PROGRESS REPORT - CSANR Organic Cropping Research for the Northwest

Title: Evaluating and developing varieties for organic systems

Principal Investigator:
Dr. Stephen Jones, Dept of Crop and Soil Science
Washington State University, Pullman, WA. 509-335-5462, joness@wsu.edu

Cooperators:
Dr. Carol Miles, Horticulture and Landscape Architecture, WSU, Vancouver, WA
Dr. Blair Goates, USDA-ARS, National Small Grains Germplasm Research Facility, Aberdeen, ID
Dr. Phillip Reeves, USDA-ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND
Kevin Murphy, PhD student, WSU Pullman, WA

Date: January 1, 2005 to December 31, 2005

Keywords: Plant breeding, organic, wheat

Abstract:

We completed a two-year study designed to answer the question: "Are the highest yielding varieties in conventional farming systems also the highest yielding varieties in organic farming systems?" Four of the five site-years showed highly significant variety x system interactions, indicating that there is little to no correlation between the ranking of varieties for yield between conventional and organic systems. From this data we can draw two inferences. First, yield in organic farming systems are not currently optimized and second, the development of organic crop breeding programs appears to be vital to the continued improvement and competitiveness of organic wheat farming.

In our second year field evaluations of historical and modern wheat varieties, we identified varieties that 1) contain weed suppression traits; 2) are suited to out-competing weeds; 3) yield well under low-input conditions; 4) yield well under different mechanical tillage systems; 5) contain high levels of micronutrients and; 6) are resistant or moderately resistant to the current race(s) of stripe rust and dwarf bunt. It is our objective to select for these traits each generation in the field as we develop varieties uniquely suited to organic farming systems.

In our breeding program, we work closely with farmers in an evolutionary-participatory breeding project, where the farmers will begin to develop their own varieties. These varieties will be optimally adapted to their system of farming. We are continuing to evaluate and identify advanced breeding lines that do particularly well in organic systems in an effort to release wheat varieties for organic farmers.

Objectives:

Our objectives for the 2005 year included:

1. Answer the question, "Are the highest yielding varieties in conventional systems also the highest yielding varieties in organic systems?"
2. Evaluate historical wheat varieties for their ability to suppress weeds, their ability to yield well in organic fields and their ability to yield well under different tillage systems.
3. Evaluate historical varieties and advanced breeding lines for end-use quality traits and micronutrient content.
4. Evaluate historical varieties and advanced breeding lines for resistance to stripe rust and dwarf bunt.
5. Continue our farmer participatory breeding project with organic and low-input conventional farmers in the varietal development process on their own farms.
6. Evaluate advanced breeding lines and modern cultivars for yield and test weight under organic production conditions.
7. Incorporate the traits for long coleoptile and emergence from deep planting in our modern wheat varieties.

Procedures:

Objective 1: We grew a nursery consisting of 35 soft white winter breeding lines and modern varieties (genotypes) in three locations under two types of agronomic systems: organic and conventional. This was a split-block design experiment, with the genotypes replicated four times in a randomized complete block design in each nursery. Each genotype was evaluated for yield and test weight. See Figure 1 for a summary of the results from this study.

Objective 2: We grew 63 spring wheat varieties (56 historical and 7 modern) in a randomized, replicated split-plot field trial. Yield was taken for each variety in two types of cultivation systems (no-cultivation and rotary harrow used four times). In addition, weed biomass (g/plot of dry weight) was taken for each variety at the end of the season before harvest. This gave us an indication of weed suppression ability of the varieties. See Figure 2 for yield trial results for the historical and modern varieties over 2 years.

Objective 3: We evaluated historical soft white, hard red and hard white spring and winter wheat varieties for several traits important to overall quality and marketability. Baking and milling tests are performed on all wheats from the organic fields. Full evaluation of bread, cookie, cake and noodles are done at the USDA Western Wheat Quality Laboratory in Pullman, WA. In addition, we collaborated with Dr. Phil Reeves to analyze the micronutrient content of seven different minerals in each variety. Preliminary results from this study are shown in Table 1.

