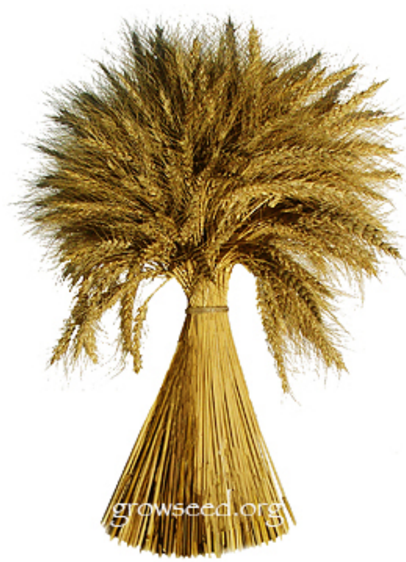
University of Massachusetts
Cooperative Extension

2010
'World Grains'

Evolving Landrace Winter Wheat for Climate Resilience, Quality and Yield on New England Organic Farms



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Evolving Landrace Winter Wheat in New England

'Current research confirms that wheat yields in organic farming systems will not be optimized until varieties are bred for and selected in organic systems. Dr. S. Jones, WSU, 2005

Project Rationale: Why Restore Landrace Grains?

Since the dawn of agriculture, farmers have been breeding landrace grains for humankind. Landrace grains are the living embodiment of a plant population's evolutionary and adaptive history, an ark of diversity born over generations into our hands. They are the expression of species interaction of the plant in its environment and the human culture that shapes it. Landrace grains have evolved over millennia of natural and farmer selection to be well adapted to local conditions and carry wide genetic diversity.

Wheat is not native to North America. The landrace diversity native to the Fertile Crescent and Europe does not exist in the village farms of New England. Modern wheat is bred for yield in conventional systems but with the hidden cost of uniformity and dependence on agrochemicals, in weather and soil conditions vastly different than New England.[1] Nutrition and flavor are neglected. Uniform pedigree cultivars lack the genetic diversity to adapt to unprecedented climate change weather extremes, and are more susceptibility to evolving biotic and abiotic pressures and disease[2]. Wheats for New England's organic systems need greater height to better compete with weeds, effective nutrient scavenging capacity in organic soils, and delicious complex flavor and quality traits for artisan breads.

Landrace wheats are an underutilized source of economically important traits for New England's burgeoning market for locally-grown grains for artisan breads. Seed diversity is the raw material for local adaptability. We procured genetically diverse landrace wheats from Europe, many are rare, some are on the verge of extinction. Our best landraces were generously put in our hands by peasant farmers in Europe, spanning France, Germany, Hungary and the Republic of Georgia, and by the USDA genebank. None of the landraces are commercially available. Our project is conducting an on-farm selection and breeding program to address growers' unmet needs for delicious, high nutrition varieties adapted to local conditions and markets. Traits that we are selecting for include: nutrient absorption efficiency, height for weed competition, durable resistances as a complex of traits that contribute to stable, competitive yields, and post harvest baking quality, nutritional value and flavor. [3] This project represents a community-based approach to strengthen our New England regional grain supply.

Project Objectives

1. *Select superior wheat genepools and varieties* best-adapted to New England organic farms for end-use in high quality artisan breads and products such as parched green wheat.
2. Implement *on-farm breeding* strategies to evolve/adapt diverse wheat genepools, and
3. Establish a *farmers' cooperative* for on-farm breeding, seed exchange and marketing development of locally-grown wheats with unique, high qualities and competitive traits.

In 2008, Eli Rogosa, Heritage Grain Conservancy, in cooperation with the University of Massachusetts Extension established an organic wheat breeding program to develop hard red winter wheat varieties that will thrive in the mid-New England climate. A breeding site was established at the UMass agronomy farm in Deerfield, MA and at the Colrain Seed Farm, Colrain, MA. Landrace wheat was procured from European researchers, peasant farmers, genebanks and cooperating European wheat breeders.

