ALFALFA SEED QUALITY FAVORED BY WATER STRESS

Clinton C. Shock, Erik B.G. Feibert, and Lamont D. Saunders
Malheur Experiment Station,
Oregon State University

Jim Klauzer
Clearwater Supply
Ontario, OR

Summary

Two alfalfa varieties ('Tango' and 'Accord') were grown for seed using subsurface drip irrigation with four evapotranspiration (ET_c) replacement levels: 80, 60, 40, and 20 percent of the accumulated water needs. After the start of flowering the alfalfa was irrigated every 3-4 days at the corresponding ET_c replacement level. Over the 3 years seed quality was maximized at 20 to 30 percent of ET_c replacement level, but seed yield was maximized by 40 to 50 percent ET_c replacement level. Seed quality at 40 to 50 percent ET_c replacement was above certification standards each year. The results suggest that alfalfa seed production can be maximized with 40 to 50 percent ET_c replacement using drip irrigation.

Introduction

In the 1980's, research at the Malheur Experiment Station with furrow-irrigated alfalfa demonstrated that water stress was associated with high alfalfa seed yields (Shock et al. 1990). There is a strategic balance between the amount of water needed to sustain growth and productivity and water stress sufficient for the alfalfa plant to remain reproductive rather than vegetative. Achieving uniform water stress along the entire length of the field with furrow irrigation is problematic because water application is not uniform. Alfalfa in areas of the field where more water soaks into the soil remains vegetative, while alfalfa in dry areas can become excessively stressed. Subsurface drip irrigation can be used to apply water more uniformly, allowing for more uniform water stress. Subsurface drip irrigation also has environmental benefits compared to furrow irrigation, due to 1) more efficient water use, 2) reduction of deep percolation of water, and 3) elimination of runoff losses of water and nutrients.

Since uniform water stress along the whole field length is feasible with drip irrigation, accurate irrigation management becomes important. The purpose of this experiment was to determine the level of deficit irrigation that optimizes alfalfa seed quality and yield.

Materials and Methods

Establishment Procedures

Alfalfa was grown for seed on a Nyssa silt loam of modest fertility (pH of 7.8, 1.5 percent organic matter [OM]) and field history of modest productivity. The site was chosen to be representative of fields used for alfalfa seed production. The field was previously planted to wheat. Two varieties of alfalfa were planted on April 6, 2000 at 2 lb/acre in 30-inch rows. Tango, with a dormancy rating of six was planted in the upper half of the field and Accord, with a dormancy of four was planted in the lower half of the field. The alfalfa was irrigated with drip tape (T-Tape TSX 515-16-340) buried at 12-inch depth between two alfalfa rows. The drip tape was buried on alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 PSI with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour. In 2000, the year of establishment, the field was irrigated uniformly the whole season. The seed was harvested with a commercial combine.

In early March of each of the following years, the field was cultivated with a triple-K and Prowl® at 3.3 lb ai/acre was broadcast. The alfalfa was flailed (clipped back just above ground level) on May 3, 2001 and 2002, and on May 1, 2003 to delay flowering until air temperature was adequate for leafcutter bee activity.

Alfalfa leafcutting bee (*Megachile rotundata*) populations were maintained at standard levels using four houses with nesting boards at the center of each field edge.

Alfalfa Irrigation

The following irrigations were applied to all plots before flowering: 2 inches on May 23 and June 1, 2001; 2 inches on May 17, May 30, and June 6, 2002; and 2 inches on May 23 and June 2, 2003. Flower bud break started on June 1, 2001, June 15, 2002, and June 7, 2003. After the start of flowering, the alfalfa was irrigated at four levels of alfalfa crop evapotranspiration (ET_c) replacement (20, 40, 60, and 80 percent) with five replicates of each treatment (Table 1). Each treatment was irrigated every 3-4 days. The amount of water to be applied to each treatment at each irrigation was calculated as the respective percentage of the difference between the accumulated ET_c and the accumulated amount of irrigation water plus precipitation applied. Both ET_c and irrigation water plus precipitation were accumulated from the start of flowering. Irrigations were terminated on August 21, 2001, August 15, 2002, and August 7, 2003. Each plot consisted of eight alfalfa rows spaced 30 inches apart, 480 ft long, with two subplots corresponding to the two alfalfa varieties. Each plot was irrigated separately by its own pressure regulator, electronic solenoid valve, and water meter. Water meters were read before and after each irrigation.

Alfalfa ET_c was calculated with a modified Penman equation (Wright 1982) and peak alfalfa crop coefficients using data collected at the Malheur Experiment Station by an AgriMet weather station (U.S. Bureau of Reclamation, Boise, ID) adjacent to the field. The ET_c was estimated and recorded from dormancy break until the final irrigation. Dormancy break occurred on March 1, 2001, March 26, 2002, and March 10, 2003.

After the alfalfa was flailed, the ET_c was adjusted using crop cover. The crop cover was derived from weekly measurements of the percent ground cover until full cover was achieved. Full cover was achieved by mid- to late May, before flowering.

Determination of Soil Water Content
Soil volumetric water content was determined by Gro-Point™ soil moisture sensors (Environmental Sensors Inc., Victoria, British Columbia, Canada). The Gro-Point sensors use TDT (Time Domain Transmissometry) technology to measure soil moisture. One Gro-Point sensor was installed at 12-inch depth and one at 20-inch depth in each plot. The Gro-Point sensors were installed horizontally halfway between the drip tape and the alfalfa row in the plot center. Sensors were located 70 ft from the center of the field in the Tango subplots. Sensors were connected by buried cables to electronic communication boards housed in two locations in the field. The electronic communication boards were connected by a cable to a personal computer in the station office, allowing the soil water content to be read and logged every hour.

Soil volumetric water content was also measured with a neutron probe to verify moisture readings from the Gro-Point sensors. One access tube was installed in each plot halfway between the drip tape and the alfalfa row in the plot center. The neutron probe access tubes were located 15 ft from the center of the field in the Tango subplots. Neutron probe readings were made twice weekly at the same depths as the Gro-Point sensors. The neutron probe was calibrated by taking soil samples and probe readings at 12-inch and 20-inch depths during installation of the access tubes. The soil water content was determined gravimetrically from the soil samples and regressed against the neutron probe readings, separately for each soil depth. The regression equations were then used to transform the neutron probe readings during the season into volumetric soil water content. Regression equations were: $Y = 2.12 + 0.0039X$ ($R^2 = 0.86$, $P = 0.001$) for the 12-inch depth, and $Y = -15.04 + 0.0068X$ ($R^2 = 0.96$, $P = 0.001$) for the 20-inch depth, where X = 32-second neutron probe counts and Y = percent soil volumetric water content. Volumetric water content measured by the Gro-Point sensors was adjusted to volumetric water content measured by neutron probe using regression equations for each depth separately (Fig. 1).

Lygus Bug Monitoring and Control
Lygus bugs (*Lygus hesperus*) were monitored twice weekly by taking three 180° sweeps with an insect net in each plot. The total numbers of early and late lygus instars and lygus adults in each sweep were determined. When the total number of lygus (early and late instars, and adults), averaged over all plots, reached four per sweep, insecticides were applied. The insecticides were of short longevity and were applied in the late evening to minimize adverse effects on the leafcutting bees. The timing of insecticide applications was affected by wind and commercial application spraying schedules.

