Title: Local organic landrace wheat programs – position paper

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Cover photo: Sonora wheat and Sonora wheat barm baguettes (2008 formulation)

Paraphrase from patent law:
No patent can be obtained that removes from public use a material or process that was known or in public use prior to the patent.

Paraphrase from monopoly law:
The public should not be confronted with zero choice as a result of monopolistic business practices.

It is human to err, but it is a waste if we do not learn from our mistakes and act accordingly.

Mistakes are the portals of discovery.
James Joyce (1882-1941)

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Chapter 1:
A history of wheat on the American continent

The origin of wheat is generally accepted to be in the Middle East, beginning some time after the last ice age 10,000 years ago. During the millennia since then it has been taken to almost all the countries on earth by explorers, conquerors and colonizers. The process of selection and maintenance of wheat varieties appropriate to each climate and soil type has been continued over a period of perhaps 6,000 years, and such varieties are often referred to as "landrace varieties". There are hundreds of these land race varieties, and they vary greatly in their appearance and agricultural character.

The American continent was only relatively recently planted with wheat. Wheat has been grown in the Americas since about 1500, soon after Columbus's discovery of America, beginning probably in Mexico and spreading quickly into South America and South Western parts of North America. Varieties grown were from the Mediterranean region and were probably immediately successful in the corresponding climate. Introduction of wheat on the Eastern seaboard, in the 1600s, was via settlers from Western Europe and again the climate and wheat types were reasonably well matched, although problems with rust abounded. The next round of wheat introduction was in the late1700s as a result of settlement in the region of California, and the varieties from Spain were well matched to the Californian climate.

Last, in the 1870s, was the successful introduction of wheat into the Great Plains stretching all the way into Canada. Success with wheat was a long time coming to the Plains. The wheat varieties appropriate elsewhere in North America, were inappropriate for the Plains with their cold, and regionally severely cold, winters coupled with very hot and humid summers. Finally the immigrants came with their wheat from a corresponding climate; they came from Eastern Europe and the Ukraine, where the climate and soil are the best match for the Great Plains.

Economic success due to wheat came first on the East coast of the United States in the late 1600s and continued until being overtaken by the wheat productivity of the West coast in approximately 1860. However the greatest economic success due to American wheat came to the Plains states by about 1880. Each of these regions continues to grow wheat, but the Great Plains States have become the modern breadbasket. This huge success in the Plains had a difficult beginning because the hard red wheat type that grew there was unlike the familiar softer white wheat varieties from the West, and the East, or the softer red wheat varieties also from the East. All wheat was milled with stones, and although there was some attempt to sift out the bran and germ to produce refined endosperm flour, the flour was usually whole grain even after sifting, in the sense that all parts of the original grain were still present. The sifting process was to remove larger particles, which meant in practice that a portion of the bran was removed, but the germ was still present having been spread onto the endosperm flour. Bread was made with a starter, which was itself fermented from the whole grain flour. The same stone milling process produced unfamiliar whole grain flour from hard red wheat. Even after sifting the brittle and finely divided hard red wheat bran remained in the flour; in particular it produced darker colored bread at a time when the ideal for bread was a light color. The wealthy were catered to and provided with expensively sifted refined flour, and the rest of the population wanted refined flour too. Fashion was such that the richly flavored and dark colored whole grain breads of Eastern Europe and the Ukraine were not sufficiently appreciated to become popular. The sheer volume of wheat being produced, suddenly, throughout the Plains generated an extremely rapid development of a milling process to remove the dark red bran, as well as the germ from the hard red wheat grain. The new milling method was *roller milling,* using metal rolls grooved especially to slice away the germ and peel off the bran from grain that had first been moisturized to ease the process. The resultant refined endosperm flour was instantly popular; the bread was whiter than people had ever experienced and had an appealing texture. In retrospect it appears that stone mills were abandoned almost instantly in 1880 all over the Western world, in favor of the new roller mills. To add to the degree of whiteness in the bread, a purified yeast isolate in combination with refined sugar, had become available and a completely new method of bread making was brought onto the scene. Somewhat later in the early 1900s, cheap fats made by hydrogenation of vegetable oils became available and were used to texturize the bread. People in the Western world were eating a totally different staple bread than had ever been eaten before. Stone ground whole grain flour and whole grain bread made with a mixed culture starter became exceedingly rare.

After the widespread introduction of roller milling the softer wheat varieties fell from favor, because their bran and germ was not so effectively removed in the roller milling system. The regions to the West and East of the Great Plains could not compete either with the sheer quantity of Great Plains wheat produced, nor with the fall from favor of their best varieties. Also in the 1800s there was a tremendous enthusiasm for hybridizing food plants. By the end of the century with the publication of Mendel's laws of inheritance, plant breeders were confident that they could produce in a plant any desired characteristic. As a result the US government started regional agricultural stations that were given the directive to "improve wheat", as well as other food crops, which was interpreted to mean the hybridization of wheat to be hard red and also capable of growing successfully everywhere, as well as the Great Plains. Confidence was such that Carleton in 1900, in his work " The Basis for the Improvement of American Wheats" for the US Government, writes: "*The possibilities for improvement by hybridization, accompanied by discriminating selection, in the hands of skillful breeders, seem to be practically limitless, especially in the case of a plant so closely self fertilized as wheat*." Indeed wheat hybridization programs continue to this day, with the aim of producing hard red wheat and more recently hard white wheat for roller milling to refined endosperm flour.

The population boom following World War II, created concern for the adequacy of the wheat supply, especially in Third World countries. At the same time the World War II chemical technologies originally developed for making poison mustard gas and explosives, were re-channeled into the making of insecticides and synthetic fertilizers. The chemical companies were eager for sales. One result of all this was the creation of a very glamorous program funded by the Rockefeller Foundation, and initiated in Mexico at the International Center for Maize and Wheat Improvement (CIMMYT). The original goal was to develop high yielding hybrids of corn and wheat for Mexico and then for Third World countries. By the early 1960s high yielding wheat varieties were being distributed in India especially. American farmers were also very interested in the possibility of high yields on their wheat. The US government agricultural research stations soon began providing similar hybrids for American farmers. Indeed, most wheat breeders around the World began breeding wheat similarly for farmers in their own countries. The high yielding attribute of these new wheat hybrids was the result of choosing wheat character that would allow intensive, high input agriculture. Normally tall wheat cannot be too densely planted or it will bend over and lodge when the wind cannot flow between the stems. Nor can a heavy dose of fertilizer and extra irrigation be used on tall wheat, because it will grow too densely and lodge unless lightly planted accordingly, which would contradict the goal of increased yield. So the hybrids developed for dense planting and generous treatment with fertilizer and irrigation, were chosen to be short in stature and with large heads. Immediately problems were recognized with short stature wheat: the weeds were usually much taller and spoiled the expected luxuriant growth of the wheat. The intense planting made the wheat more vulnerable to disease and insect attack. These problems were solved by clearing the land with herbicide before planting the wheat, and by the application of pesticides when the wheat became diseased or attacked by insects. The expectation was that the expense of the inputs would be easily offset by the increase in income from so much more wheat produced. Even now, many wheat hybrids are still being provided which are "hard red", "short" and "high yielding" under the assumption that farmers will grow them using herbicide clearance of the land, intense planting, added fertilizer, and pesticides if there is a disease or insect problem. This is considered to be the "conventional " way to farm. The original work by Norman Borlaug was rewarded with a Nobel Prize and the switch to this new agriculture was dubbed the "Green Revolution".

