RELATIONSHIP BETWEEN WATER STRESS AND SEED YIELD OF TWO DRIP-IRRIGATED ALFALFA VARIETIES

Clinton C. Shock, Erik B.G. Feibert,
and Lamont D. Saunders
Malheur Experiment Station,
Oregon State University
Jim Klauzer
Clearwater Supply
Ontario, OR 2003

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. In the 2003 season, Tango seed yield was highest at 67 percent of Et_c replacement or 24.1 inches of applied water and Accord seed yield was highest at 64 percent of Et_c replacement or 21.6 inches of applied water.

Introduction

Past work at the Malheur Experiment Station in the 1980's demonstrated that water stress was associated with high alfalfa seed yields. 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 down the 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 dry. Subsurface drip irrigation applies water more uniformly allowing for uniform water stress. Subsurface drip irrigation also has environmental benefits compared to furrow irrigation, due to 1) more efficient water use, 2) elimination of deep percolation of water, and 3) elimination of runoff losses of water and nutrients. The purpose of this experiment was to determine the level of deficit irrigation that optimizes seed yield of two alfalfa varieties.

Methods

Establishment Procedures

Alfalfa was grown for seed on a Nyssa silt loam of modest fertility and 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 field was irrigated uniformly the whole season. The seed was harvested with a commercial combine.

2003 Procedures

Alfalfa Irrigation

On March 10 the field was groundhogged once. The field was sprayed with Prowl on March 11. The alfalfa was flailed on May 1 to delay flowering. On May 2, the field was groundhogged twice to thin the plant stand. Flower bud break started June 7. Approximately 2 acre-inches of water were applied to all plots on May 23 and June 2. After June 7, 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 to replace the percentage of the Et_c deficit that had accumulated since the last irrigation. Irrigations were terminated on August 20.

Each plot consisted of eight alfalfa rows, 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 on March 10 until the final irrigation on August 18. After the alfalfa was flailed, the Et_c was adjusted using crop coefficients. The crop coefficients were derived from weekly measurements of the percent ground cover until full cover was achieved.

Determination of Soil Water Content

Volumetric soil water content was determined by one Gro-Point soil moisture sensor (Environmental Sensors Inc., Escondido, CA) 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 allowing the soil water content to be read and logged every hour.

Alfalfa Seed Yields
On August 19, biomass samples were taken in each subplot by cutting the plants at ground level in 3.3 ft of one row. The samples were weighed, oven dried, and weighed again. The dried samples were separated into stems, leaves, and seed pods.

The alfalfa was desiccated with Boa (Paraquat dichloride) at 0.63 lb ai/acre and Reglone (Diquat) at 0.5 lb ai/acre on August 29. On September 12, 66 ft of each subplot was harvested with a small plot combine (52-inch width). The harvested seed was cleaned to separate the plant debris from the seed. The seed and the debris were weighed. A subsample of 2001 and 2002 seed from each plot was analyzed for quality by the Oregon State University Seed Laboratory on June 30, 2003. A 400-seed sample was taken from each subsample and analyzed for germination, hard seed, abnormal seed, and dead seed.

Lygus bug monitoring and control
Lygus bugs were monitored twice weekly by taking three 180° sweeps with an insect net in each plot. The total number of early and late instars and adults was counted at each location. When the total number of insects (early and late instars, and adults) reached four per sweep, insecticides were applied (Table 1).

Table 1. Aerial insecticide applications for lygus bug control, Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	Product	Rate lb ai/acre
June 11	Capture	0.1
June 11	Cygon	0.5
June 26	Metasystox-R	0.5
July 16	Dibrom	0.9
July 16	Warrior	0.02
August 4	Capture	0.032
August 8	Dibrom	1.4
August 8	Warrior	0.03

Results and Discussion

Differential Irrigation
The total Et_c from dormancy break to the start of flowering (March 10 to June 6) was 11.4 inches, substantially higher than the approximately 4 inches applied uniformly to all plots (Fig. 1a). After the start of flowering, the treatments were clearly differentiated in terms of cumulative amount of water applied over time (Fig. 1b). The total amount of water applied after the start of flowering was 21.4, 16.2, 10.8, and 5.4 acre-inches per acre for treatments 1-4, respectively. The total Et_c from the start of flowering until the last irrigation was 26.8 acre-inches. The total Et_c for the season was 38.2 inches.