Alfalfa Biomass Yields
Biomass samples were taken in each subplot by cutting the plants at ground level in 3.3 ft of one row on August 6, August 22, and August 19, in 2001, 2002, and 2003,

respectively. The samples were weighed, oven dried, and weighed again. The dried samples were separated into stems, leaves, and seed pods. The separated samples were oven dried and weighed.

Alfalfa Seed Yield and Quality

The alfalfa was desiccated with Boa® (Paraquat dichloride) at 0.63 lb ai/acre plus Reglone® (Diquat) at 0.5 lb ai/acre on August 29 each year. On September 5, 2001, September 9, 2002, and September 12, 2003, 66 ft of each subplot was harvested with a small-plot combine (52-inch width). The harvested seed was cleaned and weighed. A 400-seed sample was taken from each subplot and analyzed for germination, hard seed, abnormal seed, and dead seed by the Oregon State University Seed Laboratory. Seed size was determined by weighing a 504-seed sample from each subplot.

Data were analyzed using analysis of variance (General Linear Models procedure) and regression (Response Surface Analysis) from NCSS software (NCSS, Kaysville, UT).

Results and Discussion

Differential Irrigation

The total ET_c from dormancy break to the onset of flowering was 11.7, 10.1, and 11.4 inches in 2001, 2002, and 2003, respectively. The total amount of water applied plus precipitation from dormancy break to the onset of flowering was 6.2, 6.9, and 7.6 inches in 2001, 2002, and 2003, respectively. There were small differences between treatments in the average soil volumetric water content during the period from clipback to the onset of flowering (Table 1). These differences were unrelated to the treatments. The average soil volumetric water content was higher during the pre-flowering period than the post-flowering period for the 20 percent, 40 percent, and 60 percent ET_c replacements. For the 80 percent ET_c replacement, the average soil volumetric water content was close to or lower during the pre-flowering period than the post-flowering period.

The total ET_c from the onset of flowering to the end of August was 25.1, 25.1, and 26.8 inches in 2001, 2002, and 2003, respectively. The total ET_c from dormancy break to the end of August was 37.9, 35.3, and 38.2 inches in 2001, 2002, and 2003, respectively.

After the start of flowering, the treatments were clearly differentiated in terms of the total amount of water applied and the actual percent of ET_c replaced (Table 1). The treatments followed fairly closely the experimental plan.

Each year, there was a significant trend for increasing average soil volumetric moisture content with increasing ET_c replacement (Table 1).

Alfalfa Seed Quality

The response of seed quality to ET_c replacement was similar for the two varieties. There was a trend for increasing germination with decreasing ET_c replacement each year (Table 2, Fig. 2). There was a trend for increasing germination plus hard seed with decreasing ET_c replacement in 2001 and 2002, but not in 2003 (Table 2, Fig. 3). There was a trend for increasing abnormal plus dead seed with increasing ET_c replacement in 2001 and 2002, but not in 2003 (Table 2, Fig. 4). There was a trend for increasing seed size with increasing ET_c replacement each year (Table 2, Fig. 5).

Alfalfa Biomass and Seed Yields

The response of biomass dry yield, seed pod dry weight percentage, seed pod yield, and seed yield to ET_c replacement was similar for the two varieties. There was a trend for increasing biomass dry yield with increasing ET_c replacement each year (Table 2, Fig. 6). Averaged over years and varieties, seed pod dry weight as a proportion of the whole plant dry weight was highest with either 40 or 60 percent ET_c replacement (Table 2, Fig. 7). Averaged over years and varieties, seed pod yield was highest with 60 percent ET_c replacement (Table 2, Fig. 8). Averaged over years and varieties, seed yield was highest with either 40 percent or 60 percent ET_c replacement (Table 2, Fig. 9).

Calculated from the regression equations, maximum seed pod yield was achieved with 46 percent, 57 percent, and 60 percent ET_c replacement in 2001, 2002, and 2003, respectively (Fig. 8). Averaged over the 3 years, seed pod yield was highest with 55 percent ET_c replacement.

Calculated from the regression equations, maximum seed yield was achieved with 40 percent, 51 percent, and 67 percent ET_c replacement in 2001, 2002, and 2003, respectively (Fig. 9). Averaged over the 3 years, seed yield was highest with 50 percent ET_c replacement (Fig. 9). Calculated from the regression equations, maximum seed pod dry weight percentage was achieved with 22 percent, 49 percent, and 45 percent ET_c replacement in 2001, 2002, and 2003, respectively (Fig. 7). Averaged over the 3 years, seed pod dry weight percentage was highest with 44 percent ET_c replacement.

Conclusion

The increasing water deficit from the irrigation treatments caused the alfalfa plants to shift from higher vegetative growth to more reproductive growth, with the highest reproductive growth at a moderate level of water stress. Highest seed pod dry weight percentage, seed yield, and seed pod yield were achieved with 44, 50, and 55 percent ET_c replacement, respectively. Highest seed quality (highest germination and lowest defective seed) was achieved with 20 to 30 percent ET_c replacement. The alfalfa seed size decrease with decreasing ET_c replacement was more pronounced below about 50 to 60 percent ET_c replacement. For certification purposes, alfalfa seed must have a minimum germination plus hard seed of 85 percent in Oregon. Each year and averaged over the 3 years, calculated germination plus hard seed for a 50 percent ET_c replacement was close to or higher than 85 percent. This suggests that alfalfa seed production can be optimized at 40 to 50 percent ET_c replacement. An ET_c replacement of 40 to 50 percent would maximize seed yield without reducing seed quality below certification standards and would maintain larger seed sizes.

References

Shock, C.C., T. Stieber, B. Stephen, V. Cairo, L. Saunders, B. Gardner, A. Bibby, and D. Tipton. 1990. Water stress and alfalfa seed yields. Oregon State University Agricultural Experiment Station Special Report 862:5-10.

Wright, J.L. 1982. New evapotranspiration crop coefficients. J. Irrig. Drain. Div., ASCE 108:57-74.

Table 1. Water applied plus precipitation and soil volumetric water content for an alfalfa seed crop submitted to four irrigation treatments. Average soil volumetric water content is the average of the 12- and 20-inch depths. Soil volumetric water content for pre-bloom period in 2001 was not available. Malheur Experiment Station, Oregon State University, Ontario, OR.

ET_c replacement		Total water applied from the onset of flowering to the last irrigation	Total water applied from dormancy break to the last irrigation	Average soil volumetric water content	
Planned	Actual			Clipback to bloom	Bloom to last irrigation
---------- % ----------		------------ inch ------------		------------ % ------------	
2001					
20	21.1	5.3	8.6		18.3
40	38.0	9.5	14.6		29.0
60	62.2	15.6	19.7		31.7
80	77.8	19.5	23.0		30.9
average					27.5
2002					
20	22.3	5.6	11.4	26.5	18.4
40	38.5	9.7	15.5	31.0	25.1
60	62.1	15.6	21.4	32.0	30.9
80	78.3	19.6	25.4	28.3	33.0
average				29.4	26.9
2003					
20	24.3	6.5	10.5	33.0	19.7
40	39.7	10.6	14.6	33.0	25.0
60	60.3	16.2	20.2	32.6	26.8
80	80.0	21.4	25.4	32.0	32.3
average				32.7	26.0
3-year average					
20	22.5	5.8	10.2	27.7	18.8
40	38.7	10.0	14.9	30.8	26.5
60	61.5	15.8	20.4	33.4	30.2
80	78.7	20.2	24.6	29.7	32.1
LSD (0.05)					
Treatment	3.3	0.9	0.5	NS	7.3
Year	NS	1.0	0.4	2.0	1.3
Trt X Year	NS	NS	NS	NS	2.7

Table 2. Seed quality for alfalfa submitted to four irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR.

