Yield and Water Use of Barley Cultivars Compared Under an Irrigation Water Gradient at Marana, 1987.

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Abstract

This study was initiated to determine how barley cultivars perform outside the environment for which they were selected. Also, a comparison was made of water use by a one-irrigation barley with water use of a commercial cultivar selected for high yield conditions. Six barley cultivars bred for differing growing conditions (Westbred Gustoe and Westbred Barcott - high input; Arivat and Prato - medium input; and, Seco and 2-22-9 - low input) were compared under 12 water regimes delivered by a line-source sprinkler system. Water use of Seco, a one-irrigation barley, and Westbred Gustoe, a commercial barley, was monitored with a neutron probe. The barley cultivars bred for high, medium, and low input conditions performed best in their respective optimum water levels with the exceptions of Westbred Barcott and Prato. Westbred Barcott (high input) yielded relatively well over all water levels, and Prato (medium input), performed similar to a high input barley. Seco (low input) used slightly less water than Westbred Gustoe (high input), primarily due to its earlier maturity. The water extraction pattern with depth was similar for both cultivars due to the frequent shallow irrigations applied in this study. The water extraction pattern of Seco needs to be investigated under one-irrigation conditions.

Introduction

Introductory genetics courses teach that the phenotype = genotype + environment + genotype x environment. In crop production, this relationship may be stated: yield is related to the cultivar, the growing conditions, and the interaction of the cultivar with the growing conditions. A typical example of the application of the above relationship is with hybrid corn and nitrogen supply. The increased yields obtained with hybrid corn (cultivar) were not possible without increased nitrogen supply (growing condition) and without the ability of the hybrid corn to utilize the increased nitrogen supply to its advantage (cultivar x growing condition interaction).

Barley breeders are certainly aware of the above-mentioned concept, and barley genotypes have been bred for differing growing conditions. For example, barley breeders presently select genotypes which are responsive to favorable or high input growing conditions. In the past, barley was bred for the average farmer or growing condition to minimize losses in bad years. Seco, a one-irrigation barley developed at the University of Arizona and released by the Soil Conservation Service in April of 1987, was bred to utilize a soil profile full of water from a single irrigation near planting.

This study was designed to address the following questions: (1) How do barley cultivars perform outside the environments for which they were selected? Are productive cultivars in poor growing conditions also the most productive in better growing conditions? (2) How does water use of a one-irrigation barley compare to that of present commercial cultivars?

MATERIALS AND METHODS

A field study was initiated at the Marana Agricultural Center in the 1986-87 growing season comparing 6 barley cultivars under 12 water regimes delivered by a line-source sprinkler system. The previous crop was Sudan grass, and the soil type was a Pima clay loam. Approximately 214 lbs N/A and 67 lbs P_2O_5/A were applied preplant.

The seed was planted with a grain drill on December 15, 1986 into moisture from a recent rainfall. Soil moisture was measured on January 7, 1987 at the 1 - 2 leaf stage (roots 6 - 12 inches deep) at 1 foot increments from 0 to 5 feet. These measurements revealed 74, 59, 35, 15, and 6% of field capacity or 1.3, 1.3, 0.95, 0.33, and 0.09 inches of plant-available water per foot of soil. The barley cultivars were bred for different input levels: Westbred Gustoe and Westbred Barcott = high input, present day cultivars; Arivat and Prato = medium input, older cultivars; and Seco and 2- 22-9 = low input, one-irrigation barleys.

A line-source sprinkler system was laid out through the center of the test. This was a typical, solid-set system, consisting of a single 3" pipe with impact sprinklers on 24" risers. The impact sprinklers apply more water to the soil near the sprinkler line than they apply at further distances. Normally, this application difference is taken care of by adjacent sprinkler lines. But as a single line of sprinklers, this system applied a gradient of water: more water near the pipe and lesser amounts farther away from the pipe.

Barley cultivars were planted perpendicular to the sprinkler system. These plots were intersected by 12 different water regimes. Thus, the experimental design was a split block with 6 cultivars, 12 water regimes (not randomized) and 4 replications. Individual plots were 20 ft x 6.7 ft.

Prevailing winds influenced the amounts of water delivered to the 12 water regimes. Actual water applications in each regime were measured and are presented in Table 1. The total quantity of water available for crop use included residual soil moisture (approximately 3.4 inches), the variable amount of irrigation water applied to the plots (1.4 to 12.4 inches) and rainfall (3.5 inches).