Soil moisture was closely related to the irrigation treatments (Fig. 2). The average soil moisture content at 12-inch depth from June 7 through August 20 was 31, 25, 23, and

20 percent for treatments 1-4, respectively. Soil moisture content at 12-inch depth for treatments 1-3 was similar during irrigations, but became lower between irrigations in accordance with the irrigation treatments. Soil moisture content at 12-inch depth for treatment 4 (irrigated at 20 percent Et_c), remained lower than for the other treatments during and after irrigations. Soil moisture content at 20-inch depth was lower than at 12-inch depth for all treatments (Fig. 3). Soil moisture content at 20-inch depth for treatments 1-3 was similar during and between irrigations. Soil moisture content at 20-inch depth for treatment 4 did not respond to irrigations.

Alfalfa Seed Yields

Alfalfa seed yield increased with increasing Et_c replacement (Fig. 4) and applied water (Fig. 5), reached a maximum, and then decreased. Tango seed yield was highest at 67 percent of Et_c replacement or 24.1 inches of applied water (total water applied from the start of the season) and Accord seed yield was highest at 64 percent of Et_c replacement or 21.6 inches of applied water.

Each year, seed pod dry matter as a percentage of total plant dry matter increased with increasing Et_c replacement, reached a maximum, and then decreased (Fig. 6). In 2003, seed pod dry matter was highest by 49 and 37 percent of Et_c replacement for Tango and Accord, respectively (Table 3).

The Et_c replacement that resulted in the highest seed yield increased over the years (Table 2). The Et_c replacement that resulted in the highest seed pod dry matter was lower in 2001 than in 2002 or 2003. Seed pod dry matter was maximized by lower Et_c replacement than seed yield in 2001 and 2003.

Germination decreased with increasing Et_c replacement for the 2001 and 2002 seed (Fig. 7). Seed defects (hard seed, abnormal seed, and dead seed) also increased with increasing Et_c replacement (Table 3).

Lygus bug insecticide applications were effective in maintaining the population below the economic threshold (four lygus bugs per 180° sweep) until around July 11 (Fig. 8).

Table 2. Highest calculated seed yields, and evapotranspiration (Et_c) replacement strategies resulting in highest seed yield and maximum percent seed pod dry matter for two alfalfa varieties in 3 years, Malheur Experiment Station, Ontario, OR.

	Tango			Accord		
Year	Highest seed yield	Et_c replacement for highest seed yield	Et_c replacement for highest % seed pod dry matter	Highest seed yield	Et_c replacement for highest seed yield	Et_c replacement for highest % seed pod dry matter
	lb/acre	--------- % Et_c ---------		lb/acre	-------- % Et_c ---------	
2001	643	39	32.7	736	45	20
2002	449	51	49.3	533	50	47.4
2003	251	67	48.7	303	64	37.2

Table 3. Effect of evapotranspiration replacement strategy on seed defects averaged over two varieties in 2001 and 2002, Malheur Experiment Station, Ontario, OR.

	Hard seed	Abnormal seed	Dead seed
2001			
20	5.7	1.8	0.4
40	6.9	3.4	4.3
60	8.2	3	3.2
80	12.7	4.7	7.1
LSD (0.05)	5.5	2.2	4.1
2002			
0	12.1	5.4	5.8
40	16.5	4.5	6.8
60	24.8	4.2	12.7
80	27.1	5.2	28.5
LSD (0.05)	6.9	ns	6.2