More recently the confidence displayed by wheat breeders has been even further enhanced by new techniques and knowledge of the wheat genome. But it appears that it is difficult and perhaps impossible to truly insert only a "single" trait, most likely because traits such as disease resistance are the result of a group of interacting genes that provide ongoing immunity. At a recent grain field day the observation was made that while inserting a gene into wheat to increase protein content, they had been surprised to find that the trait for rust resistance had also been introduced. The same wheat breeder also has the idea to look for desirable traits in wheat that might have been lost, as a result of hybridization for other characteristics. Also from this breeder, when asked to evaluate the protein pattern from a landrace wheat, he observed that the bands of protein that he would expect for a good bread wheat were missing. He actually said that he would therefore dismiss this variety. However this is the landrace variety *Sonora* that has shown great resilience in the California climate, having been grown again successfully since 1991. It has produced grain with 15.5% protein (12% moisture basis) under favorable conditions, it has been made into a very pleasing whole grain bread, and it has a following at farmers markets. To avoid embarrassment the name of this breeder is not given, also there is no doubt that other wheat breeders in similar positions would have reached all these same conclusions. Their perspective does not include the possibilities arising from consideration of a new set of criteria for wheat evaluation. i.e. towards a whole grain end product, and locally appropriate character suitable for organic farming. The need to increase wheat yield agriculturally, at this point in time, becomes moot when considering whole wheat as the end product. As much as 25% more wheat would be available as human food, if wheat was milled into whole wheat flour. This makes use of the knowledge that the process of roller milling to refined flour involves the removal of up to 25% of wheat from human use. There is also a limit to the yield possible for wheat while still maintaining the protein level required for good nutrition and bread making; both are highly dependent on the nitrogen available from the soil. Eventually the amount of nitrogenous material that can be added is governed by cost, and so presents a limit to nitrogen added to the soil. A sustainable reliably satisfactory yield of good quality wheat would seem to be the more important goal than shear yield increase.

So the impediment to producing ideal hybrid wheat, is not so much about perfecting the techniques for hybridization, as it is actually knowing which traits to bring out in a hybrid. Objective examination of the consequences of breeding for ability to produce refined flour in a roller mill, ability to make a refined flour bread and pasta, and short stature, reveals that these traits are actually dangerous to our collective well being, see Chapter 2. We should be giving new and much more careful consideration to the traits to choose for wheat hybrids. In fact we should probably hold off altogether until we properly evaluate the character of the landrace wheat varieties that have stood the test of centuries in their country of origin, and how they can be most appropriately accommodated in matching local indigenous plant and animal communities. Environmentally appropriate agriculture for the production of nutritionally valuable grain should be the primary goals. Ideas for using these appropriately grown wheat varieties in whole wheat foods abound, and the market is wide open.

The reality is that the momentum of the colossal combination of current wheat breeding programs, with the refined flour milling, yeast and baking ingredient industries, cannot be instantly changed. The suggestion here instead, is to make room, in parallel with the current wheat breeding programs, for locally sustainable (organic) landrace wheat programs that aim to produce wheat for single pass whole grain milling, whole wheat bread and whole wheat pasta, as well as other whole wheat foods. If our free enterprise system is truly functioning then there should be a simultaneous appearance of local grain handling infrastructure. Sensibly, all this should have already happened, but we still wait in 2008.

Chapter 2:
Consequences of the decision to refine hard red wheat from the Plains States, by roller milling, from 1880 onwards.

Perhaps the first consequence of aiming all wheat in the Western World for refinement in the roller mill was the fall from favor of successful landrace wheat varieties. Here are three examples:

The tetraploid cone wheat varieties (*Triticum turgidum ssp. turgidum*) are characterized by very large plants, rust resistance, and high yields of grain. However the softness of the grain caused them to immediately fall from favor with the advent of roller milling in the 1880s. Also the refined flour from *T. turgidum ssp turgidum*, apparently did not perform well in the then new refined-flour-yeast-isolate bread making system, nor was it accepted for modern refined wheat pasta. The cone wheats remain as a “gene source” and oddity, instead of the major crops that they were until the 1880s in the Mediterranean countries, especially in Spain, Portugal and Italy as well as regionally in England and France. Some countries were less rapidly influenced by the roller milling revolution, and these countries continued growing this type of wheat for a few more years. For example, in 1921 Percival records extensive cultivation of this cone wheat type in Transcaucasia, and somewhat smaller areas in Turkestan and Siberia.

In Germany, by 1900 the regionally well adapted and uniquely Germanic *spelt* landrace wheat varieties accounted for only one third of their total winter wheat crop. *Spelt* varieties possess enhanced winter hardiness in comparison with other winter wheat. For example in the exceptionally cold winter of 1900-1901, in Germany, a third of the winter wheat crop was lost compared with a loss of only one percent of the *spelt* crop. *Spelt* also possesses resistance to diseases such as rust, smut and bunt, and the tough spikelets resist attack by birds.

In California the wheat crop fell from 3 million acres in 1884 to a low of 600,000 acres by 1910. By 1919, the white wheat varieties remaining, including landrace *Sonora* and *Club* wheat varieties, made up only one third of the total Western wheat. In 2008, the total wheat crop in California was not much increased, at approximately 800,000 acres. More significant is the fact that of the total bread wheat planted, only 25% was white wheat and was totally composed of modern hybrids. California wheat breeders continue to bow to the criteria of hard wheat for roller milling to refined flour, and shorter stature for conventional farming. Over the years this has resulted in the introduction of a series of hard red and hard white wheat hybrids that fail to retain disease resistance, and have therefore been continually replaced by newly hybridized varieties. Such continual change causes great frustration to farmers, millers and bakers. A further irony in California is that farmers are encouraged to grow white wheat with a low protein, to supply bakers of short pastry, cookies and cakes, which are replete with refined sugar and hydrogenated fats. The move to remove hydrogenated fats from baked goods is recent and by no means completely accomplished as yet.