Table 1. Water application by the line source sprinkler system. The sprinkler system was situated between plots 6 and 7.

	Plot (east to west)											
Date	1	2	3	4	5	6	7	8	9	10	11	12
	Water applied (inches)											
Jan 8	0.8	1.3	1.4	1.7	2.0	2.2	2.2	1.9	1.5	1.0	0.9	0.6
Mar 12	0	0.3	0.8	1.4	2.0	2.3	2.4	2.2	1.8	1.4	1.1	0.9
Mar 24	0	0.4	0.8	1.1	1.5	1.7	1.6	1.6	1.3	1.0	0.8	0.6
Apr 7	0.1	0.2	0.8	1.2	1.7	1.9	2.0	1.7	1.7	1.5	1.2	1.0
Apr 17	0	0	0	0.6	1.5	1.8	2.1	1.6	1.6	1.3	1.0	0.9
Apr 28	0.4	0.9	1.2	1.5	1.7	1.8	2.0	1.5	1.5	1.2	1.2	0.9
Total	1.4	3.1	5.0	7.5	10.5	11.7	12.4	10.6	9.4	7.5	6.1	5.0

The grain was harvested from 4.5 ft. x 18 ft. plots with a small plot combine during May 23 - 30. Grain moisture was determined using the oven method, and grain yields were adjusted to 10% moisture. Plant height and lodging were recorded. Aboveground dry matter from a 9 square foot area was sampled from irrigation plots 1, 3, and 6 for Westbred Gustoe, Arivat, and Seco. The samples were weighed and then corrected for moisture, using an oven-dried subsample. Total aboveground plant yields were corrected to 10% moisture. Non-grain, above ground yield was calculated as the difference between total above ground plant yield and grain yield. Harvest index was calculated as the proportion of grain to total above ground plant yield.

Soil moisture was determined to a depth of 9 feet for Gustoe and Seco on plots 1 (low water) and 6 (high water), using a neutron probe. Measurements were first recorded on Jan. 22 at the early tillering stage of growth and again after major rainfall events and before and after irrigations. Water use was calculated from changes in soil water content, including any additions of water from rainfall and irrigation. Losses of water by deep percolation were considered negligible since low soil-moisture contents were observed deeper in the soil profile throughout the study. Data are only presented for the first 5 feet of soil because changes in soil moisture below this level were minor.

RESULTS AND DISCUSSION

YIELD

Grain yields are presented in Fig. 1. The most obvious difference in yield is due to the irrigation treatment, which is expected and not of major interest in this study. The relative performance of the barley cultivars at the various irrigation levels is of major interest, however. On irrigation plot 1 (low water), Westbred Barcott and 2-22-9 yield approximately 1000 lbs/A while Prato and Westbred Gustoe yield approximately 240 lbs/A, a four-fold difference. Yields of Prato and Westbred Gustoe are also low in relation to the others on irrigation plots 11 and 12 (low water). The relative yields of the cultivars start to change in plots 3, 4, 9, and 10 (intermediate water levels). In irrigation plots 5, 6, and 8 (high water), Westbred Gustoe, Westbred Barcott, and Prato are definitely superior to the other cultivars.

The proper interpretation of these results is difficult since a preplant irrigation filling the soil profile with water was not applied as is preferred by the one-irrigation barleys (Seco and 2-22-9). Truly high-yielding conditions were not present, which would have favored the high-input barleys (Westbred Gustoe and Westbred Barcott). Nevertheless, the high-input barleys (Westbred Gustoe and Westbred Barcott) yielded best at the high water levels compared to the others. Westbred Barcott, however, also performed well in the lower irrigation levels. Arivat, a medium-input barley, was not spectacular at any irrigation level, but was more productive on a relative basis at intermediate water levels. Prato, also a medium-input barley, yielded relatively poorly at low water levels but was superior at high water levels, as is expected of high-input barleys. Seco and 2-22-9, performed relatively better at the low rather than high water levels, as expected.

Grain yield, non-grain yield, total plant yield, and harvest index are presented in Table 2. The harvest index of the cultivars is remarkably different over water levels. The yield advantage of Seco at low water levels appers to be due to a greater proportion of dry matter in grain, or a larger harvest index. Westbred Gustoe has the largest harvest index at high water levels. At intermediate water levels, the cultivars do not differ in harvest index. Thus, partitioning of dry matter appears to play an important role in the adaptation of cultivars to various growing conditions. These data support the theory that yield improvements obtained by the introduction of a new cultivar under a given growing condition are often due to partitioning of available biomass rather than an increase in total biomass.