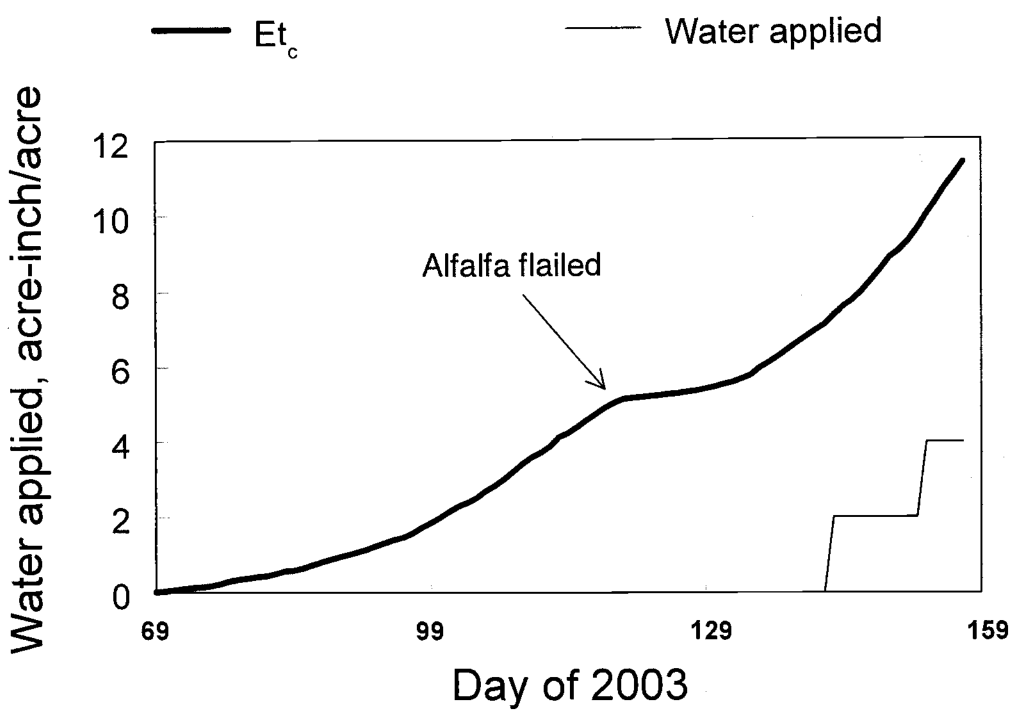

Figure 1a. Cumulative water applied from dormancy break to flowering compared to Et_c for alfalfa seed, Malheur Experiment Station, Oregon State University, Ontario, OR, 2003.

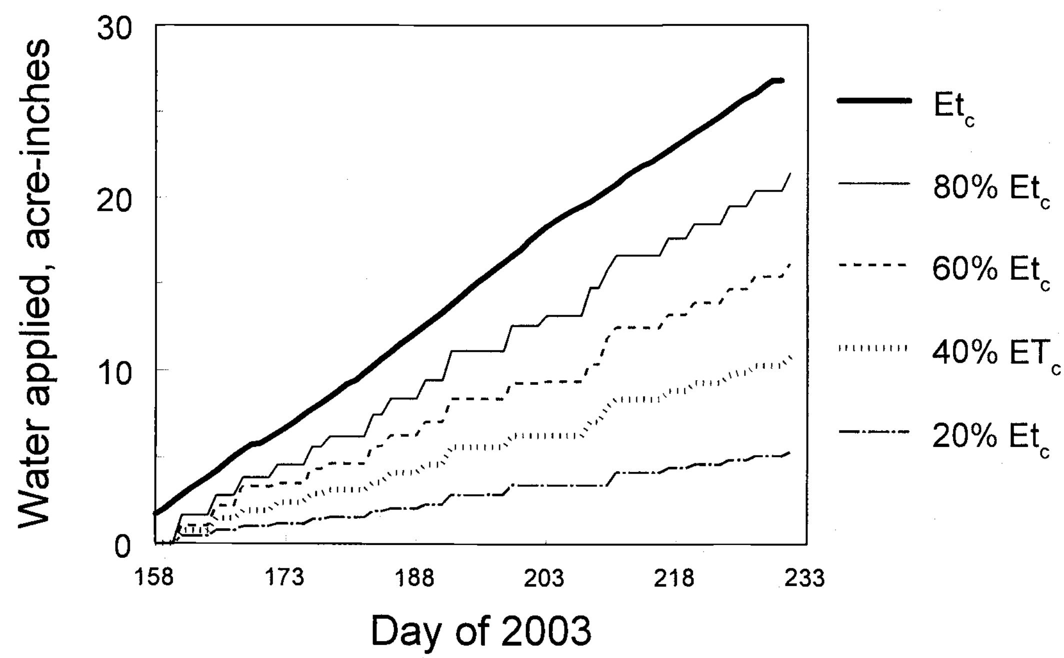

Figure 1b. Cumulative water applied after flowering compared to Et_c for alfalfa seed submitted to four drip-irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2003.