A serious consequence of developing hybrid wheat for roller milling, was and still is, the presentation of the most basic staple on earth as refined flour, and making it into refined bread and refined pasta. We now know that vitamins, essential oils, vital minerals, fiber and other nutritionally essential phytochemicals are concentrated in the bran, aleurone and germ of the wheat grain. Also we know that these are the very parts that are removed during the roller milling process yielding refined white endosperm flour. The deficiency diseases that can be attributed to the absence of B-vitamins in refined wheat flour were prevented finally, by the mandatory addition of B-vitamins in the 1940s, a full 60 years after the roller milling process first prevailed. It took another 60 years to further enrich refined flour with folic acid to reduce the prevalence of neural tube defects in the newborn and also to reduce the risk of developing Alzheimer's disease in the elderly. Folic acid is naturally present in wheat germ, and if whole wheat foods are eaten as a staple, a health-giving amount of folic acid is naturally supplied. Much more recently in 2004 the US government advocated yet again, that the most healthful way to eat wheat is in the entirely edible whole grain form, based on a very large accumulation of research data. Previously, such advice was practically ignored by the milling and baking industry, for example the recommendation to eat "whole grain" foods was changed to eating "grains", in almost all the milling and baking industry publications and in newspaper articles quite soon after the first introduction of the USDA pyramid food guide in the 1990s. Extreme disregard of whole wheat was manifested by the artisan refined flour bread movement, which also began in the 1990s. This movement significantly slowed the progress towards whole grain bread acceptance and demand that had begun in the late 1970s and 1980s. The 1990s style of artisan baking involved avoidance, at least, of bleached flours and hydrogenated fats; it was strongly supported by the yeast makers and specialty producers of unbleached and organic refined flour. The organic refined flour is very frequently devoid also of any compensating vitamin enrichment. Constipation, diverticulitis, colon cancer, coronary artery disease, adult-onset-diabetes and obesity are among the diseases that can largely be prevented by eating wheat in the whole grain form. There is more detail to preventing obesity especially, and that is adequate exercise, as well as the concomitant absence of refined sugars and hydrogenated fat, in the diet. (Also, please see Chapter 1.)

Yet another consequence has been the consolidation of milling and baking interests so that refined flour milling is performed in just a few very large mills in each state. Transportation costs are great, bringing grain to these mills and then sending the flour to the far corners of each state. This consolidation has caused the demise of local infrastructure for wheat and grain handling and whole grain milling, so that currently wheat farmers entering the market with a view to providing their wheat locally need to provide all the handling, all the way to the consumer. Local wheat production for local whole wheat products is the new ideal, to contribute to regional self sufficiency against isolating disasters. Wheat will still be imported from the Plains States to supplement the local supplies, but the availability of whole wheat products locally needs to be re-established.

Now, there is a latent demand for whole wheat foods produced organically. The difficulty for people wanting to eat whole wheat bread has been compounded by the fact that for more than 125 years bakers have not made bread in ways that properly use whole wheat flour to make appealing breads. The old fashioned bread making methods using mixed culture starters give pleasing whole grain breads, but there has been a loss of confidence in these methods, and their description has been lost; they have yet to be used in earnest again. False whole wheat flours have been concocted from the roller milling fractions of bran and endosperm. As a means of prolonging shelf life of this concocted flour, wheat germ was omitted. When the wheat germ fraction produced by roller milling is included in such flours it turns rancid rather rapidly, and the shelf life is decreased. The problem is a combined effect of grain moistening before roller milling, and isolating the germ oils from the antioxidant powers of the bran polyphenolics. In any case this concocted whole wheat flour lacks the flavor qualities of a stone ground whole wheat flour, that is milled without moistening and provides good spreading of the oily germ on the endosperm and bran. Also, whole wheat flours have been presented to bakers without adequate attention to the need for sufficient gluten protein. For truly pleasing whole wheat bread 15% protein (on a 12% moisture basis) is needed in the grain, with about 13% protein representing the minimum amount, for a good whole wheat bread. Whereas in commerce, the gluten protein in refined flour is routinely adjusted to match the end use, whole wheat flour is usually presented "as is" and frequently contains less than 13% protein. Unfortunately, this has contributed to the prevalent lack of confidence in baking with whole wheat flours. Wheat has been grown for too long without the requirement for the greater quality needed for whole wheat breads, and the lack of devoted whole wheat milling.

When wheat is short-stemmed drought tolerance is compromised, since the plant hardly reaches sufficient height to accommodate the long head if rain is inadequate and irrigation cannot be provided. The organic farmer provides neither herbicide nor synthetic pesticide, and may prefer not to irrigate, so short wheat varieties grown organically are too easily overwhelmed by weeds. In general, modern short wheat varieties are therefore inappropriate for organic farming. Appropriately selected, naturally taller, landrace wheat varieties are more likely to be farmed successfully by organic methods.

Currently there is particular concern about the rapidly increasing carbon dioxide levels on earth, and their contribution to global warming. The tendency is to consider that trees are the best at sequestering carbon dioxide to mitigate this effect, but crop plants such as wheat that cover vast areas have the potential for great capacity to remove carbon dioxide from the air, directly in proportion to their bulk. Short wheat varieties can be as little as one third of the height of normally tall wheat. Correspondingly the greenery of leaf and stem in short wheat is possibly only one third of that present in tall wheat, and short wheat is also known to have a much reduced root size. Surely this means that by planting short wheat almost exclusively, we are loosing at least half of the capacity to sequester carbon dioxide than was available from the naturally tall wheat grown before the 1960s "Green Revolution". And how much carbon dioxide sequestration is lost when herbicides are used to take out weeds, and the herbage surrounding wheat fields? Considering the vastness of areas planted to wheat, and the area cleared with herbicides, this is alarming.

Wildlife takes refuge in crop plants where indigenous plants once grew. Where wheat is grown it is likely that the indigenous plants grew tall enough to give cover to wildlife from predators. So what is happening to wildlife faced with only densely planted short stemmed wheat in which to hide and nest? An example is the Pintail duck, once the most prevalent duck in North America, which nests away from water in the shelter of the vegetation of the Prairies, especially in the Prairie Pothole region that includes parts of North and South Dakota, Iowa, Minnesota and Montana. Is the rapid decline in the number of Pintail Ducks seen since the 1950s, due to the planting of the Prairies with dense stands of short wheat, coupled with surrounding ground clearance with herbicides by conventional farmers? Would the return to tall wheat, grown organically, reverse this disturbing trend?

In conclusion: There is a need for *new local organic wheat landrace agriculture* linked with *new local whole wheat product development industry*. The benefits will be locally available whole wheat foods that may be unique in each region, increased sustainability of the wheat crop, increased carbon dioxide sequestration which will slow global warming, and increased accommodation of the locally indigenous plant and animal life, as well as increased healthfulness of the population. The urgency for this is so great that it cannot be adequately expressed. The ubiquitous production of refined wheat flour is a total mistake that must no longer be perpetuated. If there is not the will to fund the necessary localized programs with available USDA grants, then there must be legislation to phase out the production of refined wheat flour just as we are legislating against pollution. And, if the legislation is not forthcoming because of industrial lobbying, then we must sue the producers of refined flour products just as the producers of hydrogenated fats are being sued until they stop their disrespectful and irresponsible production. The current refined wheat food situation is untenable. The choice to eat truly whole grain bread in restaurants is still virtually non-existent, and have you the reader ever managed to find a restaurant pizza with a whole wheat crust? Is truly whole wheat bread available to the poor who eat bread in high proportion in their diet?

Chapter 3:
A study on wheat appropriate for organic agriculture, and whole wheat products, in California.

Introduction

An experimental wheat agriculture program was begun in 1991, as part of ongoing personal research, to understand why whole wheat bread is not normally produced and enjoyed, when it has such a huge capacity to promote good health and wellbeing.