Et_c replacement	Germination				Germination plus hard seed				Abnormal plus dead seed				Seed size			
	2001	2002	2003	Avg.	2001	2002	2003	Avg.	2001	2002	2003	Avg.	2001	2002	2003	Average
	-------------- % --------------				-------------- % --------------				-------------- % --------------				-------------- seeds/lb --------------			
Tango																
80	77.8	36.4	69.6	61.3	89.0	64.4	86.6	80.0	11.0	35.6	13.4	20.0	193,294	186,189	183,089	187,619
60	82.5	58.4	79.8	72.9	91.5	84.4	89.2	88.1	8.5	15.6	10.8	11.9	195,013	188,068	189,636	190,612
40	88.0	73.8	83.4	81.7	93.0	87.8	88.2	89.7	7.0	12.2	11.8	10.3	196,248	196,125	195,013	195,796
20	92.0	79.0	82.0	83.8	97.8	90.0	88.8	91.8	2.0	10.0	10.8	8.0	197,900	226,088	206,647	210,212
avg	84.8	61.9	78.7	74.8	92.6	81.7	88.2	87.3	7.3	18.4	11.7	12.6	195,645	199,798	193,596	196,299
LSD (0.05)																
Treatment				5.0				4.5				4.6				6,416
Trt X Year				5.0				4.0				4.0				9,471
Year				2.5				2.0				2.0				NS
Accord																
80	73.2	42.0	69.6	61.6	87.4	68.2	88.2	81.3	12.6	31.8	11.8	18.7	194,210	187,206	184,802	188,739
60	88.0	58.2	77.6	74.6	95.6	81.8	90.2	89.2	4.4	18.2	9.8	10.8	195,090	186,002	187,572	189,555
40	82.8	70.6	76.8	76.7	91.6	89.6	87.6	89.6	8.4	10.4	12.4	10.4	197,686	197,004	192,280	195,657
20	92.0	74.4	75.8	80.7	97.6	87.6	85.6	90.3	2.4	12.4	14.4	9.7	206,907	228,375	208,822	215,258
avg	84.0	61.3	75.0	73.4	93.1	81.8	87.9	87.6	7.0	18.2	12.1	12.4	198,029	199,647	193,369	196,998
LSD (0.05)																
Treatment				8.3				4.5				4.5				6,816
Trt X Year				7.7				5.1				5.1				9,599
Year				3.8				2.5				2.5				4,800
Average over varieties																
80	75.5	39.2	69.6	61.4	88.2	66.3	87.4	80.6	11.8	33.7	12.6	19.4	193,752	186,754	183,945	188,199
60	85.6	58.3	78.7	73.8	93.8	83.1	89.7	88.7	6.2	16.9	10.3	11.3	195,056	187,035	188,604	190,065
40	85.4	72.2	80.1	79.2	92.3	88.7	87.9	89.6	7.7	11.3	12.1	10.4	196,967	196,564	193,647	195,726
20	92.0	76.7	78.9	82.2	97.7	88.8	87.2	91.0	2.2	11.2	12.6	8.9	201,903	227,231	207,735	212,648
avg	84.4	61.6	76.8	74.1	92.8	81.7	88.1	87.5	7.1	18.3	11.9	12.5	196,837	199,720	193,483	196,651
LSD (0.05)																
Treatment				3.8				3.5				3.2				5,781
Trt X year				4.5				3.2				3.3				8,798
Year				2.2				1.6				1.6				4,399

Table 3. Seed yield and seed pod dry weight for alfalfa submitted to four irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR.

ET_c replacement	Yield				Seed pod yield				Biomass yield				Seed pod dry weight			
	2001	2002	2003	Average	2001	2002	2003	Average	2001	2002	2003	Average	2001	2002	2003	Average
%	lb/acre				lb/acre				tons/acre				%			
Tango																
80	292.6	115.9	225.8	210.4	690.4	726.0	1,545.7	987.4	3.88	4.91	4.70	4.49	9.1	7.1	16.9	11.0
60	575.8	467.8	270.0	437.9	1,186.5	1,483.3	1,604.3	1,415.7	3.04	3.32	3.02	3.13	19.3	23.2	26.9	23.1
40	617.4	352.6	160.9	392.4	1,038.5	808.0	1,288.1	1,045.3	2.96	2.44	2.42	2.61	20.9	15.4	26.8	21.0
20	581.5	84.0	72.2	245.9	924.4	281.0	614.8	606.2	2.11	1.27	1.68	1.69	21.7	9.5	18.6	16.6
avg	516.8	255.1	181.0	322.3	955.8	751.4	1,297.3	1,006.0	3.00	2.99	2.95	2.98	17.7	13.8	22.3	17.9
LSD (0.05)																
Treatment				92.7				256.8				0.50				4.0
Trt X Year				165.1				381.1				0.59				6.1
Year				82.6				190.5				NS				3.0
Accord																
80	411.3	142.4	252.7	271.3	555.8	714.3	975.8	761.1	3.24	4.32	2.63	3.33	12.1	7.7	15.9	11.5
60	678.7	509.5	338.5	508.9	1,319.9	1,229.6	1,073.4	1,228.1	3.06	3.10	2.67	2.94	21.5	15.9	23.6	20.4
40	726.6	470.2	196.5	464.4	1,635.3	948.5	1,217.8	1,240.9	2.97	2.36	2.22	2.52	28.7	17.9	27.5	24.7
20	571.7	141.4	94.4	281.7	1,064.8	351.3	714.3	710.5	2.02	1.47	1.46	1.65	29.9	10.7	23.4	21.2
avg	597.1	315.9	224.2	387.2	1,234.1	788.7	988.0	994.3	2.82	2.73	2.25	2.60	24.3	12.9	22.8	19.8
LSD (0.05)																
Treatment				97.8				205.9				0.40				2.2
Trt X Year				139.4				289.3				0.71				5.4
Year				69.7				144.7				0.36				2.7
Average over varieties																
80	352.0a	129.1a	237.3a	239.7a	692.7	720.2	1,282.3	898.4	3.55	4.80	3.66	4.01	10.7a	7.4a	15.2a	11.1
60	627.3b	488.7b	304.3b	473.4b	1,253.2	1,412.5	1,452.0	1,369.8	3.05	3.21	2.84	3.04	20.4b	20.1b	26.0bc	22.2
40	672.0b	411.4b	180.7c	429.7b	1,336.9	878.3	1,253.0	1,143.1	2.96	2.40	2.32	2.56	24.8c	16.7c	27.1b	22.9b
20	576.6b	112.7c	82.1d	263.2c	1,007.5	322.0	708.5	679.3	2.06	1.38	1.57	1.67	25.8c	10.1d	21.0c	19.0c
avg	557.0	285.5	202.0	354.5	1,058.7	802.8	1,173.9	1,014.6	2.91	2.95	2.60	2.82	20.4	13.6	22.5	18.9
LSD (0.05)																
Treatment				85.8				193.7				0.40				3.2
Trt X Year				115.0				289.8				0.53				5.0
Year				57.5				144.9				0.26				2.5