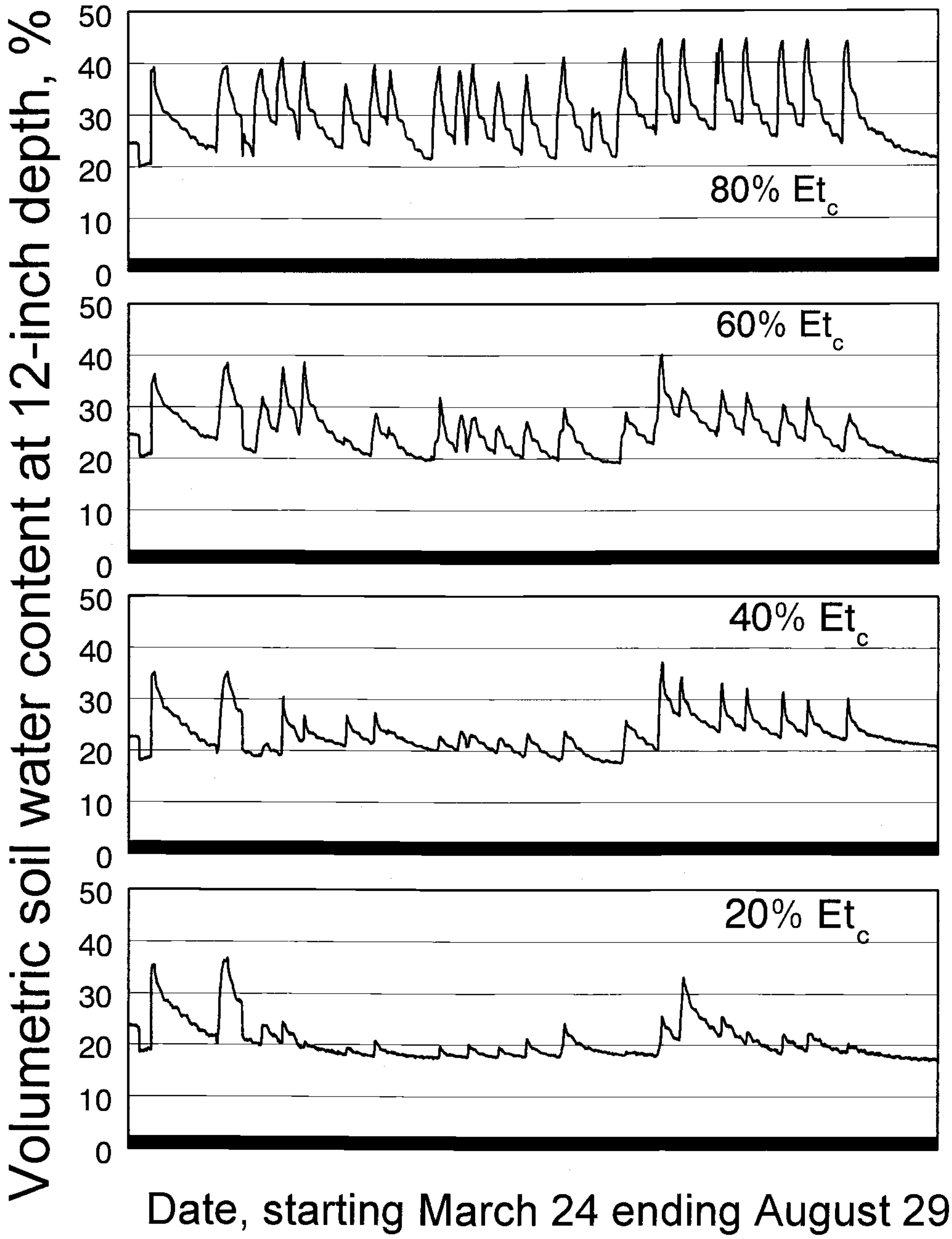

Figure 2. Soil moisture response to irrigation treatment in a drip-irrigated alfalfa seed field, Malheur Experiment Station, Oregon State University, Ontario, OR, 2003.