Objective 4: We evaluated all of our varieties and breeding lines in the organic nurseries for resistance to stripe rust. Rust resistance was scored as a percentage of the plant leaf area infected in a plot, from visual inspection. In addition, we sent 35 lines from our advanced soft white wheat breeding nursery to Dr. Goates in Aberdeen, ID to test for resistance to dwarf bunt. Bunt is currently controlled by fungicidal seed treatments not allowed for certified organic production. Results from this experiment can be found in Table 2.

Objective 5: At Spillman Farm in Pullman, we grew out unselected, early generation populations from crosses designed specifically for our cooperating farmers. These populations were harvested in bulk and a subsample replanted on the fields of four farmer cooperators. These populations will now be pressured by both natural selection and farmer assisted selection and develop into genetically diverse landraces highly adapted to the farming systems and agroenvironments of the farmers.

Objective 6: Our advanced breeding lines and modern checks were evaluated in four locations for yield and test weight. These are randomized complete block design experiments, with four replications for each genotype. The highest yielding breeding lines, with good quality and test weight will be advanced in each location for further evaluation next year. These lines are the most likely candidates for varietal release specifically for organic farms in the near future. Results from two locations are shown in Tables 3 and 4.

Objective 7: To determine the gene action, transmission and response to selection of the gene(s) responsible for coleoptile length in wheat, we are conducting a diallel study of 7 winter wheat varieties with a range of coleoptile lengths. This year we obtained results from the parents and F_3 populations and replanted subsamples of these populations to test for response to selection. In addition, we are conducting field trials at the Dryland Research Station in Lind with populations derived from crosses of modern varieties to historical long coleoptile cultivars. These populations are subjected to pressures of deep planting and soil crusting, and natural selection determines the best emerging plants and these plants make up the population replanted the next year. This study will be concluded next year.

Progress Towards Objectives:

Our most important conclusion was that the highest yielding varieties in conventional systems are not the highest yielding varieties in organic systems (See Figure 1). This tells us that breeding for organic agriculture should be conducted in certified organic fields. It also illustrates the point that yield in organic systems has not been optimized and will not be fully optimized until breeding and selection occurs within these organic systems. Additionally, for the second year, we found significant variation in weed suppression ability of the 63 cultivars tested. We found particular cultivars that are better adapted to weed competition than to repeated harrowing and vice versa. We identified historical and modern spring and winter wheat cultivars that yield well in low-input and organic conditions. In addition, we began collaborations with Dr. Reeves and Dr. Goates (see above) to test for both micronutrient content and dwarf bunt resistance in our wheat cultivars and breeding lines (See Tables 1 and 2 for preliminary results).

We have striven to work with farmers in the development of varieties suited to their agroecosystem. This is a long-term objective, however the first steps in this project are in place. We have identified historical wheat cultivars with excellent quality characteristics (and many more with poor quality characteristics), and included these cultivars in our crossing scheme. We are getting closer to understanding the gene action and response to selection of the gene(s) responsible for long coleoptile in wheat. Additionally, our population selection for superior emergence properties has received strong natural selection over the past three years in the form of significant soil crusting and low soil moisture.

We feel that active selection for mineral content, dwarf bunt and stripe rust resistance, weed competitiveness and weed tolerance, quality, emergence and yield in organic systems will assist us in the development of wheat varieties specifically adapted to the agronomic conditions and potential marketing opportunities of organic farmers.

Outputs

Publications:

Murphy K., D. Lammer, S. Lyon, B. Carter, S.S. Jones (2005). Breeding for organic and low-input farming systems: An evolutionary–participatory breeding method for inbred cereal grains. Renewable Agriculture and Food Systems 20: 45-55.

.