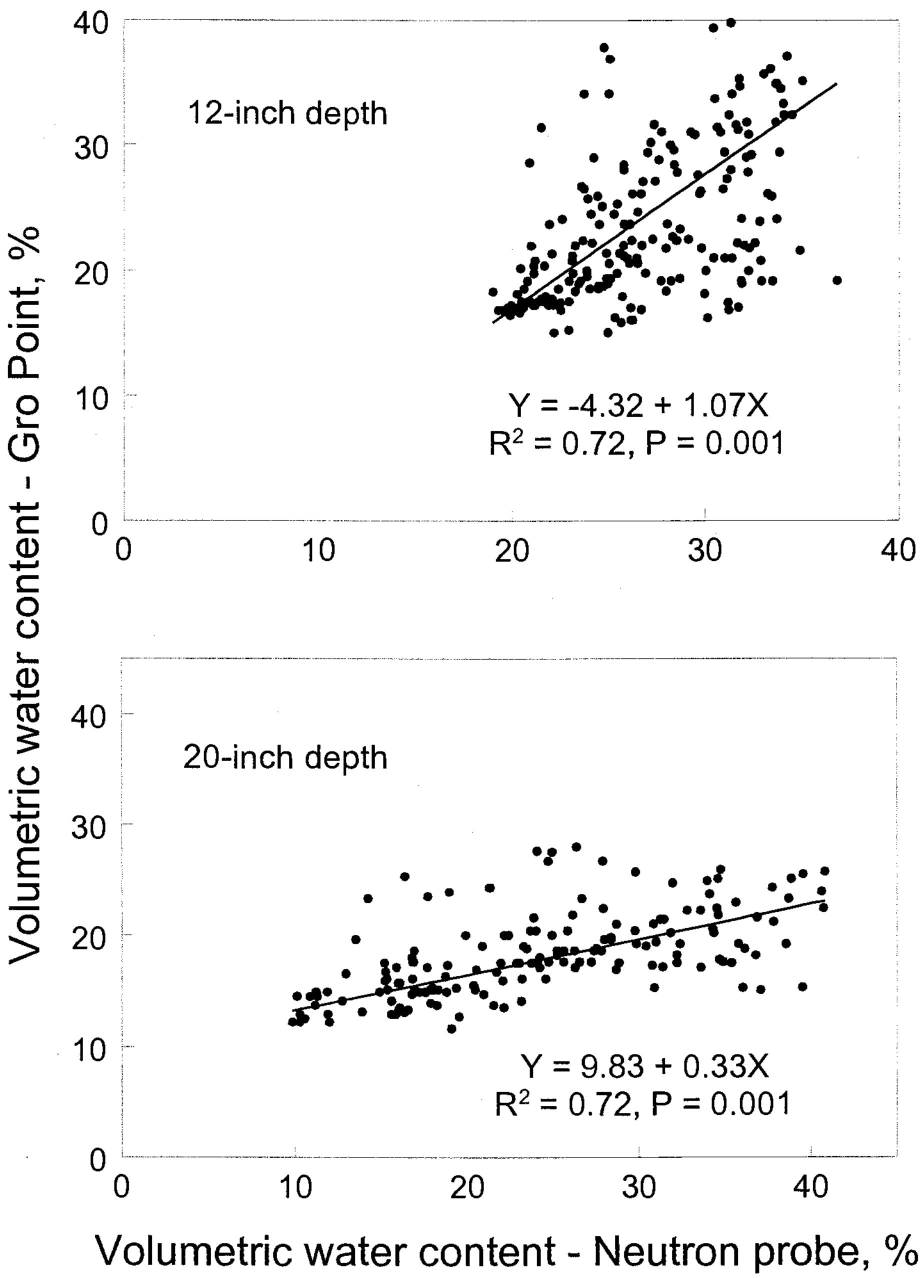

Figure 1. Relationship between volumetric soil water content measured by neutron probe and by Gro-Point sensors. Malheur Experiment Station, Oregon State University, Ontario, OR.