Workplan Summary:

Year 1 - Agronomic screening and crossing the best adapted landraces together to create new landraces with enhanced adaptability to ecologically-managed, organic systems	
Year 2 - Selection, multiplication, continued screening and crossing.	
Year 3 - Partnerships with organic farmers for on-farm crop evolution and seed system	

Year 1 - 2008 - 2009 - Agronomic Screening, Crossing Elite Landraces to Create New Landrace Genepools: In 2008, 96 landrace winter wheats[1] were planted in the second week of September in three randomized replicated plots 3' x 4' or according to availability of seed. AC Maxine was used as a control. Each seed was planted 12" apart. The paths were under-sowed with red clover to suppress weeds. Plots were not sowed with clover to evaluate the wheats' alleopathic root exudate-capacity to suppress weeds. In the previous year the field was sown in rye and cover crops that were tilled in one month prior to planting. The field were fertilized with composted manure from Martin's Compost, Greenfield, MA at the rate of 10 tons per acre. A summer field day was conducted that hosted 65 farmers.

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[1] The 96 populations were chosen based on the research of Nikolai Vavilov, field visits to peasant seed-savers in Europe, and were contributed by the USDA genebank and cooperating European researchers and farmers. Heritage wheats grown in 1800s New England were included.

Year 1 Spring 2009: Agronomic Screening and Selection in 3′ x 4′ Plots

Populations were evaluated for disease (fusarium, bunt, leaf/stem rust), weed suppressive capacity, architecture (thick stem, no lodging, height/weed competition), color (indicator of N-utilization efficiency), whole plant robustness, tolerance to drought/heavy rains, dates of maturity and yield (number of tillers x seeds per head) and 1000 kernel weight (density). We eliminated half of the populations, and rogued out about 60% the plants with less desirable traits from the populations with the highest overall scores. Trials were also planted at the Colrain Seed Farm that had temperatures averaging 10 degrees lower than the UMass site.

Breeding Projects:

1. ***Mirstaja***: Mironovstaja x Banatka x Bezostaja. Russian Mironovstaja has fat seed, tall stalks and excellent winter hardiness. Banatka is reknowed for baking quality. Bezostaja has sturdy stalks and fat seed. Progeny are being selected for high yield, rich flavor and baking quality.

2. ***Rogosa***: Banatka x Bezostaja. Banatka was high yielding in wet 2009 and the dry 2010 summer, but tends to lodge (fall over) in higher fertility fields. Bezostaja has a sturdy erect stalk. The progeny of Banatka x Bez are being selected for high yield with sturdier stalks.

3. ***Einka***: Delicious einkorn (*T. monococcum*) x dika (*T. carthlicum*) which exhibits higher resistance to fusarium head blight than modern wheats. Fusarium is a serious mildew-type disease that is a critical pressure to New England growers. Recurrent mass selection combined with introducing desired traits, may increase fusarium resistance in wheat[2].

Instructions on how to hand-pollinate wheat: http://growseed.org/pollinating-wheat.pdf

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[2] Current Knowledge on the Genetics of Fusarium Head Blight Resistance in Wheat - Implications for Resistance Breeding. Hermann Buerstmayr, Barbara Steiner, Marc Lemmens.BOKU-University of Natural Resources and Life Sciences Vienna, Department IFA-Tulln, Institute for Biotechnology in Plant Production, Konrad Lorenz Str. 20, A-.3430 Tulln, Austria

<u>Year 2 2009 - 2010: Segregation, Selection and Multiplication</u>:

The 15 most robust, highest yielding populations from year 1 were planted in replicated, randomized strips 100′ x 4′ at three sites (UMass, Colrain Seed Farm, SIT Farm in Brattleboro, VT). We selected intensively, saving seeds from the elite 30% of plants with the least disease, and the highest number of tillers with fat seedheads. For yield data please refer to the 2010 chart in the appendix. The fertility and soil organic matter (OM) in each site was significantly different. Colrain had the highest OM. UMass and SIT had lower OM. UMass had the highest N. The modern wheat AC Maxine yielded highest at UMass. In the lowest fertility site, SIT, the modern and landrace wheats did fair to poor, but the ancient wheats emmer and einkorn yielded the highest, exhibiting consistent stable yield under high fertility or under stress. A summer field day was conducted that hosted 70 farmers. Seeds were disseminated to participating farmers.