Work on wheat followed a decade of research with natural mixed lactic and yeast ferments (barm) to make whole wheat breads. Unfortunately the existence of an overwhelming amount of information on refined flour baking has meant that it has taken until now in 2008, after more than 25 years of effort, to bring the essential elements of historical whole wheat barm bread making again to light. The difficulties have been compounded. Nobody is alive today, who can describe bread from unsifted whole wheat flour, as it was before 1880, and people now are in a state of disbelief that a food so ubiquitously available for so long, as is refined wheat flour, could be so unhealthful. People have become accustomed to eating refined flour products and evidently either become ill, or manage the deficiencies with laxatives and nutritional supplements.

To continue with the description of efforts towards a local landrace wheat program: A wide range of historical wheat varieties was obtained initially. The main source for sample amounts of wheat varieties of interest was the USDA Small Grains Collection, Aberdeen, Idaho. A few samples of other varieties were obtained from seed companies, or as gifts. By 2006, more than 70 varieties had been grown. Very early in this work one criterion for selection became white wheat of a similar type to the originally successful white wheat varieties introduced into California. In practice these were short season (spring wheat) varieties, that headed up at the end of the rainy season, in late April or early May. Most selections were in existence before the advent of roller milling in 1880. Some additional selections that possessed a particular characteristic or were a neglected wheat type were also included in the testing. Eventually the concept of *locally appropriate landrace varieties for organic agriculture* dominated the selection process. Only the taller wheat varieties that were developed before the Green Revolution of the 1960s were included, since these would be appropriate for organic agriculture that avoided herbicide and pesticide use. The shortened varieties developed for conventional agriculture dominate the present seed market, and it was realized that there was a latent need for non-proprietary wheat seed locally appropriate for organic farmers. For Californian wheat farmers, such wheat varieties were almost all white wheat varieties. In fact the dry summers in California are conducive to white wheat, which elsewhere in a humid or rainy summer would sprout in the ear. Red varieties are generally less drought-tolerant than white varieties, and give low yields in California compared to regions with higher precipitation, and they resist sprouting in the ear in summer humidity; hence their value in the Plains and other regions with rain in summer.

The location of most trials was in the San Francisco Bay Area, and the Sacramento Valley. Initially the samples were planted on land prepared as raised beds for vegetables, and with only enough seed (5-10 grams) to plant 4 feet x 8 feet plots. Seed was planted between late November and mid February, to take advantage of the winter rainfall; there was no irrigation with extra water. No scientific effort was made to add organic soil amendments, or to combine seeding with other crops such as clover and poppy, and borders of flax and alfalfa, but on occasions all these were tried. The wheat grain was obtained each year, using hand harvesting, threshing and winnowing methods until the yield per variety was approximately 25#, when mechanized methods were used. Several years elapsed before this quantity was obtained and during that time varieties that did not perform well were not further propagated. In 2003, the cold wet late spring weather was particularly conducive to rust disease. These conditions had not been encountered previously in the 11-12 years of the trials, and allowed the susceptible varieties to be recognized.

Two years later, in the season of 2004 – 2005, in order to systematically investigate rust susceptibility, a standardized trial of 26 old fashioned varieties, one recent hard white hybrid and a border planting with another modern hybrid, was carried out by Lee Jackson, University of California Wheat Specialist, and his UC Davis crew Diane Prato-Mayo and Don Stewart. A description of the method for this trial, the results and conclusions follow. From the results it was possible to identify 12 varieties of wheat that would be appropriate for organic agriculture in the Sacramento Valley, and most likely for other comparable regions throughout California.

Field test in Yolo County, California to compare stripe rust disease susceptibility, yield and protein of 26 short season old-fashioned wheat varieties

Method: Old fashioned wheat varieties were chosen with the commonality that they were in existence before 1960, and had been successfully grown previously in Yolo County, California. See Table I. Scientific evaluation of their stripe rust susceptibility was needed. For comparison, one recently developed hybrid white wheat (UC 1296) was also tested and the total plot area border was planted with the wheat variety Anza, which is also a post 1960 variety. The test site was newly disked fallow land, in the Sacramento Valley. No amendments were added, even though the soil was likely low in nutrients especially nitrogen. The plots were planned to be rain-fed, and no arrangements were made to irrigate. The total planting area was sufficient for 90 plots each 20 feet x 5 feet, arranged in a rectangle of 10 plots by 9 plots. Seeds were planted at the rate of 100 grams per plot. The planting pattern was a randomized block design with four replicates for most varieties (entries 1-19). Where seed was scarce, less than four randomized replicate blocks were planted. A tractor was used to pull a plot planter that planted nine drill rows, with 5-6 inch spacing between rows, in each 20 feet long plot.

Planting date was December 3, 2004. Harvesting was selectively mechanical and by hand, during July 2005. Mechanical harvesting was with a Wintersteiger Seedmaster Universal 150 plot combine.

Evaluation of rust susceptibility was by Lee Jackson on May 20, 2005, when the wheat grain was in the soft-dough stage. Comparison was made by estimating the area of the flag leaf affected by stripe rust, and assigning a number on a scale of 1 – 8. (1 = 0 - 3%; 2 = 4 - 14%; 3 = 15 - 29%; 4 = 30 -49%; 5 = 50 - 69%; 6 = 70 - 84%; 7 = 85 - 95%; 8 = 96 - 100%).

Yield values were calculated (pounds per acre) from the weight of clean grain obtained from the known area of each plot.

The weight (grams) of 1,000 kernels was measured.

Percent protein content of the harvested grain, on a 12% moisture basis, was determined by a standardized method at the California Wheat Commission Laboratory, under Sam Huang

A comparison of the results was used to eliminate from further propagation those varieties susceptible to stripe rust, and to determine which varieties were likely to grow with the greatest overall success, in the Yolo County climate.

Results and discussion: Field conditions precluded high yields and high protein values. Weed pressure was very great and no fertilizer of any kind was used. Since the goal of the investigation was to compare wheat varieties under the same agricultural conditions, these problems were not an impediment. The mean comparative yield was 340 pounds per acre, obtained from the 19 varieties that had been planted in 4 replicate, randomly placed plots, and is well below that to be expected under favorable farm conditions. No attempt was made to correlate yield values obtained, with those expected under optimized farm conditions.

The results are listed in Table I.

Selection of varieties appropriate for continued propagation was based first on ability to resist stripe rust. Those varieties with more than 3% stripe rust infection were not further considered. Varieties showing mean comparative yield values below 250 pounds per acre were also excluded from further propagation. The exceedingly low yield from Mauri wheat was due mainly to the effect of the very large seed planted, such that only half as many plants could be produced in each plot, compared with several other varieties. All plots were planted at 100 grams per plot. Spelt wheat varieties were harvested as spikelets, and so for a more meaningful comparison of yield approximately 70% of the observed yield might be equivalent to the grain produced. Of the two durum wheat varieties Durum-Iraq yielded 439 pounds per acre whereas Durum-Iran yielded only 267 pounds per acre, so the latter was also discontinued from further propagation. In comparison, the UC 1296 new variety was resistant to stripe rust and yielded 365 pounds per acre, which is higher than the mean of the 19 varieties considered for the calculation of the mean comparative yield. A total of 12 varieties could be selected for continued propagation based on stripe rust resistance and yield ability. See Table II. These 12 selected varieties compared favorably with UC 1296 with respect to both stripe rust resistance and comparative yield.