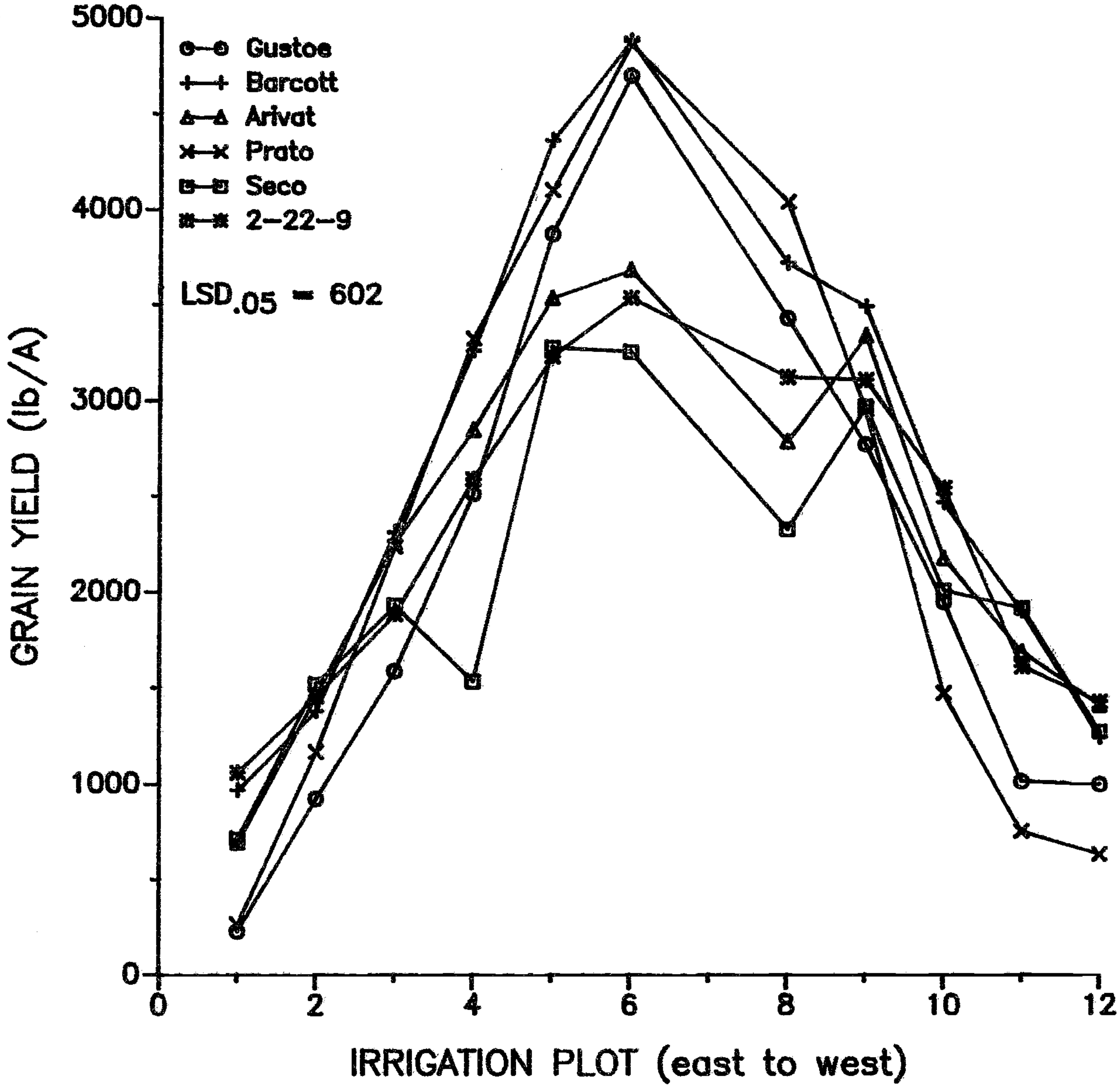

Figure 1. Grain Yields as Influenced by Cultivar and Irrigation Treatment.

Table 2. Grain yield, above ground non-grain yield, total above ground plant yield, and harvest index as influenced by water application and cultivar.