Year 2 Spring-Summer, 2009: Selection and Multiplication of Elite Landraces in 4′ x 100′ strips

<u>Year 3 2010-2011: Continued Selection and Dissemination</u>:

Improved populations and breeding genepools from year 2 were planted in replicated, randomized strips 100′ x 4′ at UMass and at 4 cooperating organic farms for continued on-farm selection; Cr Lawn - Colrain Seed Farm, Tevis and Rachel Robertson-Goldberg - Crabapple Farm, Adam Dole - NESFI-White Oak Farm, Ryan Voland - Red Fire Farm. Varieties with similar dates to maturity were mixed.

Eli participated in the EUCARPIA Organic Cereal Breeding conference in Paris, and the Hungarian Biodiversity Conference in which a team established an EU Cereal Biodiversity Network for exchange of germplasm and experiences.

2010 Agronomic Data

	VARIETY	Tiller/ plant	seed/ tiller	seeds/ plant	weight (10 heads)	seed weight/ plant	plants/1 lb seed	lb /acre	1000 kernel weight
1	Mirskaya	21.3	58.4	1244	28.3	60.28	7.5	5,707	48.45
2	Banatka	24.4	40.2	981	18.8	45.87	9.9	4,324	46.77
3	Novo-Ukraina	17.4	44.2	769	24.7	42.98	10.55	4,057	55.88
4	Zyta	14.7	50.2	738	26.9	39.54	11.5	3,722	53.58
5	Rouge de Bordeaux	16.5	45.6	752	22.4	36.96	12.3	3,480	49.12
6	Lutescens	17.2	49.8	857	21.2	36.46	12.4	3,452	42.57
7	Canaan	22.6	33.7	762	14.9	33.67	13.5	3.170	44.21
8	Poltavka	15.7	41.7	617	19.5	28.86	15.7	2,726	46.76
9	Rogosa	10.3	56.5	582	25.7	26.47	17.1	2,503	45.49
10	Geza	11.0	43.4	477	23.0	25.3	17.9	2,391	52.99
11	Maxine	11.2	43.3	485	21.5	24.08	18.8	2.274	49.65
12	Red Lamas	12.8	40.9	524	18.2	23.3	19.5	2,195	44.5

Note: Yield is best determined using the column on 'how many seeds will it take to produce one pound of seed, the 6th data column. *Mirstaya yields 2.5 more than AC Maxine!*

Agronomic Categories:
Tillers per plant, tillers per seed, seeds per plant, seed weight per 10 heads, seed weight per plant, how many plants produce one lb of seed, yield per acre at planting rate of 5 lbs/acre (12" spacing between each seed), 1000 kernel weight

Height
After the wheat reached structural maturity, plant heights were measured. At all locations, emmer was the tallest variety at 64 inches. The shortest variety was AC Maxine at 31.3 inches. Next shortest was Zyta at 36 inches. *NOTE: Height data will be added.*

Nutritional Analysis - 2010 Harvest

Variety	Protein	Phosp	Potass	Calcium	Mag	Zinc	Copper	Man	Iron	Boron
Emmer	18.47	0.51	0.44	0.04	0.16	45	5	32	53	1
Kavkaz	18.24	0.47	0.5	0.04	0.16	32	9	35	43	2
Maxine	18.13	0.48	0.47	0.04	0.15	47	5	38	47	2
Ukrainka	17.44	0.5	0.39	0.04	0.17	37	6	38	53	2
German	17.16	0.5	0.49	0.04	0.17	47	7	18	38	2
Lutescens	16.93	0.47	0.42	0.04	0.15	38	7	35	48	2
Freedom	16.93	0.51	0.47	0.05	0.17	43	7	37	53	2
Poltavka	16.7	0.49	0.41	0.04	0.18	37	6	36	48	2
Einkorn	16.47	0.45	0.41	0.04	0.16	67	7	51	51	3
Hungary	15.62	0.47	0.39	0.04	0.16	31	6	34	44	2
Lamas	15.5	0.46	0.45	0.03	0.15	25	6	31	43	2
Bordeaux	15.5	0.46	0.39	0.03	0.16	30	6	38	52	2
Zyta	15.28	0.45	0.47	0.04	0.15	33	8	35	49	2
Einkorn J	15.22	0.47	0.42	0.04	0.15	64	5	55	42	2
Canaan	14.93	0.46	0.38	0.04	0.16	46	6	14	38	1