Presentations and Workshops:

K. Murphy, November 2005. "Breeding Wheat for Organic Systems", CSSA-ASA-SSSA, Salt Lake City, Utah

K. Murphy, November 2005. "Participatory Breeding Program for Cereals", CSSA-ASA-SSSA, Salt Lake City, Utah

K. Murphy, December 2005. "Genetic assessment of the need for organic plant breeding programs in winter wheat (*Triticum aestivum*, L.)", 7th International Wheat Conference, Mar del Plata, Argentina

S. Lyon and K. Murphy, December 2005. "WSU Organic Wheat Breeding Program: Objectives and Results", Organic Grain Production Workshop, Spokane, Washington

Impact

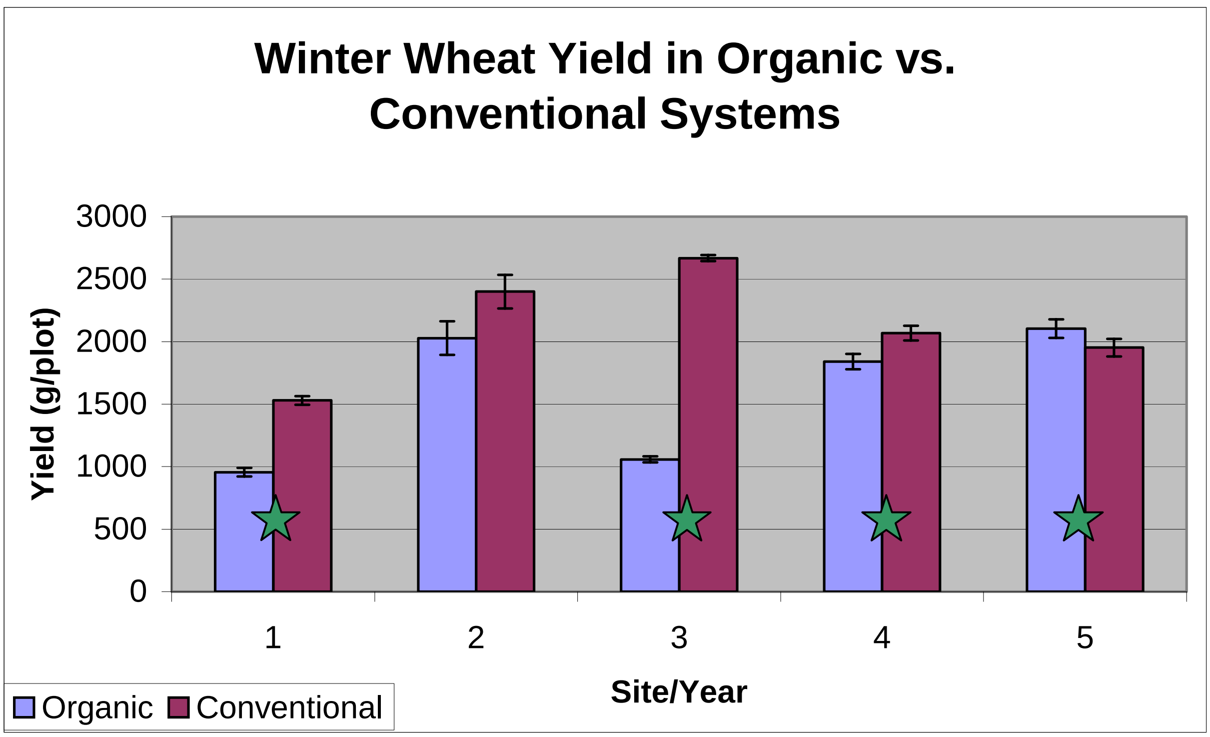
Breeding is a long-term process and any impact is yet to be determined.