The 1,000 kernel weight is an indication of relative kernel size and is useful for considering how the grain can be used. For example in planting a selected number of seeds per acre. The value is interesting for the whole grain bread maker, because the larger grain size gives a whole grain flour with a somewhat reduced amount of bran compared with a small kernel size. A very low 1,000 kernel weight would indicate shriveled or inadequately filled grain. In no case was the kernel shriveled, which would have been reason to discontinue propagation.

The selected varieties for continued propagation in Yolo county, Table II, included five hexaploid white common wheat varieties (*Sonora, Wit Wolkoring, Chiddam blanc de Mars, Jammu, Foisy*); one hexaploid purple common wheat variety (*Ethiopian Blue Tinge*); two hexaploid spelt wheat varieties (*Switzerland, Spain*); two tetraploid durum wheat varieties (*Iraq, Blue Beard*); and two tetraploid turgidum wheat varieties (*Maparcha, Akmolinka*).

Other observations: Plant height was not especially measured, but the approximate height with respect to a 5 feet 9 inch height person was noted. Close to harvest time: the modern hybrid white variety *UC1296* was knee high and the tallest *Akmolinka* was waist high. In other years and other fields the overall height is much increased and the relative height order changes somewhat. However the heights recorded demonstrate the great difference between the tetraploid turgidum wheat varieties and the example modern white hexaploid wheat, which was designed for conventional agriculture. In the case of *Chiddam Blanc de Mars* and *Ethiopian Blue Tinge*, when they were fully ripened and well dried in the field the heads curved over very strongly to give a much reduced effective height for combine harvesting. These latter varieties will be continued at least for the near future because they are both comparatively prolific, and they may grow tall enough in other regions in California with more rain in winter. Ideally the height should be such that the wheat heads are well above the weeds, so that the combine harvester sickle bar can be set high and yield a crop relatively free from weed seed. It would be even better to have concomitant reduction in weed pressure with suitable crop rotation or co-cropping.

Lodging was not a problem in this sparse harvest, for any variety.

Conclusions: From our wheat collection, 12 old-fashioned and naturally taller varieties were demonstrated to be relatively resistant to stripe rust, and to yield well enough to justify further propagation, in the climate of Yolo County, California.
Much more research is needed to discover the details of the most favorable ecology for each variety. The ecology is meant here to include at least soil description and content, crop rotations, localized wildlife and climate. Ideally conditions should be such that a high protein (13-15%) crop is produced, in satisfactory yield for a just return.

Table I.Wheat variety evaluation 2005, summary of results.

Source or ARS ref. number	Sample entry number	Name	Yield (lb/acre)	1000 kwt	Stripe Rust	Protein 12% moisture basis
UC Davis	1	UC 1296	365	37.7	1.0	6.73
CItr 6111	2	White Australian	256	31.9	6.5	8.00
UC Davis	3	Federation (UC Davis)	238	28.5	4.3	7.49
P I 347132	4	Mauri	113	44.4	1.0	8.96
CItr 3036	5	Sonora	288	28.5	1.0	7.92
CItr 4066	6	Little Club	198	20.7	4.8	8.14
CItr 1697	7	Baart	327	40.3	5.0	8.38
CItr 4733	8	Hard Federation	359	31.6	5.3	7.62
1 PI 347864	9	Spelt - Switzerland**	478	25.8	1.0	8.34
CItr 8380	10	Turkey	236	31.0	6.3	8.71
PI 479660	11	Wit Wolkoring	291	27.8	1.0	8.12
CItr 4067	12	Pacific Bluestem	221	30.8	5.3	8.68
1 CItr 7327	13	Chiddam Blanc de Mars	395	27.8	1.0	6.84
4 PI 116232 5 PI 108979	14	Tuscan mix	439	30.7	6.5	7.90
7 CItr 7289	15	India 44 (Jammu)	283	29.7	1.0	7.59
3 PI 125343	16	Maparcha	517	29.0	1.0	6.76
4 PI 438971	17	Akmolinka	448	32.8	1.0	9.94
4 PI 481581	18	Durum - Iraq	439	38.0	1.0	8.88
J. George	19	Blue Beard	567	34.2	1.0	8.50
1 CItr 5246	20	Foisy	623	24.4	1.0	9.35
8 CItr 7291	21	India 45	49	27.1	1.0	7.77
PI 348428	22	Spelt - Spain**	639	30.5	1.0	10.34
D. Jason	23	Ethiopian Blue Tinge	583	29.3	1.0	9.20
D. Jason	24	Khapli	234	25.7	1.0	10.17
5 PI 243838	25	Durum - Iran	267	29.7	1.0	8.59
D. Jason	26	Red Fife	211	22.3	1.0	9.10
D. Jason	27	Bishop	211	24.2	2.0	9.44
		Mean*	340	31.6	2.9	
		CV*	42.8	8.7	27.2	
		LSD (.05)*	210	3.9	1.1	

*Mean, CV, and LSD based on results for entries 1-19, all of which had 4 reps.

Stripe rust rating scale (area of flag-1 leaf affected):

1 = 0-3%, 2 = 4-14%, 3 = 15-29%, 4 = 30-49%, 5 = 50-69%, 6 = 70-84%, 7 = 85-95%, 8 = 96-100%.

** harvested in husk

Table II. Wheat varieties selected for resistance to stripe rust and comparatively favorable yield, in trial 2005, Yolo County, California.

Source or ARS ref. number	Wheat Variety Name	Wheat type (ploidy) (Triticum variety, by Percival)	Landrace, cultivar etc (Year collected)	Source Country
CItr 3036	Sonora	White wheat (6) (*T. vulgare var. Delphi*)	Cultivar (1907)	Durango, Mexico
1 PI 347864	Spelt 42 – Switzerland[1]	Spelt wheat (6)	Landrace (1970)	Bern, Switzerland
PI 479660	Wit Wolkoring[2]	White wheat (6) (*T. vulgare var.leucospermum*)	Cultivar (1983)	South Africa
1 CItr 7327	Chiddam Blanc de Mars	White wheat (6) (*T. vulgare var. albidum*)	Cultivar (1924)	Ville-de-Paris, France
7 CItr 7289	India 44 (Jammu)	White wheat (6)	Landrace (1923)	Jammu and Kashmir, India
3 PI 125343	Maparcha	Turgidum wheat (4)	Landrace (1937)	Laghman, Afghanistan
4 PI 438971	Akmolinka	Turgidum wheat (4)	Cultivar (1980)	North Kazakhstan, Kazakhstan
4 PI 481581	Durum - Iraq	Durum wheat (4)	Landrace (1983)	Iraq
J. George	Blue Beard[3]	Durum wheat (4) (*T.durum var coerulescens*)	Unknown	Unknown
1 CItr 5246	Foisy	White wheat (6)	Cultivar (1916)	Beaverton, Oregon, USA
PI 348428	Spelt 9/58 – Spain[1]	Spelt wheat (6)	Landrace (1970)	Oviedo, Spain
D. Jason	Ethiopian Blue Tinge[4]	Purple wheat (6)	Unknown	Ethiopia

1, Spelt was harvested as spikelets. Actual grain yield is approximately 0.7 of spikelet yield
2. Obtained under impression that variety was the same as *Wit Wol Koren* as described by Percival in 1921, and therefore that it was an old variety.
3. Originally selected by J. George for appearance and suitability for wheat weaving, from landrace collection being grown out at UC Davis approximately 1990.
4. Brought from Ethiopia by D. Jason.