Analysis was conducted at the UMass Plant and Tissue Analysis Laboratory

Year 3 - Strip Field Trials Planted September, 2010

1. Mirskaja (genepool of Bezostaja and Banatka)
2. Rogosa (genepool of Bezostaja and Banatka)
3. Banatka - Hungary
4. Mixture of Mir, Rogosa and Banatka
5. Rouge de Bordeaux - France
6. Canaan Rouge – France
7. Kavkaz
8. Mixture of Rouge de Bordeaux, Canaan and Kavkaz
9. Red Lamas – Colonial Mass/Britain
10. Poltavka - Ukraine
11. Purple - Ethiopia Zyta - Poland
12. Mixture of Lamas, Poltavka and Putple
14. Black Winter Emmer – Carpathian Mountains
15. Einkorn - Carpathian Mountains

In addition, spacing trials were planted at 6", 8" and 12" apart. 40 genebank accessions were planted for initial screening. Grain from the 2011 harvest will be evaluated for nutritional value, loaf volume, baking quality and flavor in cooperation with local artisan bakers.

Nutritional and Baking Quality Analysis

Important parameters to evaluate wheat quality for artisan breads include: crude protein, falling number, test weight and mycotoxin (DON) content. Data will be included after Year 3 harvest when there is a sufficient amount of grain to conduct the tests.

Protein is a critical factor in baking quality, influencing gluten elasticity and stretching strength, for dough with desired rheological[3] properties, ie: water absorption capacity to produce the maximum torque.

Falling Number measures the amount of time it takes for a stirring rod to fall a set distance. This is determined by the quality of starch in the kernel, a substrate for amylase enzymes that gelantinize flour and water into a viscosity, and produce sugars that support yeast activity. The falling number is an indicator of enzyme activity that influences loaf volume and bread crumb quality. It can detect damage from pre-sprouting.

Density/test weight is an indicator of baking quality. Generally the greater the test weight, the higher the flour quality.[4]

DON - **Fusarium** causes serious crop damage to Northeast wheats due to our typical rainy weather, susceptible cultivars and crop residues that host Fusarium. When moisture is high at

[3] **Rheology** is the study of the flow of matter in the liquid state and viscoelasticity.

[4] Handbook of Cereal Science and Technology, Karel Kulp, Joseph G. Ponte p.8,
Bread making: improving quality. Stanley P. Cauvain

wheat's flowering and grain filling stage, the tiny spores of Fusarium infect the spike. Fusarium contaminates the grain with deoxynivalenol (aka DON or vomitoxin) that reduces grain quality, favor1 and yield. Ben Gleason, an organic wheat grower in Vermont, states, '*Fusarium is the greatest pressure faced by New England's organic wheat growers.*' To prevent contamination of wheat food products with vomitoxin, four mills test wheat and will reject grain with more than 2 parts per million of DON. Growers recognize fusarium in the field by the bleached-out, white spikes oozing orange-pinkish spores. During wet weather, there may also be white or pink fluffy mold on infected heads. Seed can be infected with out any visible signs. Infected grain heads produce shriveled, discolored, lighter weight kernels. Guidelines for fusarium management are posted on: http://growseed.org/GiftfromGeorgia.pdf

Grain Terroir: The **ultimate test** of flour quality is if it produces a good product under the unique baking style of an artisan baker. The quality of locally produced grains are determined by the ***terroir*** of the land, the fertility, ie: nitrogen inputs that directly transfer to protein in the grain, the vitality of biological relationships in the soil, the rainfall which produces softer wheat in high rain and harder grain in less rain, and the genetic history born in the seed.