Institution/State: Dept. of Crop and Soil Sciences, Washington State University, WA

Funding Amount(s): $34,481 (CSANR)

Appendix

Figure 1. This figure shows the yield comparisons between organic and conventional soft white winter wheat nurseries at five site/years in Washington State. The conventional nursery yielded significantly higher at site/year 1, 3 and 4, while there were no significant differences in yield for site years 2 and 5. Each nursery consisted of 35 breeding lines (genotypes) and each site year was analyzed for genotype by system interaction. There was significant genotype by system interactions for all the site years except 2. This indicates significant changes in rank for the genotypes from organic systems to conventional systems within each site/year except for site/year 2. From this research, we conclude that the highest yielding varieties in the conventional system will not be the highest yielding lines in the organic system.



 Denotes site/years with significant genotype by system interactions.

Figure 2. This figure shows the grain yield of historical and modern spring wheat varieties grown in low-input conditions (no herbicides or handweeding, organic fertilizer (4-4-4), no fungicides). Of particular interest are the high ranking pre-1950 varieties that yielded well under these organic systems. For example, two varieties, Canus and Spinkota, ranked 3 and 4 respectively, out of 63, may contain traits that are particularly suited to organic conditions.

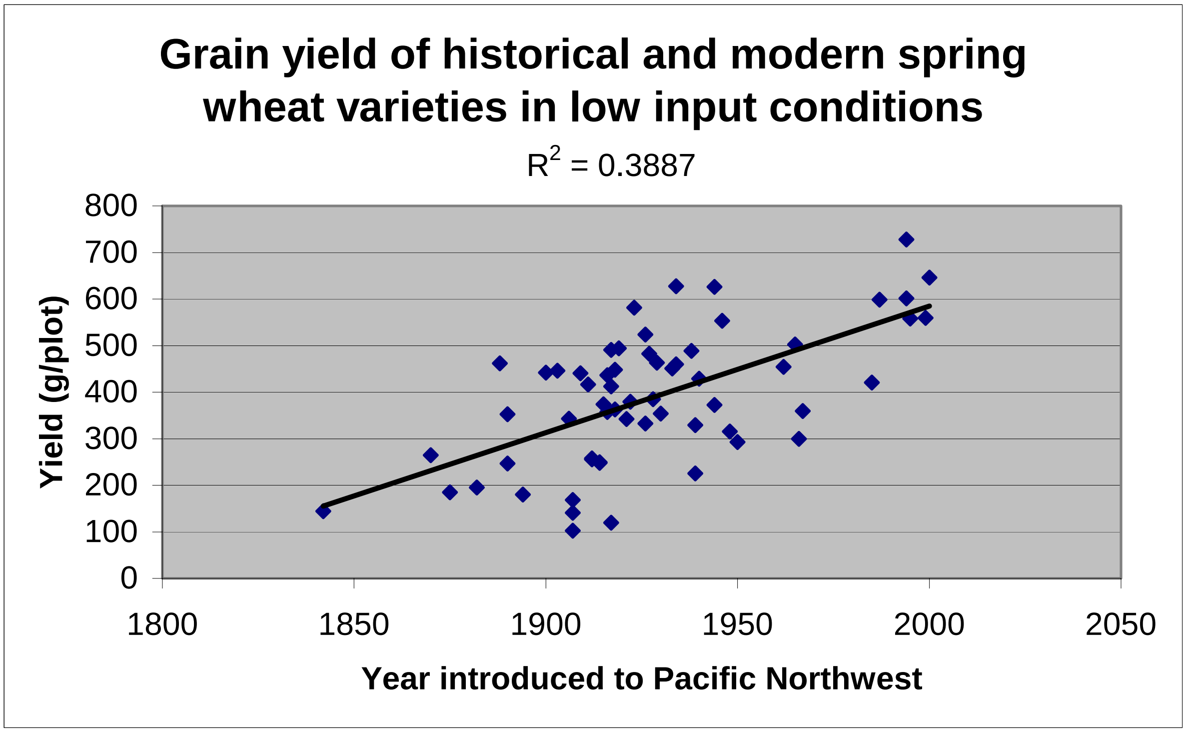


Table 1. This table shows the mineral content of 63 spring wheat varieties (blue=historical, yellow=modern) and check varieties (green). Eight minerals (Ca, Cu, Fe, Mg, Mn, P, Zn, and Se) were tested for each variety and significant variation exists within this germplasm base to suggest the possibility of breeding for higher mineral content. This work is done in collaboration with Dr. Phillip Reeves of Grand Forks Human Nutrition Research Center, in North Dakota.