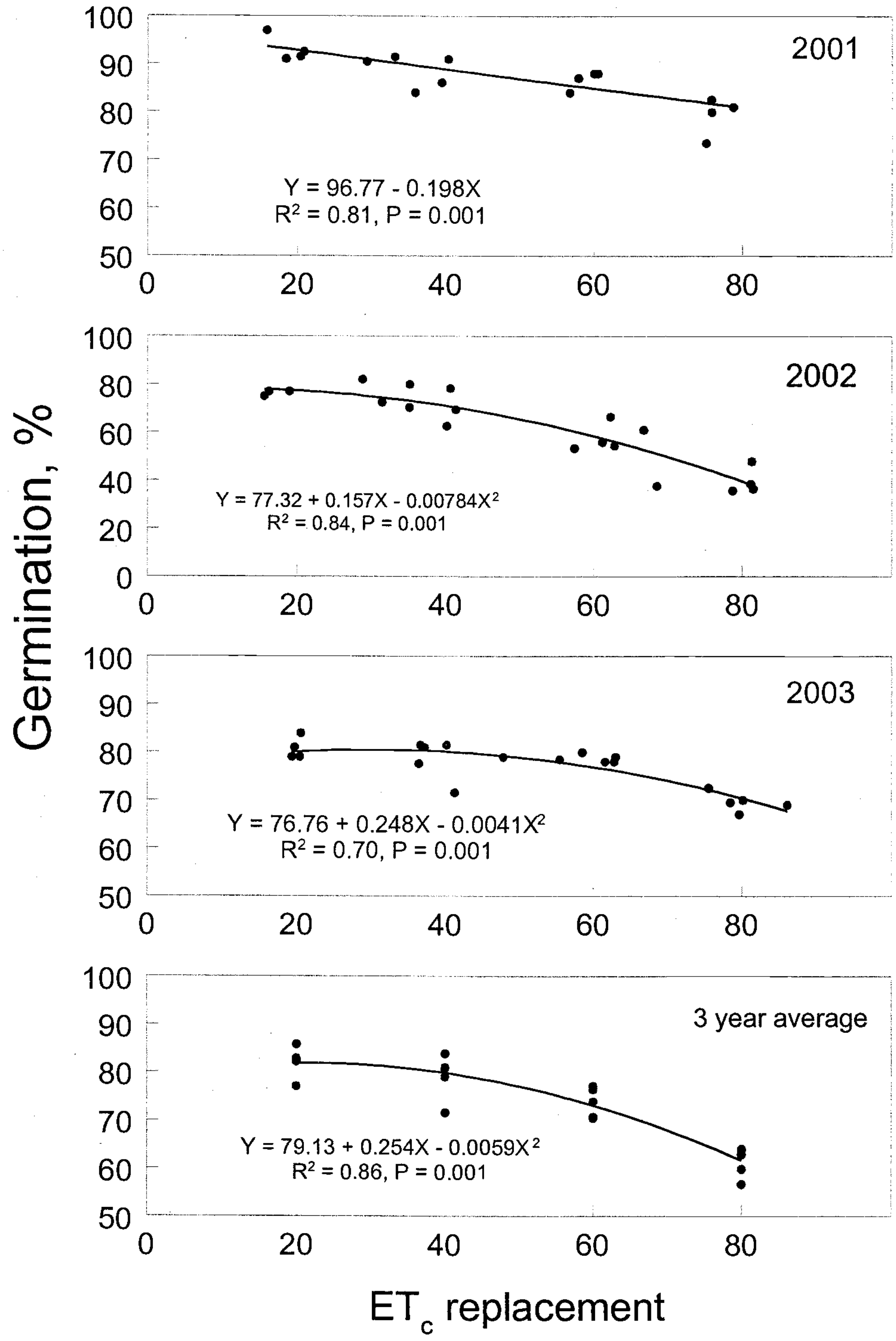

Figure 2. Alfalfa seed germination response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

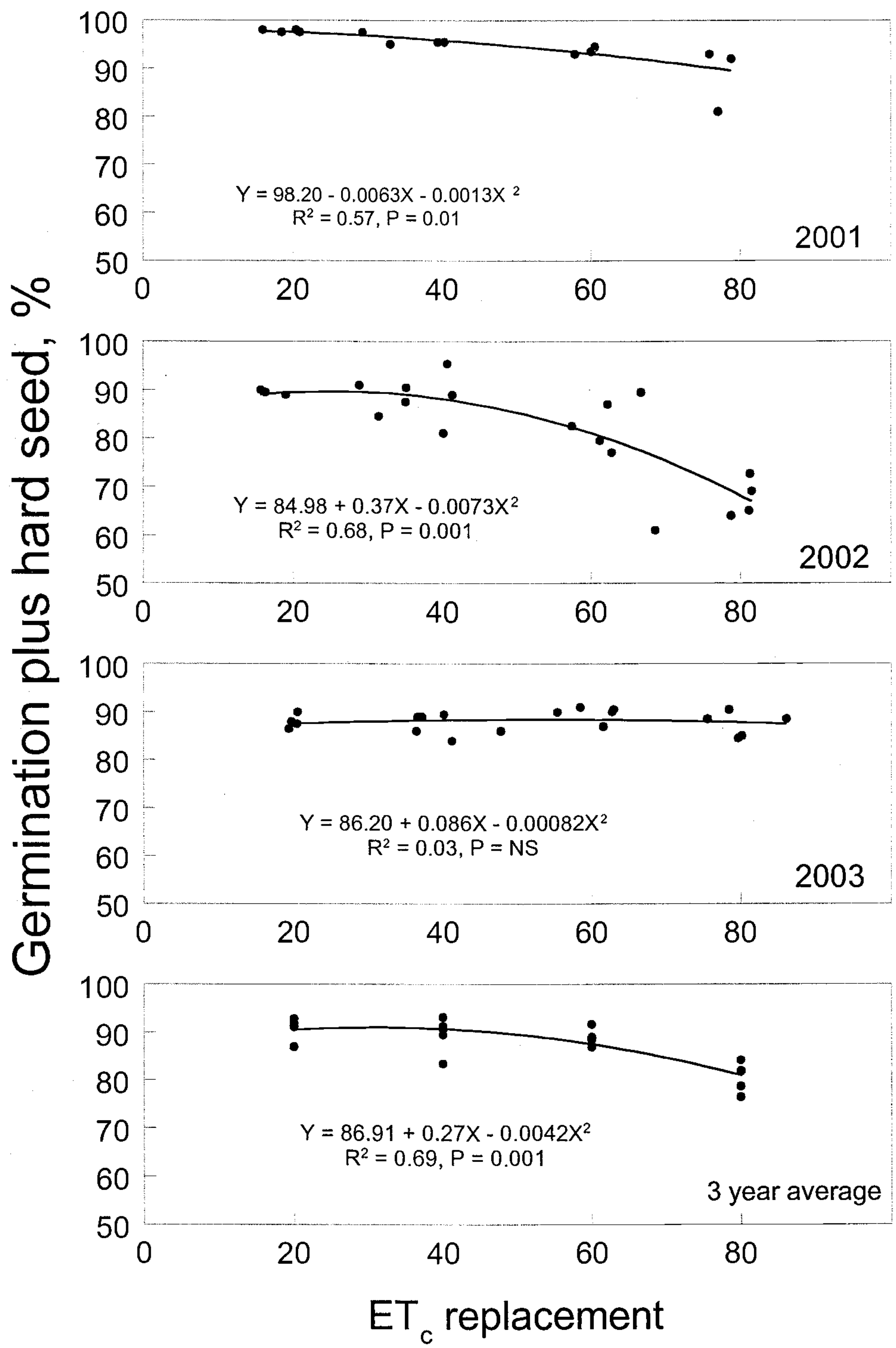

Figure 3. Alfalfa seed germination plus hard seed response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