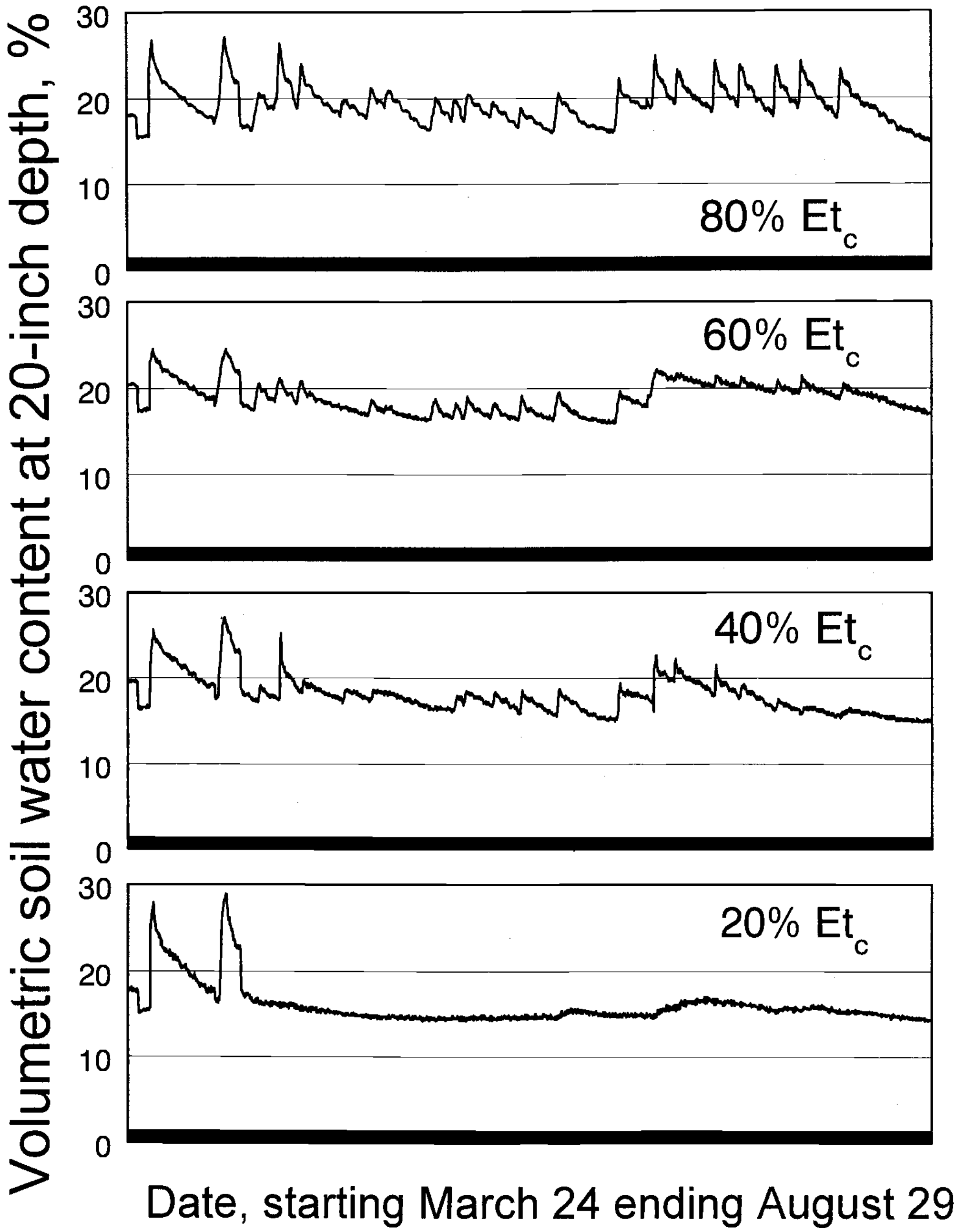

Figure 3. Soil moisture response to irrigation treatment in a drip-irrigated alfalfa seed field, Malheur Experiment Station, Oregon State University, Ontario, OR, 2003.