	Ca	Cu	Fe	Mg	Mn	P	Zn	Se
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Allen	390.9	4.36	43.48	1488	43.51	4187	30.01	19.32
Awned Onas	413.0	3.66	33.99	1340	44.42	3238	24.95	10.87
Baart 46	310.6	4.21	40.47	1580	40.39	3772	24.70	4.83
Beaver	353.7	3.38	30.44	1294	40.30	3481	26.22	6.02
Big Club	463.8	3.71	42.84	1443	45.87	4096	30.59	8.86
Big Club 43	426.9	4.03	44.83	1289	41.30	3889	26.25	8.67
Bluechaff Club	395.2	4.85	37.06	1367	33.80	3841	26.00	7.20
Bunyip	412.2	4.72	39.86	1484	49.90	3855	30.23	10.55
Currawa	410.1	4.53	43.55	1457	48.88	3933	27.32	7.93
Dicklow	443.9	4.00	32.63	1276	40.91	3209	24.77	8.81
Early Baart	604.1	4.62	37.27	1524	44.00	3860	28.70	5.81
Federation	461.1	4.46	39.06	1377	49.23	3477	30.04	4.94
Federation 67	444.6	4.46	39.10	1455	46.68	3698	28.64	6.58
Galgalos	346.1	4.53	44.26	1365	43.58	3812	30.62	10.56
Gypsum	423.8	5.33	46.36	1436	41.76	3973	32.28	3.48
Hard Fed	383.9	4.85	44.62	1538	51.42	4104	34.43	1.72
Hybrid 143	426.0	5.24	42.44	1561	43.84	4041	30.31	4.30
Hybrid 63	433.6	5.31	38.30	1494	36.53	3850	30.50	3.02
Hyper	568.8	6.38	44.91	1598	55.18	4361	31.98	1.82
Idaed 20	348.6	4.52	40.34	1279	47.32	3824	28.94	2.02
Idaed 59	479.0	5.51	52.22	1723	56.79	4738	36.17	3.91
Indian	396.3	5.72	48.84	1681	52.81	4772	34.38	4.08
Lemhi	479.8	5.73	38.14	1424	43.22	3429	29.44	2.07
Lemhi 66	463.8	5.33	42.42	1426	45.68	3412	28.93	3.40
Little Club	487.6	5.26	42.95	1492	43.21	3661	27.41	2.68
Mackey	461.2	5.71	49.92	1452	46.02	4096	37.63	3.15
New Zealand	356.5	5.43	50.02	1398	41.43	3954	32.61	5.84
Onas	384.5	5.44	36.62	1322	40.58	3424	26.31	2.58
Oregon Zimmerman	352.2	5.13	34.28	1415	40.33	4001	31.83	2.51
Pacific Bluestem	359.8	4.23	36.83	1414	44.73	3824	32.11	5.58
Picraw	396.9	4.62	32.09	1332	42.34	3531	27.24	3.21
Rink	388.3	4.94	36.07	1351	37.26	3431	21.79	2.91
Sonora	501.6	4.99	41.28	1436	47.04	4075	29.65	4.97
Surprise	376.8	4.71	31.87	1156	34.96	3080	21.68	5.47
Whiet Federation	419.0	4.63	38.19	1330	45.31	3438	29.32	4.07
White Marquis	481.4	4.57	34.14	1367	47.39	4293	33.19	4.96
Wilber	282.6	5.16	41.66	1445	38.53	3849	25.80	2.61

Table 1 continued.

