Evolutionary
Ecological Grain Production
'Less is More'

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Summary:
Evolutionary Ecological Grain Production is an approach to increase the productivity and social value of wheat by enhancing the ecological dynamics within the soil, plant and human systems. The approach can generate robust wheat plants with extensive root systems, greater adaptability to climate change, high quality nutrient-dense grains and community seed systems. In contrast to modern wheats that have been bred through a genetic bottleneck for adaptability to conventional chemical-intensive farming systems, our approach evolves wheats to achieve their potential in ecological farming systems, selecting for resilience under the weather extremes of climate change. The method involves planting landrace and modern wheat varieties spaced 12" between each seed (5 lbs per acre) in organically-managed systems, selecting elite seeds from the disease-resistant, robust seedheads and replanting year by year. When ample nutrients, root space and good tilth surround each seed, landrace wheats produced up to 20 to 40 tillers with large seedheads, resulting in stable high yields with competitive protein levels for artisan grain products.

The key practices of *Evolutionary Ecological Grain Production* include:

- **soil** - incorporating generous compost, organic matter and minerals
- **seed** - use of landraces and genepools (modern x landraces) planted at a 12" spacing for on-farm selection of the healthiest seedheads for replanting
- **cropping systems** - incorporate cover crops prior to seeding wheat and intercrop legumes
- **community seed systems -** exchange seeds selected to thrive under local conditions

Ecological Crop Improvement Methodology:
Ninety-six populations of landrace grains procured from traditional farmers in Europe and from the USDA genebank were screened under organic management in the fall of 2008. 15 of the elite populations were planted in the fall of 2009 in 4' x 50' plots x three replications, at 12" spacing per seed, or 5 lbs per acre, under organic management and selected over a three year period. Plants with complementary traits of landraces with exceptional flavor and resilience x sturdy stalks were crossed to generate genepools. Clover was planted to suppress weeds in early spring. In landraces the number of tillers and percent of dominant seedheads differs from variety to variety. At a 12" seeding rate, the landrace plants we evaluated generated from 20 to 50 seedheads according to the following break-down per plant: 20% of the seedheads tended to be large and dominant with sturdier stalks than the other tillers, 60% were large seedheads, and 20% were less filled out. Each year the dominant seedheads from the most disease-resistant and highest yielding plants were selected for complex linked traits and replanted. Plants were

scored for lodging, tillers per plant and seeds per tiller, protein and minerals. In the third year grains will be tested for falling number and fusarium - DON. In addition, each year new genebank accessions and material collected from Europe are screened.

Seeding Rates:
In the third year comparative spacing trials were planted at 8″ and 6″ spacing. We observed that the seeding rate of less than 8″; ie: 12 pounds per acre was the maximum rate to achieve the benefits of this method. At 6″ spacing, 20 lbs per acre, plants did **not** produce larger dominant seedheads. At the 6″ spacing the same plant varieties were 5 inches shorter than the 8″ spacing. Modern wheat cultivars, such as Zyta from Poland and Biodynamic-bred wheats from Germany did not produce dominant seedheads at the 12″ spacing, but produced evenly distributed large seedheads.

Mixtures:
In addition we planted replicated beds of mixtures of landraces with diverse growth habits but similar maturity rates. There was an average of 5% higher yield in the varieties in the mixtures over the plots with individual varieties alone. This may be due to decreased competition for light in the vegetative portions and/or complementary root system dynamics.

Evolving Landraces:
Every year spontaneous crosses or mutations were found in the fields. In year 1, three plants of 'Canaan Rouge' were found in a field of Rouge de Bordeaux and multiplied out to generate a new variety. In the summer of 2011 5 new promising genotypes were found from natural crosses or mutations.

Community Seed Systems: Each year a Grain Conference was conducted to exchange seed, skills and information. The circle of farmers and gardeners are developing mutually beneficial cooperation, expressing pride in their on-farm saved seed, new discoveries, uniquely developed varieties and individualized market strategies. Elite selections of all screened populations are maintained at the Heritage Grain Conservancy community seed bank, and available to the public.

Recommendations:
We recommend a general spacing of 12″ (5 lbs/acre) for on-farm crop improvement and a spacing of 10″ to 8″ between seeds (8-12 lbs/acre) for optimal yield in organic systems. A higher seeding rate than 12 lbs per acre has not generated the large seedheads in our trials, but decrease yield per plant. Since specific seeding rate recommendations vary from variety to variety, we advise that each farmer conducts on-farm trials to determine optimal seed rate for a variety according to your soil and fertility management practices, and to select for preferred traits. Contact the author for details.

Conclusion:
After three years we have observed an increased adaptability to weather extremes as measured by less lodging under heavy rain and greater tolerance to drought stress as measured by leaf color and overall plant robustness, a reduction in seed requirements (up to 95%), and stable high yield with competitive grain protein. Fusarium continues to be a limiting factor, especially

in moist seasons such as 2009 and 2011. Certain landrace varieties such as Rouge de Bordeaux and Canaan Rouge have a significantly lower incidence of fusarium. A home-made air column is being investigated to separate out the lighter infected seed. The higher yielding varieties that include: Papa Rogosa, Zaftig, Banatka and Canaan Rouge, yield between 900 to 1000 seeds per plant. The 2011 harvest yield of Papa Rogosa: planting an average of 8.8 seeds produced 1 pound of seed at 12" spacing. Complete yield charts will be included after all measurements are calculated. Baking quality testing and flavor comparisons will be evaluated in the Fall of 2011.

Climate Change Resilience

Our method integrates ecological soil management and ecological plant breeding with community seed systems. A vital soil system nourishes larger root systems. Deeper rooted plants can reach lower soil moisture, a critical mechanism to avoid heat stress, and stabilize the plant, decreasing lodging in rainy weather. With wider spacing and good soil tilth, wheat roots can grow deeper than in conventional dense spacing, enabling the plant to better survive the drought, heat and rain extremes of climate change, and produce high yielding quality grains.

Environmental benefits of the ecological crop improvement with wide spacing under organic management in comparison to conventional management include: a reduction of agrochemicals and emissions that contribute to global warming while producing competitive stable yields with good flavor and protein levels.