Table III. Approximate mature plant height in increasing order.

Wheat variety	Approx. mature plant height, inches	Ht. vs. person 5feet 9inches
UC 1296	20	knee
Chiddam Blanc de Mars	20	Knee
Sonora		
Wit Wolkoring		Knee to thigh
Ethiopian Blue Tinge	30	Thigh
Spelt - Switzerland		Thigh to hip
Spelt - Spain		
Durum - Iraq		Thigh to hip
Maparcha		Thigh to hip
India 44 (Jammu)	36	Hip
Foisy		Hip to waist
Blue Beard	48	Waist
Akmolinka	48	Waist

Chapter 4:
Making whole wheat bread again after 125 years of refined flour bread.

The practice of using whole wheat in cooking was widely discontinued after 1880 and there is a need to re-establish the techniques that were used before that for such foods as bread, porridges and pasta. Only bread is considered here, but some of the re-discovered methodology could be applied to the making of whole wheat pasta and to fermented porridges. Couscous is still a whole wheat product generally, but where it is not, these same techniques may have usefulness. The standardized formulation and method for breadmaking currently used in the assessment of wheat variety quality is essentially the same, for both refined flour bread and for whole wheat bread. This leads to an exclusion of wheat varieties from production which, if processed more favorably could give a pleasing whole wheat product.

The art and science of making bread with whole wheat flour and a mixed culture starter, has been superseded since 1880 by the making of refined wheat flour bread with purified yeast and refined sugar. Few references are available that describe bread making in detail before this date and in many cases the recipes have been “adapted for modern ingredients” when the recipe has been re-published. In any case the word “flour” has always been generally considered as the flour available, which re-emphasizes the current need to understand and describe flour as *whole* grain, or not. Similarly the “yeast” or “barm” took on a new meaning when modern purified yeast was invented. We can recognize in retrospect that both of the British words “yeast” and “barm” referred to a mixed culture bread starter (leavening). However when the microorganism causing the most gas production in bread was finally identified, just a few years before roller milling came into vogue, it was given the name “yeast”. The word “barm” continued in use, but only until about 1930 in Scotland, to describe the mixed culture leavening of bread. Jago in 1911, describes the use of a “barm” for bread making and it is the most historically likely information. The description of a barm by Jago affirms the concept that barm methodology is characteristic, and distinguishable from other sourdough starters.

To state the obvious, whole wheat flour contains the bran, aleurone and germ together with the endosperm. Refined flour contains only the endosperm. Therefore, in considering breadmaking with whole wheat flour the properties of bran, aleurone and germ need to be addressed; they occupy about 15% of whole wheat flour. In practice up to 25% of the whole grain is removed to make refined flour. Modern insight endows the bran with high water holding ability, antioxidant polyphenolics, and an inability to be digested by human digestive enzymes or by lactic bacteria, hence its description as insoluble fiber. The aleurone layer contains a wide range of enzymes that are mobilized when the grain is soaked as the first step towards sprouting, and these are directed towards oxidation and the breakdown of starch in the endosperm and non-digestible (by humans) carbohydrate polymers that are present in the aleurone. These latter are also known as *soluble* dietary *fiber* which is easily attacked by lactic bacteria, and is therefore valuable a part of our diet. Both starch and soluble fiber are broken down somewhat, into simple sugars, by these enzymes. The aleurone enzymes also release minerals, needed for the sprouting plant. The B-vitamins necessary for proper utilization of the sugars are also supplied in the aleurone layer. Similarly humans need these B-vitamins for the proper utilization of sugars in the body. Wheat germ is rich in oils and antioxidant tocopherols that naturally protect them from premature oxidation as well as more enzymes and B-vitamins, especially folic acid, needed for the proper development of the plant. It is no coincidence that people need these same nutrients for healthy reproduction.

Bread texture is essentially due to the gluten protein fraction in the endosperm. Whole wheat bread making must accommodate at the very least, dilution of the texturizing gluten, by the bran, aleurone and germ. The first requirement before assessment of whole wheat bread making potential for a wheat variety, is therefore to have grown the wheat under conditions that provide enough gluten. In practice this is ideally 15% or more total protein, and 13% protein a reasonable minimum. Currently wheat is grown predominantly for yield. Protein content much lower than this is accepted as satisfactory for refined flour bread making, from refined flour.

Whole wheat bread making methodology requires accommodation of the bran, aleurone and germ properties. Successful methods harness the naturally occurring enzymes to favorably alter these components. Leavening with a lactic ferment in symbiotic association with acid tolerant yeasts, provides an acidic environment that controls some of the enzyme activity. With a mixed culture ferment of this kind the bread has an enhanced shelf life and greater flavor complexity unknown in a yeast leavened refined flour bread. Barm bread methodology involves a mixed lactic and yeast ferment, in the presence of salty water or highly mineralized drinking water; and a mash, which is hot water treatment that enables controlled enzyme activity. The salt or minerals in the water modify the gluten and enzyme proteins, provide cofactors for the enzymes, and exclude unwanted microorganisms. Historically, the art of making whole wheat breads involved the creative use of these three basic requirements to produce a wide range of whole wheat breads from a wide range of wheat types.

The barm bread recipe 2008 (www.sustainablegrains.org) is the outcome of development and study since 1982. The fermentation is due to a mixed and symbiotic culture of yeasts and lactic bacteria and was developed from the natural microflora on whole wheat. The majority microorganisms in both a whole wheat barm and a whole rye barm similarly made, have been identified as *Saccharomyces dairensis* and an unusual *lactobacillus brevis*. *Saccharomyces dairensis,* in the wheat and rye barm starters, was identified by Herman Phaff at UC Davis in the early 1980s. The majority *Lactobacillus* sp. was isolated and identified a little later. At the time it was a revelation that these two microorganisms could be found in a sourdough produced from wheat sprouts, ground into a doughy mass; they differed from the San Francisco sourdough microorganisms that had been identified in the 1970s. Salt (part of the total bread content) added to the leavening barm, and the acidity of the lactic fermentation, exclude unwanted microorganisms. The mixed culture ferment provides flavor complexity, acids that protect the bread from molds so giving the bread a prolonged shelf life, and stability for the B-vitamin thiamin, among others properties yet to be appreciated. The mixed culture is a natural pro-biotic which is not entirely killed during baking. The whole grain bread itself acts as a pre-biotic.