	Ca	Cu	Fe	Mg	Mn	P	Zn	Se
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg
	Mean	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Huston	414.9	4.81	39.18	1369	44.05	3875	29.29	5.59
Hybrid 123	461.7	5.07	40.22	1277	34.56	3709	29.39	4.38
Red Fife	370.6	4.81	41.53	1433	41.30	3893	29.47	3.67
Canadian Red	376.1	4.48	44.13	1324	47.72	3518	31.27	5.07
Cadet	338.4	4.86	34.76	1487	43.46	3794	32.29	4.27
Canus	474.0	4.02	37.58	1379	43.85	3838	31.59	5.67
Ceres	500.4	4.54	28.09	1484	53.28	4196	27.93	5.21
Comet	437.7	3.86	40.43	1364	44.08	3682	30.6	5.82
Flomar	433.4	4.12	42.33	1410	45.60	3779	30.65	3.81
Henry	386.4	5.09	36.80	1394	39.71	3908	33.96	5.17
Hope	377.8	3.99	33.82	1378	46.01	3600	30.85	2.68
Komar	483.1	4.11	32.34	1427	41.98	3978	28.86	2.03
Lagoda	407.0	4.19	40.32	1355	39.58	3857	29.19	4.47
Marquis	408.2	3.79	30.27	1292	35.94	3794	30.37	3.14
Pilot	430.9	3.74	32.61	1435	47.67	3873	31.04	4.19
Preston	441.3	5.08	32.89	1359	41.14	3664	29.47	4.13
Red Bobs	322.3	3.13	31.43	1086	34.99	3235	26.9	2.07
Reliance	396.7	3.28	32.02	1192	34.37	3351	25.16	2.91
Reward	417.0	5.06	38.75	1314	48.17	4062	35.73	5.35
Rival	458.8	5.77	37.92	1557	47.60	4266	38.87	6.79
Ruby	381.4	3.75	37.95	1205	36.72	3449	25.76	5.67
Sea Island	524.0	4.43	33.29	1282	41.35	3643	26.95	5.92
Spinkota	370.8	3.82	47.59	1382	45.87	3707	29.86	6.25
Supreme	378.5	3.57	35.29	1156	39.81	3323	28.86	4.49
Thatcher	418.7	4.12	26.86	1208	38.48	3233	22.8	4.44
Zak	411.0	3.83	41.40	1271	42.96	3086	22.23	6.30
Alpowa	395.6	3.74	32.83	1285	31.81	3297	21.53	4.98
Scarlet	409.6	3.96	36.74	1280	42.32	3276	24.24	6.39
Westbred Express	444.7	4.93	35.28	1328	47.23	3353	22.98	6.92
Wawawai	343.3	4.29	35.96	1346	41.64	3398	24.15	3.93
Wakanz	444.9	4.09	35.50	1222	36.11	3044	20.86	3.94
Penawawa	426.4	3.59	32.15	1263	37.65	3185	22.82	7.11
Durum Std 1	323.0	3.69	38.47	924	15.16	2418	23.02	1.43
Durum Std 2	293.2	4.58	43.87	1140	17.09	2899	24.38	1.22
Durum Std 3	252.2	3.87	36.42	963	14.74	2547	22.01	1.33
Durum Std 4	281.0	3.99	36.95	961	15.20	2461	21.66	1.22
Durum Std 5	271.1	4.14	39.35	1025	15.81	2616	22.50	1.14
Durum Std 6	291.7	4.18	41.09	1077	16.39	2746	23.55	1.25
Mean Standards ± SD	**285.4**	**4.08**	**39.36**	**1015**	**15.73**	**2614**	**22.85**	**1.27**

Table 2. This table shows the results from a dwarf bunt trial performed in collaboration with Dr. Blair Goates, USDA-ARS. The nursery tested represents our best soft white wheat breeding lines. Dwarf bunt is of particular concern to organic farmers as currently the pathogen is controlled using fungicidal seed treatments that are not available for use by organic farmers. Cheyenne is the susceptible check variety and breeding lines of particular interest (in yellow: AWY 24, AWY 25 and AWY34) show genetic resistance to dwarf bunt.

