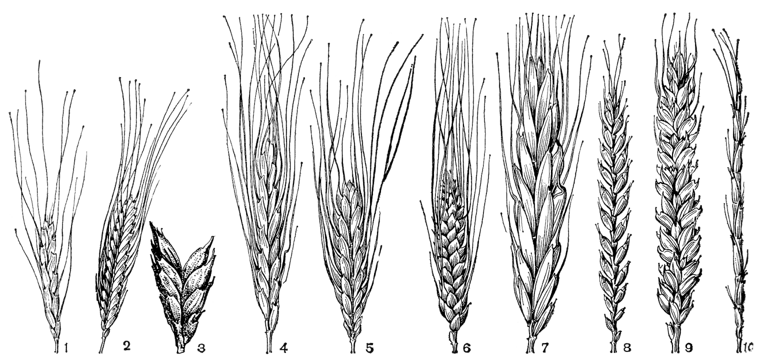
[17] Dr. Gary Bergstrom ibid

in breeding resistant wheat has been slow. To enhance Fusarium-resistance in your favorite varieties, harvest the healthiest wheat spikes on disease-free plants by hand. Rogue out infected plants and discard. This method works best with genetically diverse heritage varieties.

2. Whole Farm Biodiversity - Every Farmer a Breeder

'On-farm breeding is a combination of art and science with the emphasis on ART. That means you rely on your intuition. You don't need to generate a table of numbers and run it through a statistical program to tell you which plant to take seed from. Will you get somewhere by relying on your intuition? Absolutely!' Dr. Mark Hutton, Maine Extension plant breeder

'Today people in the industrial world are distant from both agriculture and nature. It is not surprising that few understand the power of selection. The raw material for selection is the natural genetic variation that evolved in landraces and that is created anew by mutations and adaptation. As selection is applied, plants with favorable alleles are chosen. If the non-selected individuals are removed from the population, the remaining population will have a different gene frequency from the original population and selection will have been effective in improving the performance of the population. But, no new individuals or genotypes were created. What Darwin recognized and plant breeders harness is the creative power of selection. Dr. William Tracy



Wheat Species: wild, einkorn, emmer (3,4), timopheevii, durum, polanicum, spelt, bread and aegilops

Since the dawn of agriculture, seed-saving and adaptive selection has been the right and responsibility of farmers. For over 10,000 years, heritage wheat has been the staple food for humans. Landrace seed is the living embodiment of a plant population's evolutionary and adaptive history, an ark of traits born across generations into our hands [18]. Landrace wheats have evolved over millennia of natural and farmer selection to be well adapted to local conditions and carry wide genetic diversity. Stable yields in organic conditions favor the polygenetic traits of landraces over modern pedigree uniformity. Genetically diverse populations allow for adaptation through self-

[18] Inspired by Frank Morton <wildgardenseed.com>

regulating, evolutionary natural systems that generate flexible, adaptable traits. Biodiversity is the organic farmers best defense against disease and pests, and fosters robust whole farm resilience.

The recent shift of genetic management into the hands of industry breeders has come with the hidden cost of uniformity. Commercial wheats are patented to prevent farmers from saving them. The unprecedented erosion of wheat biodiversity has resulted in dependence on a industrial-bred varieties limiting food security, nutrition and culinary art.

Liberate Diversity – Returning Seed to the Hands of Farmers

Farmers can restore the biodiversity of wheat by growing genetically diverse landraces, genepools and mixtures, and saving seed of the plants that do best in our fields. We can create **'new'** landraces from what we select, save and exchange amongst ourselves. To evolve crops that can thrive in New England, an on-farm breeding program using recurrent mass selection can increase yield, disease resistance and quality. Flavor and baking traits, unlike yield and disease resistance, are not directly influenced by natural selection. Farmers need to work closely with bakers to select varieties with delicious flavor and baking quality. Enhancing quality characteristics in a landrace population is essential for value-added organic markets. Quality seed is basis of quality bread.

Threshing Wheat in Macedonia <aegilops.gr>

On-Farm Selection Guidelines

Plant each seed one foot apart. Replicated Trials: Plant three small plots of the same size for each variety. Observe from the moment that the seed germinates. Look at the whole plant. Rogue out plants you do not want, to maintain a diverse population of traits you do want.

Traits to observe:

Early emergence____

Tillers and spikes____

Days to flowering, to harvest____

Weed suppression ____

Disease symptoms ____

Whole plant health and color____

Lodging ____

Height ____

Yield – tillers per plant, grains per 10 typical spikes____________________________

____

1,000 kernel weight ____

Quality Traits

Glutin strength by chewing______________________________________

Loaf volume____

Protein content ____

micro-nutrients ____

Flavor, aroma ____

Texture ____

Color ____

On-farm breeding is new for most of us. We invite your to share questions and experiences to build our community knowledge and skills. If you have suggestions, please contribute them to this draft!

Frequently Asked Questions

Where do I get heritage wheat seed?

The Heritage Wheat Conservancy offers varieties to serious farmers and gardeners who want to work with us to trial and multiply rare seeds. Soon enough seed will be grown out that we can share our best seed with our neighbors to build a locally-adapted community seed supply. See: growseed.org/seed.html

How do I fertilize the soil?

Provide balanced fertility with ample mineral amendments so that the plant has good fertility to achieve its full potential. Grains will "lodge" or fall over in highly fertile soil. Do not baby them. Treat the wheat like corn in your rotation. Rotate fields with a cover crop right before the wheat crop, and after, perhaps with vegetables

How far apart do I plant the seeds?