Chapter 5:
Making landrace wheat seed available in California and the founding of the Whole Grain Connection, non-profit.

The non-profit *Whole Grain Connection* was founded in 2000, primarily to provide appropriate wheat seed to organic farmers, locally in California, given that the seed that organic farmers were forced to buy, was exclusively developed for conventional agriculture and was inappropriate. Briefly, organic wheat for whole wheat end products is best produced organically in order to avoid the risk of absorption into the seed oils of pesticides, or the coating of the bran with fungicides. Since the 1880s and the advent of roller milling wheat has been hybridized to be hard and usually red, whereas in California the favored landrace varieties are white. Also whole grain breads made with white whole wheat are much lighter in color, than when they are made with red wheat. Thus white wheat is a desired and interesting type for whole wheat products. Our work from 1991 revealed this total situation, and with the cooperation of more than the 6 farmers mentioned in the catalog for 2004-2005, seed from interesting wheat varieties was eventually made available in quantities sufficient for full scale farm equipment use. Most of the wheat varieties available to organic farmers through the *Whole Grain Connection*, have been white varieties that were grown in California before the Green Revolution of the 1960s, and several were grown there before 1880. The selected varieties were originally obtained from the USDA small grains collection in Aberdeeen, Idaho in very small amounts (5-10 grams). The task of the Whole Grain Connection has been to propagate the most successful varieties until large enough amounts, more than 100 pounds, were obtained for full scale farming.

After farmers received the first 100 pounds of a variety they continued to grow the variety and could sell seed in sufficient quantity to other interested farmers. The catalog of wheat seed available in this way is available at www.sustainablegrains.org. Seed sales have given some support to the *Whole Grain Connection* program, but this is not projected as a commercially viable activity. Hence the establishment of a non-profit enterprise that could engage in the research and provide landrace seed as a public service. The catalog has not been rewritten since 2004, but has retained relevance.

The new 2008 catalog is planned to offer seed from varieties that have been demonstrated to be resistant to stripe rust, and selected as a result of the studies presented in Chapter 2. This year most of these varieties are being propagated at the Agricultural Research Service station in Tulelake, California. *Sonora* wheat growing there is being observed for quality control. In addition organic *Sonora* seed will be available from the two farmers growing *Sonora* in Yolo county, Paul Muller and Sally Fox. Experience this year has given us further insight into the wheat-lodging phenomenon. The taller wheat varieties lodge when the plants grow too closely together. Therefore we shall be recommending planting at the rate of only 60 pounds per acre when the conditions are likely to produce a greatly tillered crop. The latter occurs when the soil is richly fertilized, and well watered and sometimes after mowing or grazing. The observation argues well for learning how to double-crop with wheat.

Spelt wheat cannot be offered in the catalog yet. The propagation of spelt requires a longer growing season than we have been using for the other varieties. We also need to accommodate the spikelets in suitable planting equipment, as we scale upwards. Spelt is like rice in that it must be de-hulled, i.e. removed from the spikelet husk, before it can be used as food. Equipment for de-hulling the spelt has not yet been acquired. Perseverance towards the management of spelt is recognized as worthwhile because spelt wheat is generally disease resistant, and is not easily attacked by birds or animals. In cooler and wetter mountain regions of California the winter habit of spelt and it's winter hardiness are valuable, as is its ability to resist sprouting in the ear from summer rain; our selected spelt grain is red.

Chapter 6:
Local Organic Landrace wheat from farm to market is feasible

The value and feasibility of a local organic landrace program is being demonstrated, particularly, by two farms in the Capay Valley, Yolo County, California.

Paul Muller at Full Belly Farm, is currently growing *Sonora* wheat. The farm manages the wheat all the way to selling it as either wheat grain or whole wheat flour at Farmers Markets within the region of the farm, mostly in the San Francisco Bay area. Organic local whole wheat flour and wheat grain are rare and wanted products, and Full Belly Farm easily sells all that they produce. The one step that they cannot yet handle on the farm is grain cleaning. Fortunately there is another organic grain farmer locally who has the equipment and facility to clean their wheat, so that it is ready for milling to whole wheat flour. Seed is saved from year to year and experience each year contributes to the farm knowledge base for optimizing the *Sonora* wheat quality. Prior to 2004, the year of a local rust problem, they were growing a *Federation* red wheat variety. Not only was the *Federation* variety susceptible to stripe rust, it was a red wheat that was not so advantageous in the California climate, as the white *Sonora* wheat grown there during this last four years. The goal is to continue growing *Sonora* wheat indefinitely at Full Belly Farm, in rotation with their vegetable crops so to minimize weed pressure and maintain a high content of organic matter in the soil. Full Belly Farm also sells their clean *Sonora* wheat as seed to other farmers who would like to grow wheat organically and therefore want a relatively tall variety that is locally appropriate and non-proprietary.

Sally Fox has a farm in the vicinity of Full Belly Farm and she has grown *Sonora* wheat as a crop in most of the last 6 years. As for Full Belly Farm the one step in the process that cannot yet be managed on her farm, is the wheat cleaning. Fortunately the same local farmer can clean the wheat produced by both Full Belly Farm and Sally Fox's farm. The *Sonora* wheat grain from Sally Fox is successfully sold locally in the bulk department of a local Co-op Supermarket, in Davis, California, and also as seed to other farmers. These activities illustrate the latent demands for locally produced organic whole wheat, and for non-proprietary landrace seed in amounts appropriate for farmers using full scale equipment.

After managing simply to grow a landrace wheat variety such as *Sonora*, work has begun in the quest for a high quality wheat crop. The quality of wheat for making bread is almost entirely determined by protein content, and it was on Sally Fox's land, previously used for alfalfa, that *Sonora* with a protein content of 15.5% (12% moisture basis) was achieved. Successful whole wheat barm breadmaking with this particular crop gave us the basis for the optimal protein content for wheat destined for whole wheat bread. Our goal now is to manage the *Sonora* crop, so that a protein level of 13 – 15% will be normal. There is much research work to be done in order to manage the wheat in crop rotations and soil treatment, to achieve this high quality. Beyond obtaining a reasonable yield, the high wheat quality is acknowledged as the prime goal. On both farms in most years so far, the protein content has been too low for successful whole wheat bread making without the compensatory use of vital wheat gluten, to 15% protein, in the bread formulation.

Since the 1880 advent of roller milling for refined flour production, local infrastructure to bring wheat, and similarly other grains, from farm to table locally has degenerated to the point of non-existence. Wheat in the whole grain form is the ideal, and whole wheat flour can most sensibly be provided locally, but only if there is local grain handling and a local whole wheat flour mill. Currently there is a total lack of localized grain handling and localized whole grain milling. Each wheat region has different local needs. In sparsely populated wheat growing regions the grain handling is best divided so that the cleaning, storage and transportation arrangements are handled near the farm. Localized whole wheat mills handling pre-cleaned wheat, will be best provided in the cities because wheat is easiest to store as the clean grain, and whole wheat flour is best used while fresh. Where wheat farms are local to cities, say within 100 miles of cities, the grain handling can be consolidated either near the farm, or in the city. There are many aspects of this infrastructure that need to be learned, towards both the production of high quality whole wheat products, and the organic sustainability of the entire system. We need willingness to invest in this infrastructure, and vision to see that the investment is needed, and that as such it will be a feasible business venture.