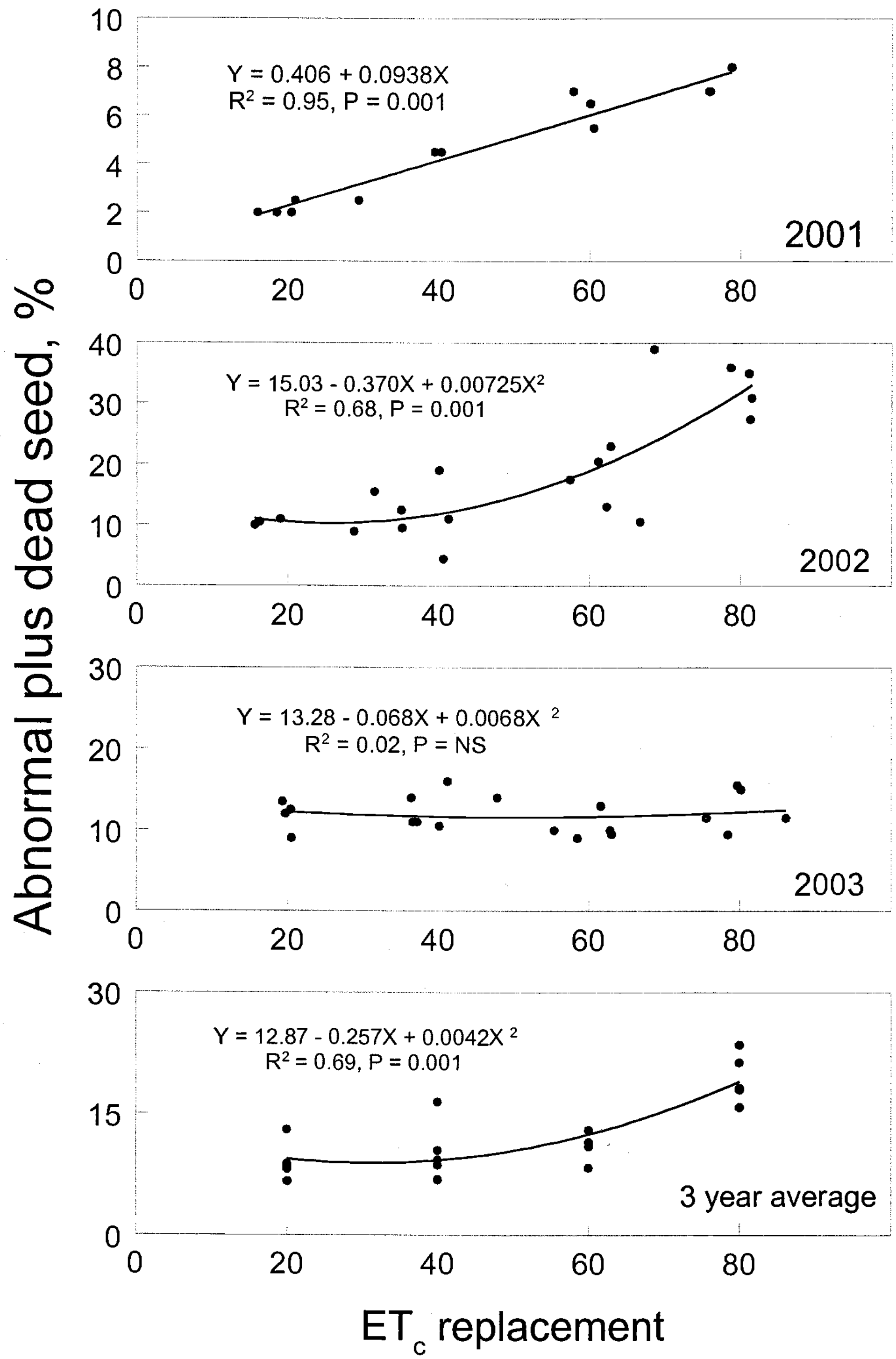

Figure 4. Alfalfa abnormal plus dead seed response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

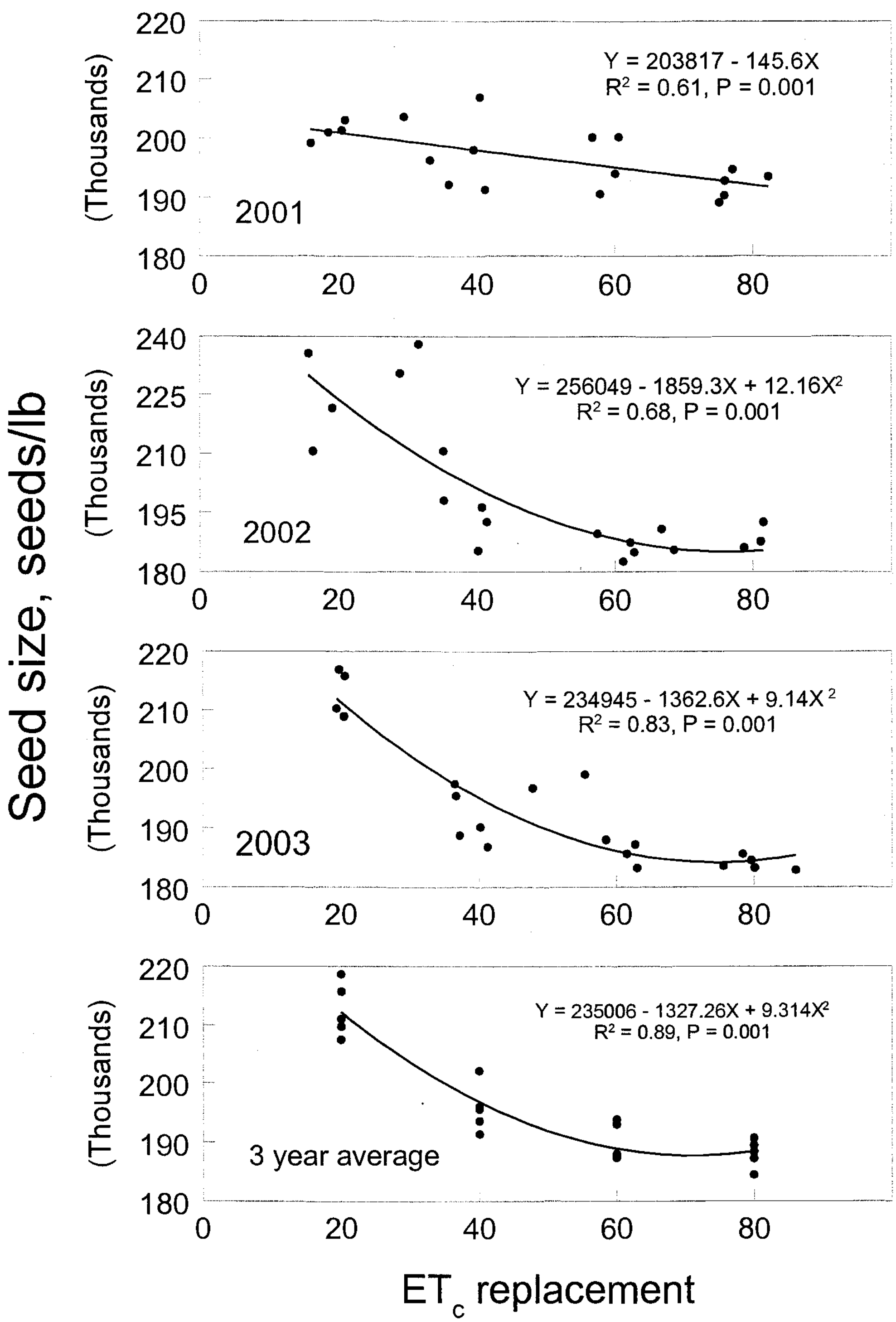

Figure 5. Alfalfa seed size response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