You'll receive about 100 seeds per variety from HWC. Plant each seed **ONE FOOT** apart in all directions for good root development and to observe each plant fully. Yes – one foot! The young roots will sense the greater availability of room and nutrients and tiller out to give a higher yield and develop fat seed. Plant to a depth of an inch or two by hand. Next season when you have a more ample supply, broadcast thinly, rake in or use a cultivator. Sow an understory of low-growing clover in a few weeks to suppress weeds. Third year you may have enough for equipment.

Replications: Plant three small plots the same size for **each** variety in a random pattern. Label each plot and make a map for back-up so you know what's what if labels are lost.

Will the different varieties cross pollinate?

Wheat is basically self-pollinating, like other crops that evolved in the dry Fertile Crescent, however there is a natural out-crossing of about 3 to 5%, varying from variety to variety. In a one acre trial, I found three spontaneous crosses this year so far, that look quite promising. As I walk through the field selecting the fattest seedheads from the most robust plants to save for seed, an unusual plant jumps out. Landraces are constantly evolving under the hands of nature and farmer selection.

When do I plant? **Winter wheats** are planted in the fall from late August to mid-September and put their energy into setting roots before freezing, then become dormant under snow cover until spring. A period of about six weeks of winter vernalization, freezing weather, stimulates the plant to flower in spring. The wheat is harvested in late July.

How much yield can I expect?

Each variety is different. One seed may produce from 200 to 500 seeds on the new plant. Yield is measured by the weight and size of the seed harvested from a plant. Our highest yielding heritage variety (so far) is from the southern Ukraine and northern Caucasus to Hungarian region, called Banatka. It averages 985 seeds per plant, but each plant had both large and small seedheads. We saved 2 pounds of the larger seedheads. Our harvest of two pounds this year can yield 400 pounds next year.

We encourage folks *to save the seed of the biggest heads from the healthiest plants*. In the beginning the yield is lower since you only save the largest heads but soon you'll reap abundant returns by growing varieties selected to thrive on your farm. On the other hand, the lowest yielder in our trials was einkorn, but it is drought hardy with stable yields in harsh conditions when the modern cultivars do not yield at all. If you want to try your hand at cross-pollinating to combine traits from different plants, download instructions on: growseed.org/now.html.

Weed Suppression: Weed suppression from alleopathic[19] root exudates and competition resulting from the plant height and shading is important to evaluate in organic variety trials. Planting low clover in early spring for a ground cover helps suppress weeds. .

When do I harvest? Harvest ripe seed when the plants have dried completely brown – before the birds get them! Use bird nets if possible.

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[19] Allelopathy is the release of plant-produced phytotoxins that suppress weeds.

Threshing - Dan Jason of <saltspringseeds.com> uses a wooden threshing box about 3 feet by 4 feet by 1 foot high with thin slats screwed onto the inside bottom for extra abrasion. I cut off th seedheads, examining for the healthiest, and put on an upside-down car mat on a tarp. A foot twist or shuffle over the seed heads removes the chaff from the kernels. Winnow off the chaff by pouring it on a windy day over a tarp, in front of a fan, or blow off the chaff with a hair dryer.

Each seed is a Noah's Ark of unique traits. Each person is an essential link in building a community seed system. Restoring the biodiversity of wheat varieties not only can improve the livelihoods of farmers and gardeners at the local level, but is a key link for robust local food systems for a planet facing unprecedented climate change and globalization.

Mironskaja Jubliana, one of the highest yielding varieties in our trials

Please contact Eli Rogosa for suggestions, critique and contributions to this working draft: growseed@yahoo.com

Links
http://www.attra.org/attra-pub/smallgrain.html
northerngraingrowers.org
cog.ca
ext.nodak.edu

i End Notes: Modern wheats' root system has been stunted to rapidly absorb synthetic nitrogen – a source of toxic nitrate. The slow green vegetative-growth period of old wheats has been changed to a short, quick ripening period in modern wheats. Early maturity sells. Rapid plant growth affects the grain quality and the protein quality. The nitrogen absorption process occurs too rapidly for the weakened plant to transform the agrochemical nitrogen into a form that humans have evolved to utilize. Excessive use of nitrogen fertilizer results in nitrate accumulation in the grain when the uptake of nitrate exceeds the plants' capacity for protein synthesis. The synthetic nitrogen accumulates in the gluten-protein and is toxic to animals and humans.

Overuse of synthetic nitrogen fertilizer on pasture for livestock causes '*nitrate poisoning'* an increasing common farm animal illness. Children with celiac disease have high levels of nitrate in their urine secreted from gluten. In fact, nitrate concentration in humans urine is used as a barometer to determine both the presence of Celiac disease and its severity. The urine's nitrate levels revert to normal on a gluten-free diet.

Scandinavian Journal of Gastroenterology. 1998, Vol. 33, No. 9, Pages 939-943 **Children with Celiac Disease Express Inducible Nitric Oxide Synthase in the Small Intestine during Gluten Challenge.** *K. Holmgren Peterson, K. Fälth-Magnusson, K.-E. Magnusson, L. Stenhammar, T. Sundqvist*

ii Smith F, Jakobsen I (2003) Mycorrhizal fungi can dominate phosphate supply to plants irrespective of growth responses. Plant Physiol. 130:16–20.