For farmers who would like to grow wheat sustainably, organically, and for local consumption, progress to continuous annual production is almost totally hampered by the lack of supporting infrastucture. The landrace seed program which is the essential topic of this paper addresses only the first step of providing appropriate wheat seed, and in this we are only at the beginning. In presenting this paper we are seeking ways to share the tasks that are needed to achieve a localized organic whole wheat supply for all. For too long we have lived without the ability to buy pleasing truly whole wheat products as part of normally available groceries.

Part II:

Localized organic landrace wheat programs, to accommodate sustainable wheat agriculture and local whole wheat products.

i. Introduction – need for landrace wheat program as part of localized organic wheat supply infrastructure and the elements of a landrace program

There is a rapidly increasing market demand for localized supplies of *whole* wheat foods, produced organically. The localized infrastructure to support this, is almost entirely missing even though wheat is versatile enough to be grown practically anywhere. Nor is there a corresponding localized infrastructure for any other whole grain food products, yet these are the staples of our diet historically.

The total infrastructure needed consists of five main parts; seed management; farm production; grain handling including cleaning, storage, distribution and single pass whole grain milling; whole wheat food production and consumer service.

Seed management

- A localized appropriate seed variety selection program
- Localized quality control of the seed in a recognized program
- Locally appropriate organic seed variety supply in amounts large enough for full scale farming

Farm production

- Local organic farms equipped with seed planters, and combine harvesters or a collection of equipment that produces reasonably clean grain

Grain handling

- Grain handlers, local to the farm, who can complete the grain cleaning, store the grain, package the grain and distribute it
- Whole grain millers who use simple single pass mills who immediately package and distribute the whole grain flour to bakers and other whole grain food producers. In some cases the grain handler will also handle the whole grain milling, and in other cases the bakers will mill their own whole grain flour. These mills are best located in population centers so that the flour can be milled and used while fresh; this is not essential, but rather the way to provide best flavor and to take advantage of the superior storability of the grain compared with whole wheat flour.

Whole grain food production

- Local bakers and other food producers using the locally produced organic grain to make organic whole grain products

Consumer service

- Education on nutritional value and quality standards to be expected and sought after, in their locally produced organic whole grain products
- Sale of local organic whole grain products. If local farmers' market outlets or grocery stores to carry these items are missing then they need to be provided.

The landrace wheat program proposed here, aims to address the *seed management* aspect of this well justified market demand for locally appropriate, organic whole wheat products. The intention is to do so in a manner sensitive to the concurrent needs to reduce agricultural pollution, reduce the loss of wildlife habitat and reduce global warming effects.

At its core, each local organic wheat landrace program will involves the evaluation and selection of landrace wheat varieties for local appropriateness. Landrace wheat varieties are here meant to include those varieties that have been grown for hundreds of years in a particular region of the world. Unmodified selections from these landrace wheat varieties, can also be included for evaluation. Developed and hybrid seed varieties can of course be used to produce organic grain for whole grain products, but only those varieties that are already well established, perhaps for at least 75 years, and of demonstrated usefulness in the organic ecosystem should be included in the landrace evaluation program. In general wheat seed has not been developed towards both local organic agriculture and whole wheat end products, since 1880. The main source for these landrace varieties will be the small grain seed collections of the USDA. The amount of seed supplied from the USDA collections is very small, just 5-10 grams, so there is need for considerable propagation effort as well as evaluation for local appropriateness. The appropriateness will be measured by the ability to yield satisfactorily and to remain disease and pest resistant through the full range of local season variations, without the use of herbicides or pesticides, and preferably using the available precipitation, without irrigation. Other contributions to appropriateness will result from consideration of the local ecology. For example, characteristics in wheat such as tallness, presence of awns, and compactness of head can be used to advantage. Tall wheat provides wildlife cover and enhanced carbon dioxide sequestration. Awns discourage attack on the wheat by birds and insects. Compact Club Wheat heads prevent loss of grain in high wind. The expectation will be that the organic farmer, after being satisfied by the variety, will keep that same variety of wheat in cultivation on their farm for a lifetime at least, and will maintain their own seed.

Whereas current wheat research programs are highly focused on the development of hybrids, in the context of conventional agriculture, this organic landrace program will involve research beyond wheat variety selection. The total ecology favorable to wheat needs investigation. Research is needed into landrace varieties of those crops associated with wheat in rotation, or as co-crops. There is a need for deeper research into the microbiology of the soil and understanding soil with respect to such properties as water holding capacity and ability to resist erosion, mineral availability, and much more, in the absence of added synthetic herbicides, pesticides or fungicides. Being able to omit the use of these last three materials would contribute significantly to the improvement of air quality, by also making their production unnecessary. The influence of wheat variety choice, and crop rotation on local wildlife, air quality and carbon dioxide sequestration also needs investigation.

Seed management will involve the provision of quality-controlled seed in amounts large enough for use with full-scale farm equipment. This may conveniently involve working with an organization belonging to the Association of Official Seed Certifying Agencies (AOSCA), such as the California Crop Improvement Association (CCIA).

Ideally, these localized organic landrace wheat programs would be carried out by the existing agricultural extension service groups, in the Land Grant Universities.

Currently wheat research programs do not adequately serve organic wheat farmers. These landrace programs are envisaged as truly serving the interests of organic wheat farmers. Given that the organic market is fast growing and representative of the consumers desire to eat organic food, the implementation of these local organic wheat research programs, is essential.

ii. Implementation and funding localized organic landrace wheat programs

The Whole Grain Connection, non-profit organization, was set up primarily to address the need for seed management in the overall process of providing organic whole wheat products, locally. Our preliminary efforts reveal that the need for this wheat seed management is a large task that needs significant funding for a devoted and well-qualified staff, and also for equipment. Since the Land Grant Universities are already organized to provide agricultural services they would seem to be an effective group to implement and manage these new localized organic landrace wheat programs.

Now that the Integrated Organic Program (IOP), is run by the USDA and Co-operative State Research, Education, and Extension Service (CSREES), this would appear to be the right place to apply for funding localized organic landrace wheat programs. Indeed this paper has been written to provide background for such an application for funding.

Since the program by its nature will aim to be considerate of the local ecology, there should be interest in providing financial support for specific aspects of the program. A particular suggestion is that Ducks Unlimited (www.ducksunlimited.org) will have an interest in seeing the Plains replanted with naturally tall landrace wheat varieties and no further use of herbicides. This has the potential to stop the alarming reduction in the number of the Pintail duck that has occurred specifically since the 1950s. The Pintail duck previously was a majority American duck species. Similarly, the much enhanced carbon dioxide sequestering effect due to the larger landrace wheat plants, planted over vast areas in place of short wheat varieties, coupled with no use of herbicides, has the potential to alleviate the sharpening increase in global carbon dioxide that is causing global warming. Funding should be available from groups interested in reducing the global warming effect.

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