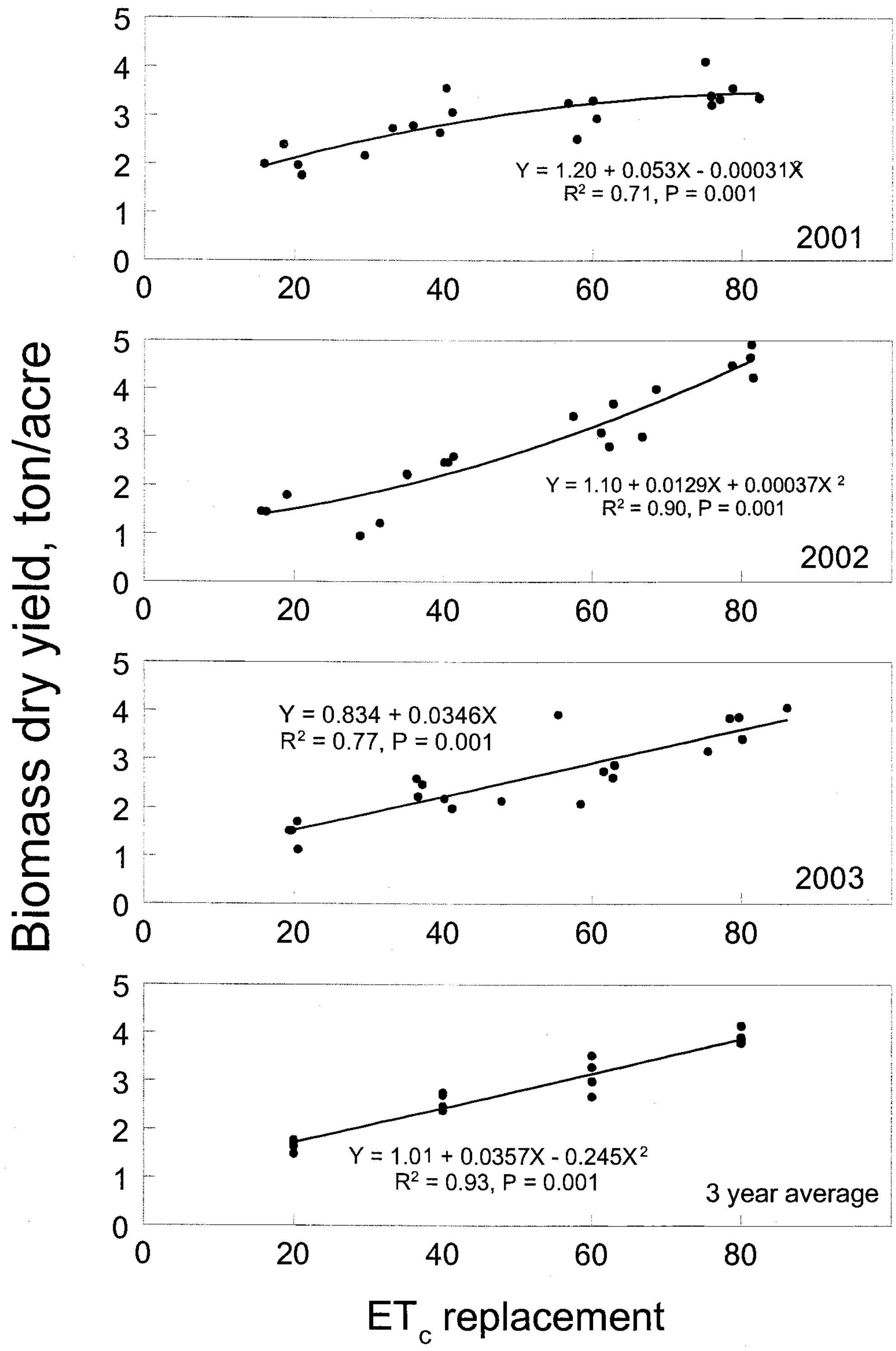

Figure 6. Alfalfa biomass dry yield response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

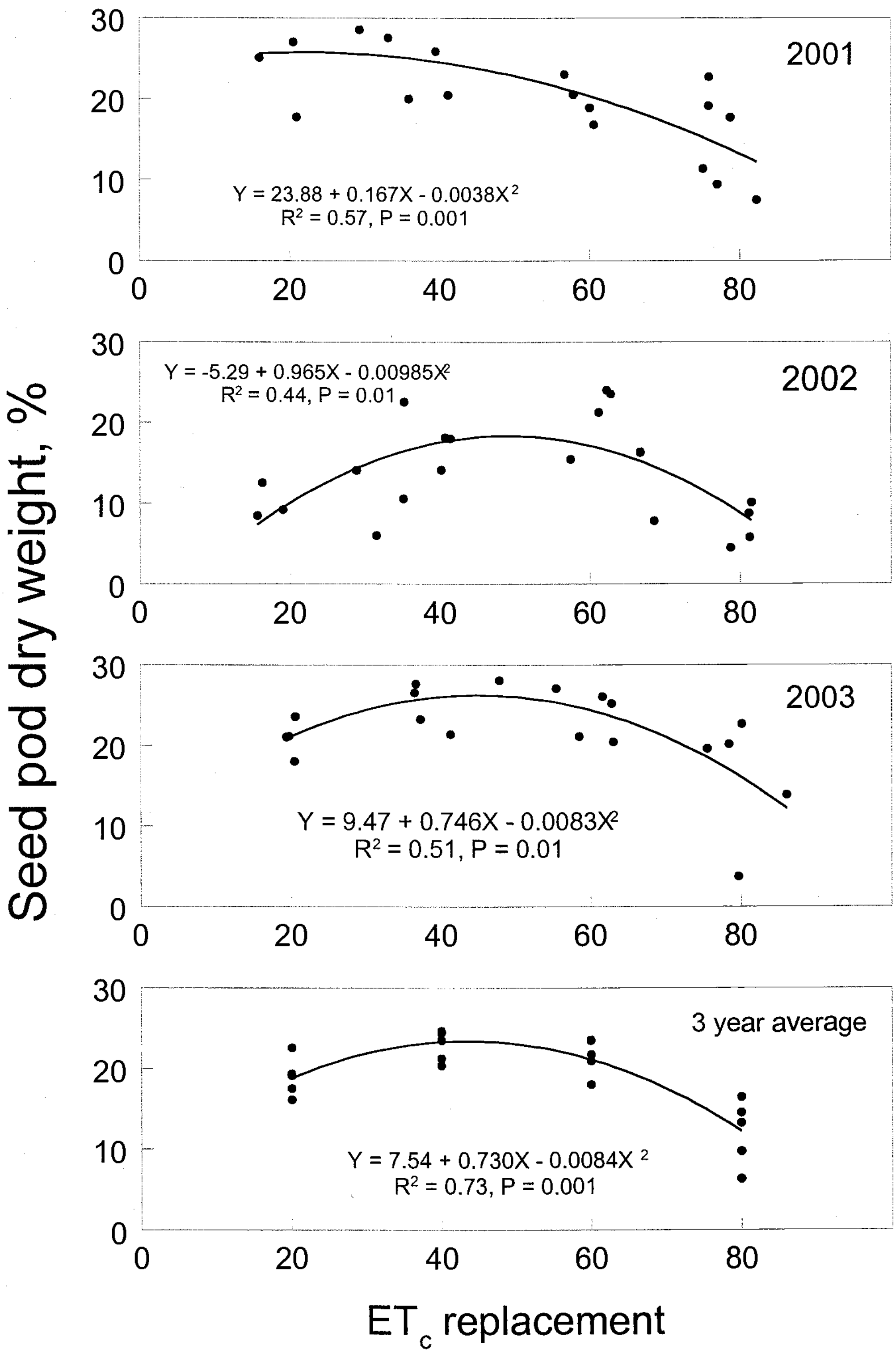

Figure 7. Alfalfa seed pod dry weight response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