Weather

Temperature and Rainfall for UMass Farm, Deerfield, MA, 2008-9, 2009-10

2009-10	September 2009	October 2009	March 2010	April 2010	May 2010	June 2010	July 2010
Av Temp	55.9	43	37	46.3	56.1	62	70.5
Inches of Rainfall	1.4	5.6	4.6	2.3	1.9	4.0	2.2
Growing Days	700	334	164	426	726	857	1182

2008-9	September 2008	October 2008	March 2009	April 2009	May 2009	June 2009	July 2009
Av Temp	63.4	49.9	25.2	58.6	59.9	65.7	69.6
Inches of Rainfall	7.66	3.20	2.72	3.12	4.00	6.34	9.67
Growing Days	600	330	159	547	735	840	1005

**Based on National Weather Service data from Amherst, MA observer station near the field trials.*
Lat: 42 23N, Long: 72 32W *http://cdo.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl*
and http://www.mass.gov/dcr/watersupply/rainfall/archive.htm

Year 1 was cool and rainy, providing a good opportunity to screen for lodging and fusarium susceptibility. Year 2's hot, dry weather was excellent for wheat production, but did not provide moisture pressure to adapt crops to New England's more typical rainy weather. Harvest maturity was one month different between Year 1 and 2. Year 1 we harvested in early August. Year 2 in early July. The growing season's temperature and rainfall, recorded by the National Weather Service from weather stations near the UMass site, are shown in the table below. Data is for Year 1: 2008-9 and Year 2: 2009-10. Spring, 2011 in the Northeast has been the wettest March - April on record in some areas according to the Northeast Regional Climate Center at Cornell University.

Cultural Practices

The seedbed at the UMass location was prepared using conventional tillage methods. In year 1 trial plots were hands seeded. Year 2 hand-seeded or with a Planet Junior. Year 3 all plots were hand-seeded. Clover was underseeded year 2 and 3 in early spring. Grains were harvested with a scissor to select for elite plants. The remaining field run was harvested with a sickle-bar mower or hand-held serrated sickle.

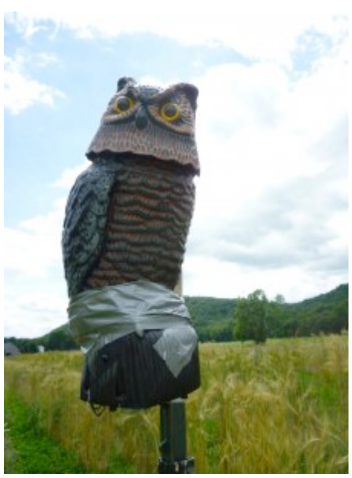
Draft 'World Grain' Publications

Guidebook: http://mysare.sare.org/mySARE/assocfiles/925516Wheat%20Booklet.pdf

How to Hand Pollinate Wheat: http://growseed.org/pollinating-wheat.pdf

Fusarium Management - Gift from Georgia: http://growseed.org/GiftfromGeorgia.pdf

Bird Pressure was a serious problem. The birds loved our grains. Without protection the grains would be lost. I placed 10 plastic owls in the fields, and changed their positions weekly. Bird nets were draped over elite genebank samples.