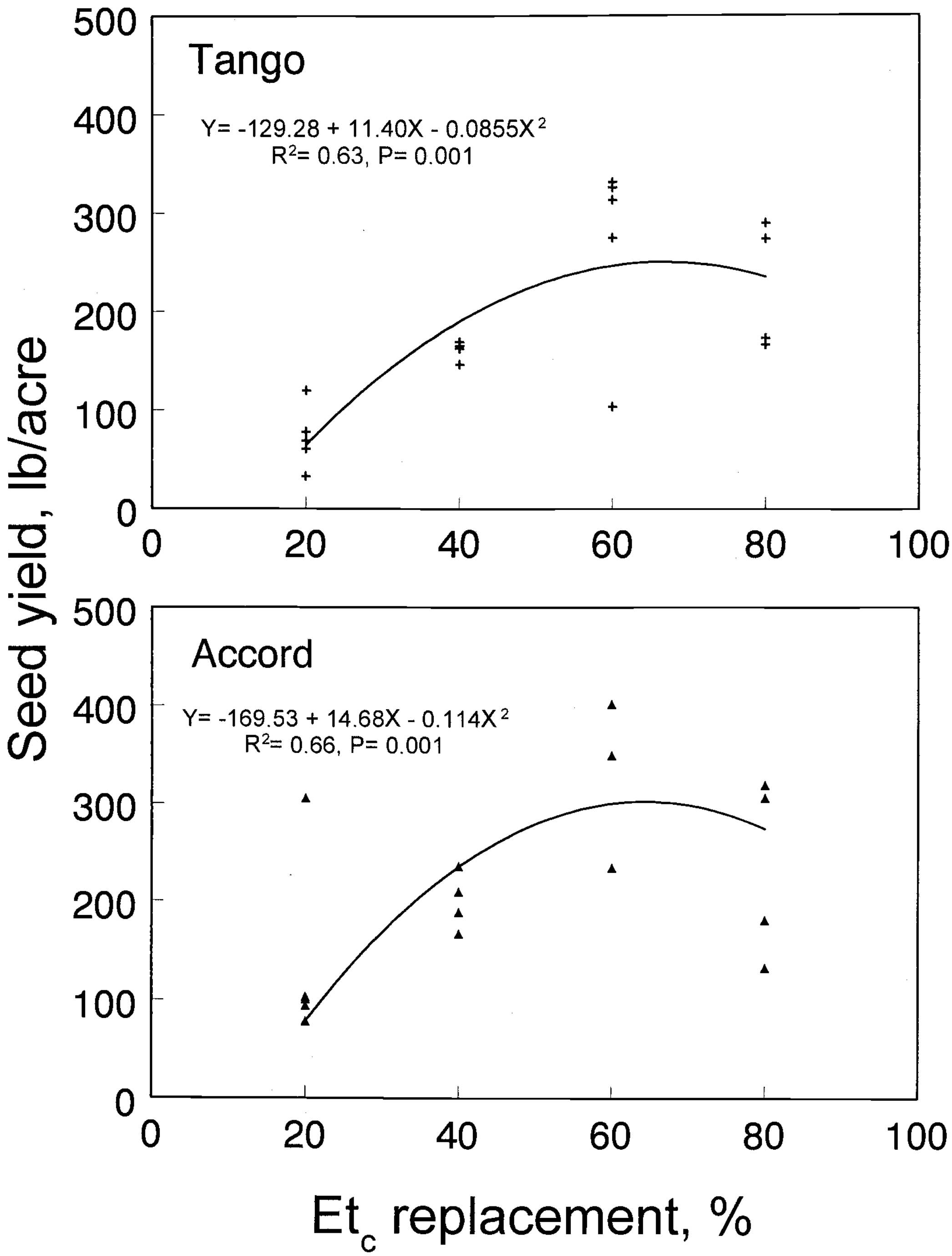

Figure 4. Alfalfa seed yield response to Et_c replacement, Malheur Experiment Station, Oregon State University, Ontario, OR, 2003.