Variety Name	Variety Number	Rep I Row	% Bunt	Rep II Row	% Bunt
AWY 1	Madsen	592	25	1272	70
AWY 2	Eltan	593	8	1273	35
AWY 3	Finch	594	8	1274	30
AWY 4	Stephens	595	60	1275	80
AWY 5	Masami	596	25	1276	60
AWY 6	WA7935C	597	50	1277	30
AWY 7	WA7970	598	70	1278	90
AWY 8	WA7971	599	90	1279	90
AWY 9	WA7972	600	25	1280	35
Cheyenne		601	90	1281	95
AWY 10	J950289-001	602	35	1282	30
AWY 11	WA7974	603	95	1283	90
AWY 12	J950052-1	604	95	1284	80
AWY 13	J950060-1	605	95	1285	80
AWY 14	J950081-1	606	50	1286	70
AWY 15	J950409-10-2	607	75	1287	80
AWY 16	J950409-10-3	608	65	1288	80
AWY 17	J950409-10-4	609	70	1289	80
AWY 18	J950409-10-5	610	90	1290	90
AWY 19	J00C0013	611	70	1291	80
AWY 20	J01C0009-11	612	70	1292	90
AWY 21	J960793-1	613	75	1293	65
AWY 22	J960793-3	614	65	1294	75
AWY 23	J960793-4	615	75	1295	50
AWY 24	J960805-2	616	5	1296	4
AWY 25	J960805-4	617	5	1297	2F
AWY 26	J961273-1	618	35	1298	35
AWY 27	J970041-5	619	60	1299	90
AWY 28	J970057-3	620	50	1300	30
Cheyenne		621	95	1301	95
AWY 29	J970057-5	622	6	1302	18
AWY 30	J970067-1	623	40	1303	20
AWY 31	J970092-3	624	100	1304	40
AWY 32	J970284-2	625	75	1305	80
AWY 33	J970536-1	626	70	1306	90
AWY 34	J970611-1	627	2	1307	0
AWY 35	J971058-2	628	80	1308	80

Table 3. Results from the advanced soft white wheat nursery in St. Andrews, WA. Entries are ranked according to yield (Bu/a = bushels per acre). T.wt = test weight.

	St Andrews Organic				
	AWY1 Nursery		**nursery mean**		
Rank	**Entry #**	**Variety**	**Bu/a**	**T.wt**	
1	4	**Stephens**	47.8	58.2	A
2	13	J950060-1	46.1	58.5	AB
3	30	J970067-1	45.2	57.1	ABC
4	5	**Masami**	44.5	59.2	ABCD
5	2	**Eltan**	44.5	58.0	ABCD
6	27	J970041-5	43.4	57.6	ABCDE
7	31	J970092-3	43.2	58.3	ABCDEF
8	32	J970284-2	42.6	59.4	ABCDEFG
9	33	J970536-1	42.4	60.5	ABCDEFGH
10	28	J970057-3	41.7	56.9	ABCDEFGH
11	23	J960793-4	41.6	58.1	ABCDEFGH
12	26	J961273-1	40.9	58.8	ABCDEFGHI
13	8	**WA7971**	40.7	58.4	ABCDEFGHI
14	1	**Madsen**	40.3	58.3	ABCDEFGHI
15	14	J950081-1	40.3	60.3	ABCDEFGHI
16	34	J970611-1	40.1	59.3	ABCDEFGHI
17	3	**Finch**	40.1	61.1	ABCDEFGHI
18	16	J950409-10-3	38.8	59.7	ABCDEFGHI
19	22	J960793-3	38.7	57.6	ABCDEFGHI
20	25	J960805-4	38.1	59.1	ABCDEFGHIJ
21	19	J00C0013	38.0	59.2	ABCDEFGHIJ
22	15	J950409-10-2	37.3	59.6	ABCDEFGHIJ
23	6	**WA7935C**	36.2	58.2	BCDEFGHIJ
24	9	**WA7972**	35.8	58.3	BCDEFGHIJ
25	12	J950052-1	35.6	58.7	BCDEFGHIJ
26	7	**WA7970**	35.4	59.0	BCDEFGHIJ
27	21	J960793-1	35.1	58.4	BCDEFGHIJ
28	20	J01C0009-11	34.7	59.5	CDEFGHIJ
29	11	**WA7974**	33.6	58.6	DEFGHIJ
30	24	J960805-2	32.1	59.3	EFGHIJ
31	29	J970057-5	31.9	58.8	FGHIJ
32	18	J950409-10-5	31.4	59.7	GHIJ
33	10	J950289-001	31.3	59.1	HIJ
34	17	J950409-10-4	29.8	59.6	IJ
35	35	J971058-2	27.3	60.9	J
	Nursery mean		**38.5**	**58.9**	