Water Applied	Cultivar	Yield[1] Grain	Non-grain	Total	Harvest Index[2]
		--------- lb/A	--------------		(%)
1.5	Gustoe	220 a[3]	1060 a	1280 a	16.1 a
	Arivat	690 b	1270 a	1960 a	33.7 ab
	Seco	710 b	840 a	1540 a	46.1 b
5.0	Gustoe	1580 a	3320 a	4900 a	33.2 a
	Arivat	2250 b	4360 a	6610 a	34.7 a
	Seco	1930 ab	4440 a	6370 a	31.4 a
11.7	Gustoe	4700 a	6820 a	11520 a	40.9 a
	Arivat	3680 b	9440 b	13100 a	28.3 b
	Seco	3250 b	6040 a	9300 b	35.7 ab

1/ Yields adjusted to 10% moisture.

2/ Harvest index = grain yield x 100/total yield.

3/ Means within a water level and column are not significantly different at P = .05 according to FLSD.

WATER USE

Water use for Westbred Gustoe, a commercial cultivar, and Seco, a one-irrigation barley, is presented in Table 3. Water use at the low water level was similar for both cultivars, except that Seco used less total water at 0 to 1 ft. At the higher water levels, Westbred Gustoe used equal or greater amounts of water than Seco at all depths. However, the difference in water use between the cultivars is small and is mainly due to one-irrigation barley maturing 2 to 3 weeks earlier than Westbred Gustoe. These data support our theory that one-irrigation barley is not drought-tolerant or conservative in water use, but rather, uses other mechanisms to remain productive under conditions of a single, deep irrigation near planting.

The water extraction pattern with depth was similar for both cultivars under the conditions of this study. Under one- irrigation conditions, roots of Seco have been found deeper in the soil profile than commercial cultivars, such as Westbred Gustoe. Due to the shallow irrigations applied in this study, Seco did not exhibit its usual deep rooting habits (data not presented). The potential of these deep roots to actually extract water has not been evaluated. The water extraction pattern of Seco grown with a single, deep irrigation near planting needs to be investigated, rather than the pattern with periodic, shallow irrigations, as in this study. These results indicate that an early, deep irrigation is necessary for Seco to exhibit its deep rooting habit and potentially exploit deep moisture.

Table 3. Water use for various soil depths and time periods as influenced by water application and cultivar.

Depth (ft)	Water Applied (in.)	Cultivar	01/22-02/12	02/13-03/03	03/04-03/11	03/12-03/23	03/24-04/06	04/07-04/16	04/17-04/27	04/28-05/14	Total
			water use (inches)								
0-1	1.5	Gustoe	.73	.62	.77	.46	.35	.27	.14	.49	3.83
		Seco	.65	.91	.49	.47	.41	.32	.17	0	3.43
	11.7	Gustoe	.97	.46	.82	1.11	1.11	1.19	1.52	1.38	8.55
		Seco	.78	.50	.86	1.20	1.28	1.33	1.65	0	7.60
	FLSD .05 *		NS	.376	NS	.163	.168	.076	.096	.099	.117
1-2	1.5	Gustoe	-.08	.04	-.01	.04	.26	0	.10	.02	.37
		Seco	-.06	.04	0	.12	.06	.10	.09	0	.36
	11.7	Gustoe	.14	.90	.32	.81	1.38	1.02	1.16	.28	6.01
		Seco	.08	.52	.29	.53	.95	.88	1.02	0	4.26
	FLSD .05		.174	.153	.068	.278	.321	.237	.098	.056	.143
2-3	1.5	Gustoe	-.07	.01	0	.01	.03	.04	.11	0	.14
		Seco	.07	-.05	-.01	.04	.06	.08	.03	0	.23
	11.7	Gustoe	0	.41	.19	-.07	.53	.17	.51	.02	1.77
		Seco	-.05	.41	.19	.26	.69	.20	.47	0	2.17
	FLSD .05		NS	.192	.064	.147	.114	.163	.109	NS	.117
3-4	1.5	Gustoe	.15	-.15	-.01	.04	.03	.01	-.01	.01	.08
		Seco	.06	-.10	-.02	.04	.05	.05	.04	0	.11
	11.7	Gustoe	.01	-.01	.22	.05	.40	.30	.57	.06	1.61
		Seco	-.03	.03	.08	.01	.21	.19	.34	0	.83
	FLSD .05		NS	NS	.096	NS	.156	.111	.105	.050	.152
4-5	1.5	Gustoe	-.01	.01	-.01	0	-.03	.06	-.02	.01	0
		Seco	-.04	.01	-.01	.05	.10	-.05	.03	0	.10
	11.7	Gustoe	-.14	.07	.12	.09	.13	.08	.34	.06	.76
		Seco	-.18	-.02	.12	.14	.22	.02	.35	0	.66
	FLSD .05		.182	NS	.087	NS	NS	NS	.211	.039	.143
Total	1.5	Gustoe	.72	.53	.74	.56	.64	.38	.32	.53	4.43
		Seco	.70	.81	.44	.72	.68	.49	.38	0	4.22
	11.7	Gustoe	.98	1.84	1.67	1.99	3.56	2.77	4.10	1.79	18.70
		Seco	.59	1.44	1.53	2.15	3.36	2.62	3.84	0	15.54
	FLSD .05		NS	.346	.423	.654	.451	.403	.328	.242	.536