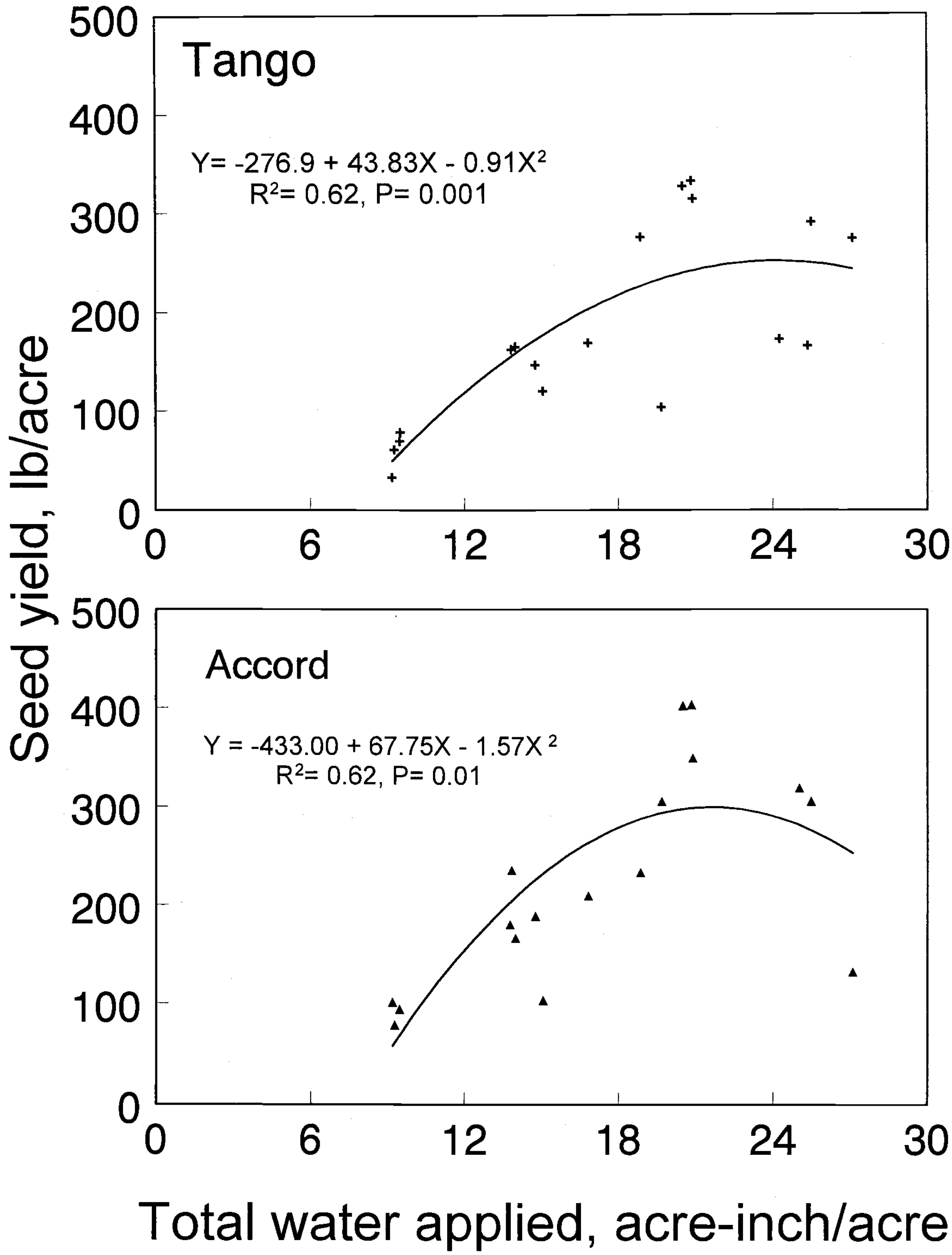

Figure 5. Alfalfa seed yield response to total water applied from the start of the season, Malheur Experiment Station, Oregon State University, Ontario, OR, 2003.