Table 3. Results from the low rainfall wheat nursery in St. Andrews, WA. Entries are ranked according to yield (Bu/a = bushels per acre). T.wt = test weight.

	Adv. Low rainfall Organic - St Andrews			**nursery mean**		
Rank	**Entry #**	**Variety**	**Pedigree**	**Bu/a**	**T.wt**	
1	**2**	**Masami-check**		42.3	60.0	A
2	9	6K000157-9	Eltan/Estica//Eltan	41.9	57.1	A
3	5	6K000072-2	Estica/Rod//WPB470	41.0	61.1	AB
4	**3**	**Buchanan-check**		40.6	58.5	AB
5	21	7K990184-4	Estica/Finley SSD-17	40.5	59.5	AB
6	22	7K990241-1	Estica/Finley SSD-75	39.1	60.7	AB
7	**1**	**Eltan-check**		38.3	58.0	AB
8	4	6K000075-7	Estica/Rod//WPB470	37.1	63.0	ABC
9	12	6K000201-1	Buchanan/Estica//Finle	36.2	60.8	ABC
10	23	7K990135-2	WPB470/Eltan	35.7	59.7	ABCD
11	11	6K000157-6	Eltan/Estica//Eltan	33.9	56.5	ABCDE
12	8	6K000197-3	Buchanan/Estica//Finle	33.9	58.9	ABCDE
13	6	6K000078-2	Estica/Rod//WPB470	33.6	60.0	ABCDE
14	18	4K020070-Bulk	Bunyip/Finch	32.3	60.6	ABCDEF
15	7	6K000157-1	Eltan/Estica//Eltan	31.5	55.5	BCDEF
16	24	7K990385-1	WA 7836/WA 7833-1	31.4	59.0	BCDEF
17	10	6K000199-4	Buchanan/Estica//Finle	30.9	59.1	BCDEF
18	13	4K020027-Bulk	Hyper/Eltan	27.6	59.2	CDEFG
19	17	4K020087-Bulk	Idaed 59/Eltan	25.5	59.7	DEFG
20	20	4K020093-Bulk	Big Club 43/Edwin	25.0	58.3	EFG
21	14	4K020001-Bulk	Surprise/Eltan	24.9	57.4	EFG
22	25	7K990027-2	Eltan/WA 7832	24.8	60.0	EFG
23	19	4K020214-Bulk	Hood/Eltan	22.7	56.6	FG
24	16	4K020129-Bulk	Eaton/Lewjain	22.3	59.3	FG
25	15	4K020079-Bulk	Rink/Eltan	20.1	56.7	G
	Nursery mean			**32.5**	**59.0**	
	CV %			22.49	1.67	
	LSD @.05			10.30	1.38	