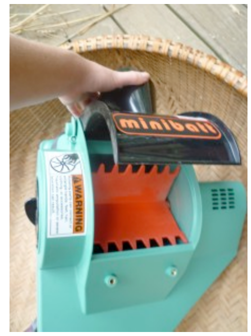


plastic owl

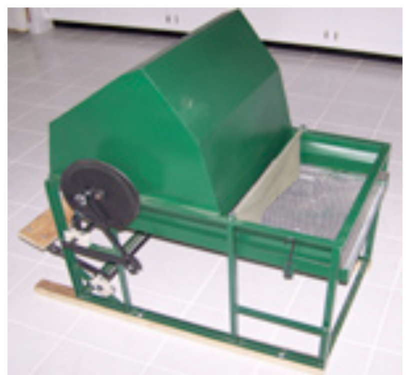
bird net protection

THRESHING METHODS

rubbing seedheads on upside-down car mat



Minibatt



Foot-powered Treadle Thresher

APPENDIX

Year 1 2008-9 Small Plot Screening

Seeds with accession numbers were sourced from the USDA GRIN genebank

1. 6401
2. 281842
3. 11463
4. RED LAMMAS 1ST wheat grown in colonial Mass
5. ZYTA Poland
6. EINKORN Haute Provence, France
7. SUKCES Poland

1st ROW

8. 272360
9. 281842
10. 272933
11. VT WINTER – Read
12. 61103
13. German Bio–Davrat
14. 251908
15. 355500
16. Estonia –Savinta
17. Rouge de Bordeaux, France
2. Melange genepool from France

2nd ROW

19. Red Lammas
20. McFadden 11463
21. 94468
22. 362024
23. 367702
24. Italian Farro, Garfagnana, Italy
25. Crete – Kostas
26. Rouge de Bordeaux, France
27. Poulard, France
3. Rouge de Bordeaux, France

ROW 3

29. 5366
30. Zyta, Poland
31. 267147

32. 267135
33. 3737
34. 254826
35. 201121
36. 326309
37. 345685
4. 499965

ROW 4
39. Haute Provence, France einkorn
40. 208455
41. 316431
42. 295348
43. 277681
44. 352466
45. 290487
46. 285883
47. 294973
5. 304093

ROW 5
49. 55559651
50. 361857
51. Zyta, France
52. 285858
53. 262610
54. Sukces, Poland
55. Rouge de Bordeaux, France
6. Purple, Ethiopia

ROW 6
57. 5366
58. 592043
59. 262614
60. 254191
61. 499963
7. Black – Jean Francois Berthelois

ROW 7
63. Melange French landrace mixture
64. 6465
65. Turkey Red
66. 5493
67. 361879
68. 35502
8. 262610

ROW 8
70. 361879
71. Maxine
72. 201131
73. 267147
74. Rouge de Bordeaux, France
75. Kavkaz
9. 361879

ROW 9
77. Black Emmer, Hungary
78. 367709
79. 3737
80. 262610
81. Swiss Landrace
10. Alsacs – JF

ROW 10
83. 251908
84. German Davret
85. 15158
86. Poulard – JF
87. Polanka – Poland
11. Garfagnana- Farro

ROW 11
89. AC Maxine, Matt Williams
90. Melange – French Mixture
91. 306509
92. 292994
12. 6000 – Crimean

ROW 12
94. Black emmer
95. Tall – Rouge de Roc
13. Melange French Mixture

Cooperating Field Site:

2009 Spring Wheat Variety Trials
Crabapple Farm, Chesterfield Massachusetts

Inventory #	Name / ID	Origin	Awned?	Average Height	Maturity Timing	Head Length	Disease Resistance 7/23	Plant Vigor (rank)
CItr 11434	25347A-1-4-11	North Dakota	90%	~34”	Mid	~3 ¼”	susceptible	3
CItr 11436	25347A-1-4-11-16	ND	95%	~34”	Mid	variable	susceptible	4
CItr 11638	26347A-1-26	ND	Yes	~34”	Mid	variable	some resistance	5
CItr 12008	MIDA	ND	Yes	~38”	Mid	~3 ¼”	susceptible	7
PI 262619	Upkli	Georgia	Yes	~34” (varied)	Mid-late	~3 ¾”	mostly healthy	8
PI 262628	Akhaltsikhis Tsiteli Dol	Georgia	Yes	~28”	Early	~3 ¾”	susceptible	1
PI 262638	Lagodekhis Grdzeltavtava	Georgia	No	~54”	Late (Winter)	4” + ?	mostly healthy	10
PI 351208	Marquis	Ontario	No	~30”	Early	~3 ¾”	susceptible	6
PI 565362	Arcadian	New York	No	~44”	Late (Winter)	4” + ?	mostly healthy	9
PI 565365	Wellman	Minnesota	No	~28”	Early	~3 ¼”	susceptible	2