*FLSD .05 - Least significant difference at P = .05 protected by a F-test.

The plots were 8 ft. wide and 15 ft. long and were planted with a 'Planet Jr.' hand planter into dry soil and then irrigated. Approximately 300 lbs. N/A was applied at both planting dates, split equally among preplant, 5-6 leaf (1st irrigation), and pre-boot (2nd irrigation) applications, and 100 lbs. P_2O_5/A was applied at the Dec. 1 planting date. The Dec. 1 planting date was irrigated on Dec. 1, Feb. 13, March 11, March 30, April 11, and April 24. The Jan. 16 planting date was irrigated on Jan. 16, March 11, March 27, April 11, April 24, and May 6. No pesticides were applied.

Plant numbers in a 12 square foot area were counted and reported as an estimate of stand for the seeding rate trial. The plots were harvested between June 4 and 8 with a small plot combine. Grain yields were adjusted to 10% moisture using the oven method. Plant height and lodging notes were recorded at harvest. Yield component analysis (head per unit area, seeds per head, and real weight) is not complete at the present time and will be presented in a later report.

RESULTS AND DISCUSSION

SEEDING RATE

The influence of seeding rate on yield of Westbred 881 and Aldura at two planting dates is presented in Figure 1. Both cultivars responded to seeding rate in a similar manner at the Dec. 1 planting date. The actual plant stands achieved ranged from 4 plants/ft^2 (30 lbs. seed/A) to 26 plants/ft^2 (240 lbs. seed/A) at the Dec. 1 planting date. Plant stands were similar for both cultivars over all seeding rates except at 240 lbs/A. At this rate, Westbred 881 achieved a better stand than Aldura, a fact that may have caused the apparent decrease in yield of Westbred 881 at the 240 lb/A seeding rate.

Competition from weeds was severe at the Dec. 1 planting date at seeding rates of 30 and 60 lbs/A only, due to weed growth in bare spots. Lodging was less than 5% in Aldura but increased from 15% (30 lbs. seed/A) to 44% (240 lbs. seed/A) in Westbred 881. Optimum yield at the Dec. 1 planting date was achieved between 120 and 180 lbs. seeds/A or between 15 and 20 plants/ft^2 for both cultivars in this study.

At the Jan. 16 planting date, Aldura achieved an optimum yield between seeding rates of 120 to 180 lbs/A or 20 plants/ft^2. Yield of Westbred 881, however, increased linearly with seeding rate up to 240 lbs/A or 30 plants/ft^2. Lodging did not occur at this planting date. Plant stands ranged from 5 plants/ft^2 (30 lbs. seed/A) to 30 plants/ft^2 (240 lbs. seed/A). Westbred 881 achieved plant stands 27% greater than Aldura at each seeding rate. The relationship between yield and stand for each cultivar was similar to that between yield and seeding rate depicted in Fig. 1.

ROW SPACING

The influence of row spacing on grain yield of Westbred 881 and Aldura at two planting dates is illustrated in Fig. 2. At the Dec. 1 planting date, Aldura attained similar yields at row spacings from 3 to 12 inches, then decreased in yield at 18 and 24 inch row spacings. Yield of Westbred 881 decreased linearly with an increase in row spacing. The highest yield achieved in this study was with Westbred 881 at the 3-inch row spacing. Lodging increased with row spacing from 2 to 20% and 27 to 66% for Westbred 881 and Aldura, respectively, due to less distance between plants within rows with wider row spacing.

At the Jan. 16 planting date, row spacings of 6 and 12 inches were optimum for both Westbred 881 and Aldura. Lodging was not observed at this planting date.