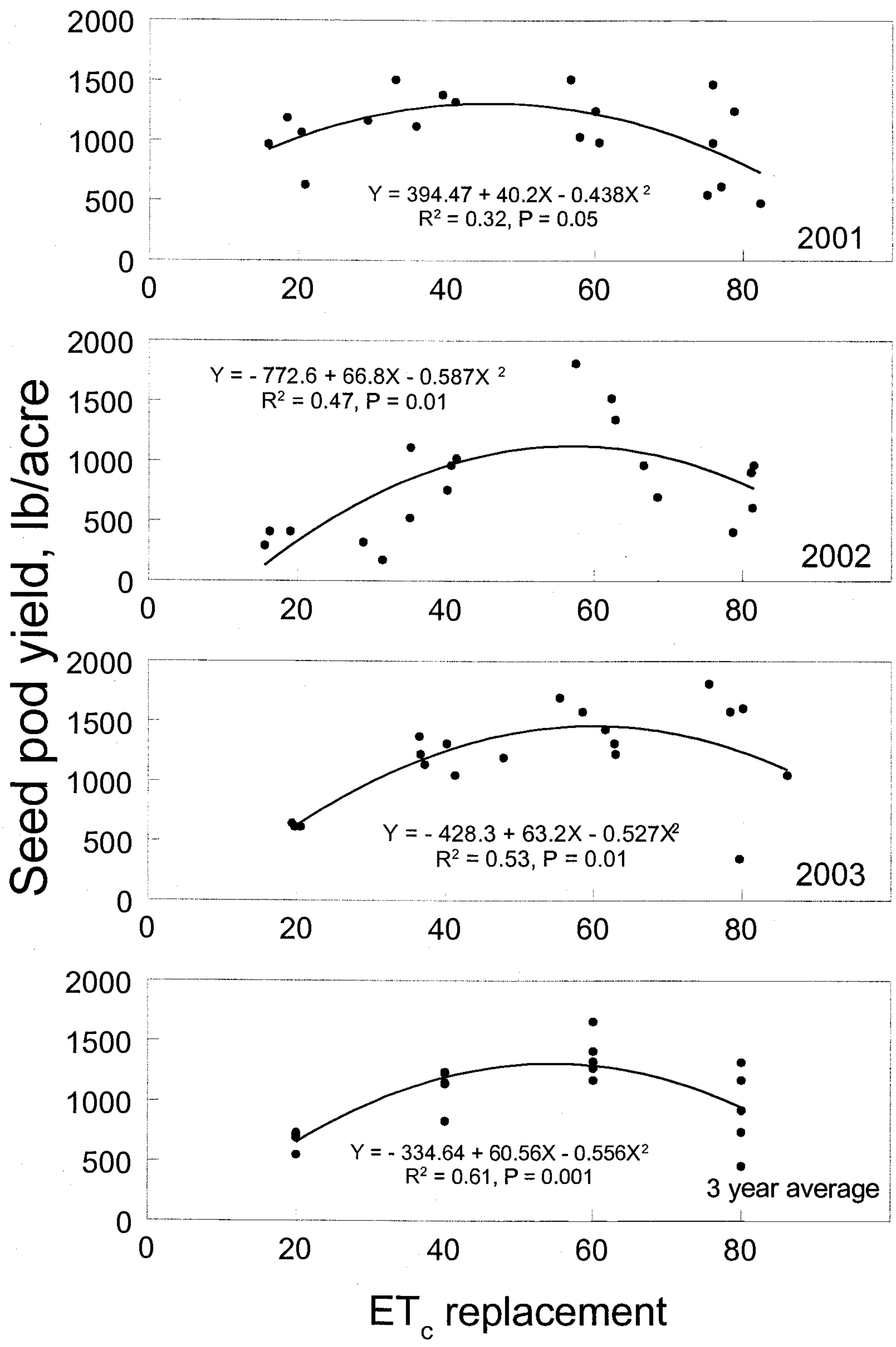

Figure 8. Alfalfa seed pod yield response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

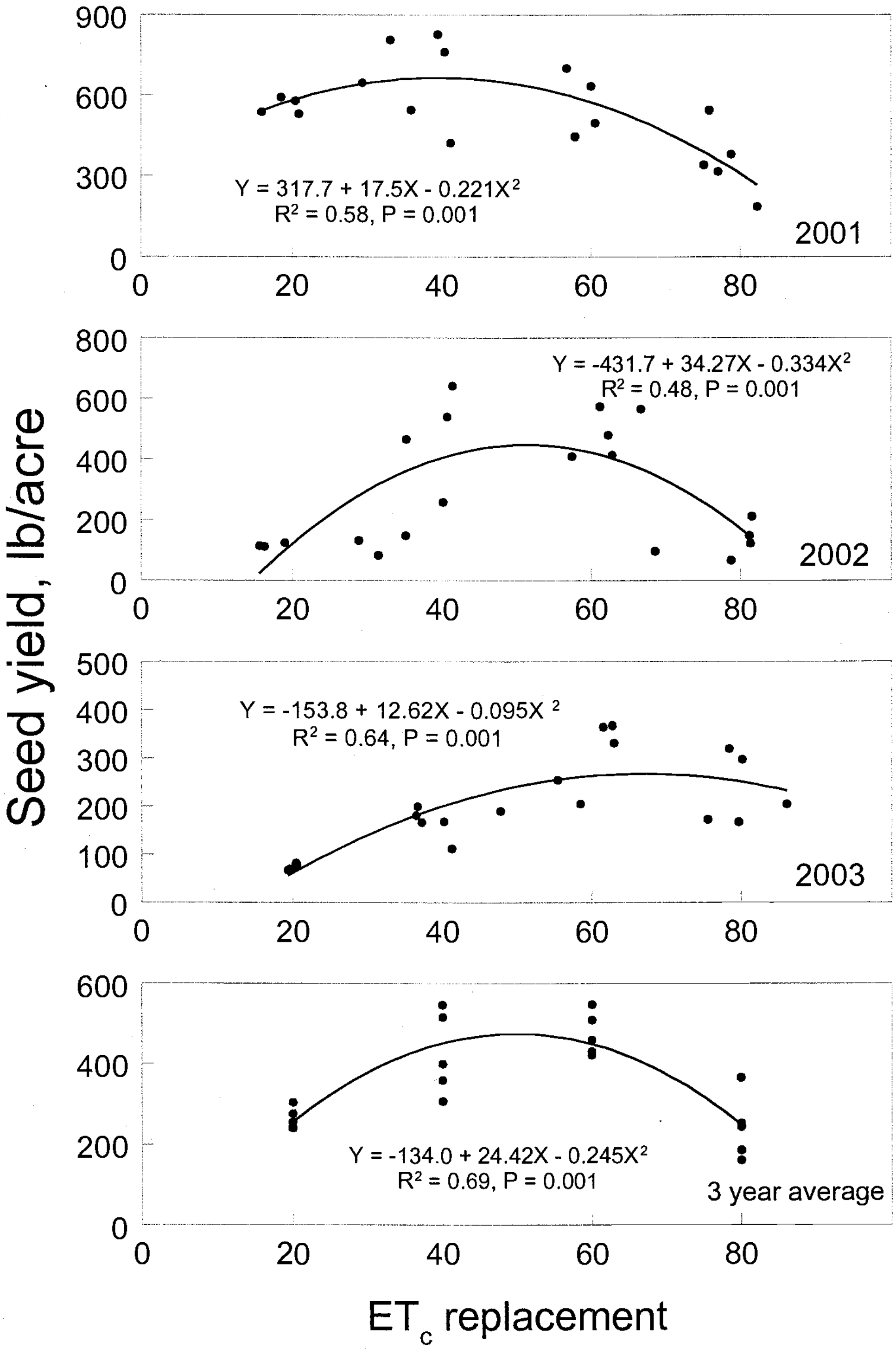

Figure 9. Alfalfa seed yield response to ET_c replacement, averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.