Other Varieties Trialed (different planting dates, different fields: Hoophouse/ Field)

Name / ID	Awned?	Average Height (HH / Field)	Maturity Timing	Plant Vigor (rank) (HH / Field)
Halychanka	No	~36” / 30”	Mid	9 / 8
Emmer	Yes	~42” / 32”	Early	10+ / 6
“Hope”	No	~32” / 10”	Late (Winter)	8 / 4

General Notes:

All varieties sown in greenhouse in 98 cell 1020 flats, 1 seed per cell, then transplanted into field location. Germination good in all varieties. Main trial field wet, got quite weedy during the trial, due to insufficient labor to keep well weeded. Meadow voles under cover of weeds did significant damage to the trials, eating off stalks when the heads were in the milk stage, or sometimes still flowering. To allow grain to ripen, plants were pulled with roots attached and placed in buckets in a greenhouse for further ripening. Some varieties had more significant rodent damage, and few heads managed to ripen seed.

Plant heights and head lengths were recorded on 7/23, while most varieties were flowering and the meadow voles had not yet chewed off the dominant stalks, and so are more representative of the plant's potential than the stalks actually harvested, which are mostly secondary stalks. Because of rodent damage to the trial, yield comparisons would be inconclusive and not valuable. Further trialing would be necessary. The later maturing varieties seemed more resistant to rust diseases, but that is possibly more a factor of different growth stages than disease resistance per se. Also note that we had no frame of reference for identifying or comparing degree of rust infestation. Hence, "disease resistance" should be taken as an indicator of greenness and general healthiness of the plant on 7/23.

<u>Notes:</u>
As of 8/30/08, all varieties EXCEPT Arcadian, Lagodekhis Grdzeltavtava, and 8 Upkli plants pulled from field. The three varieties not yet harvested appear to have the Winter growth habit, though Arcadian, Lagodekhis Grdzeltavtava, and one Upkli are headed up and starting to form grain, Arcadian is the earlier ripening of these, as we expect to pull those plants within a week or two (8/30).

"Hope" had a few plants which seemed to be true to type: awned with a spring growth habit, but most plants are awnless with a winter growth habit. A few in the hoophouse produced stalks and seeds, but some plants have died without heading up and some are still alive, but have not headed up at all (hence the short plant height).

Upkli shows the greatest genetic variability of the varieties trialled: tall & short plants, early & late, disease resistance, vigor. All were awned. The gene pool seems like it could easily lead to either a spring or a winter variety, with a few years selection. It seemed to compare favorably with the American varieties. As the truest winter plants have not yet headed, we have only gotten seed from the spring types, and to develop a winter variety it would be necessary to get another sample from the genebank.

Lagodekhis Grdzeltavtava and Arcadian should be trialed under fall planting conditions, as they seem to be Winter varieties.

Akhaltsikhis Tsiteli Dol and Arcadian had White seeds, the rest are Red seeded varieties.
Akhaltsikhis Tsiteli Dol grew poorly and seems ill-adapted to the soils or weather here. Possibly the seed lost vigor during storage, and successive grow outs would do better.
Very little difference was noticed between the varieties from North Dakota. Mida seemed most productive.

FOOTNOTES

1 Deepening the Wheat Gene Pool, T. S. Cox, Formerly Research Geneticist, USDA-ARS, Manhattan, KS 66606. Journal of Crop Production: Volume: 1 Issue: 1, ISSN: 1 092-678X Pub Date: 10/8/1997

2 Rogosa, Eli. Participatory Breeding for Climate Resilient Wheat. 2005 Organic Wheat Proceedings, France

3 Wolfe, Martin, Composite Crossing to Enhance Genetic Variability, <cost860.dk> Proceedings 2004