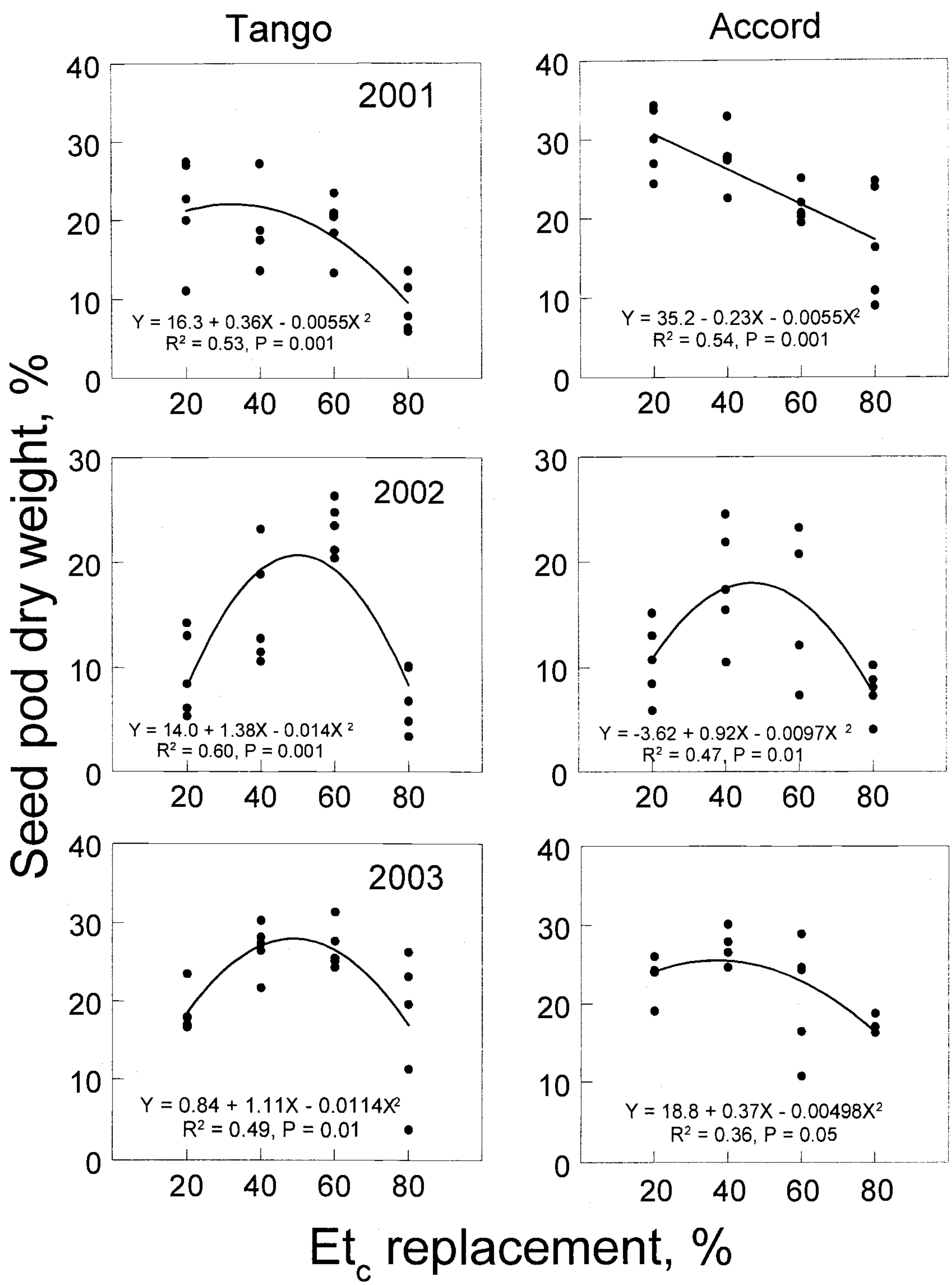

Figure 6. Response of alfalfa seed pod dry matter fraction to Et_c replacement in 2001, 2002, and 2003, Malheur Experiment Station, Oregon State University, Ontario, OR.

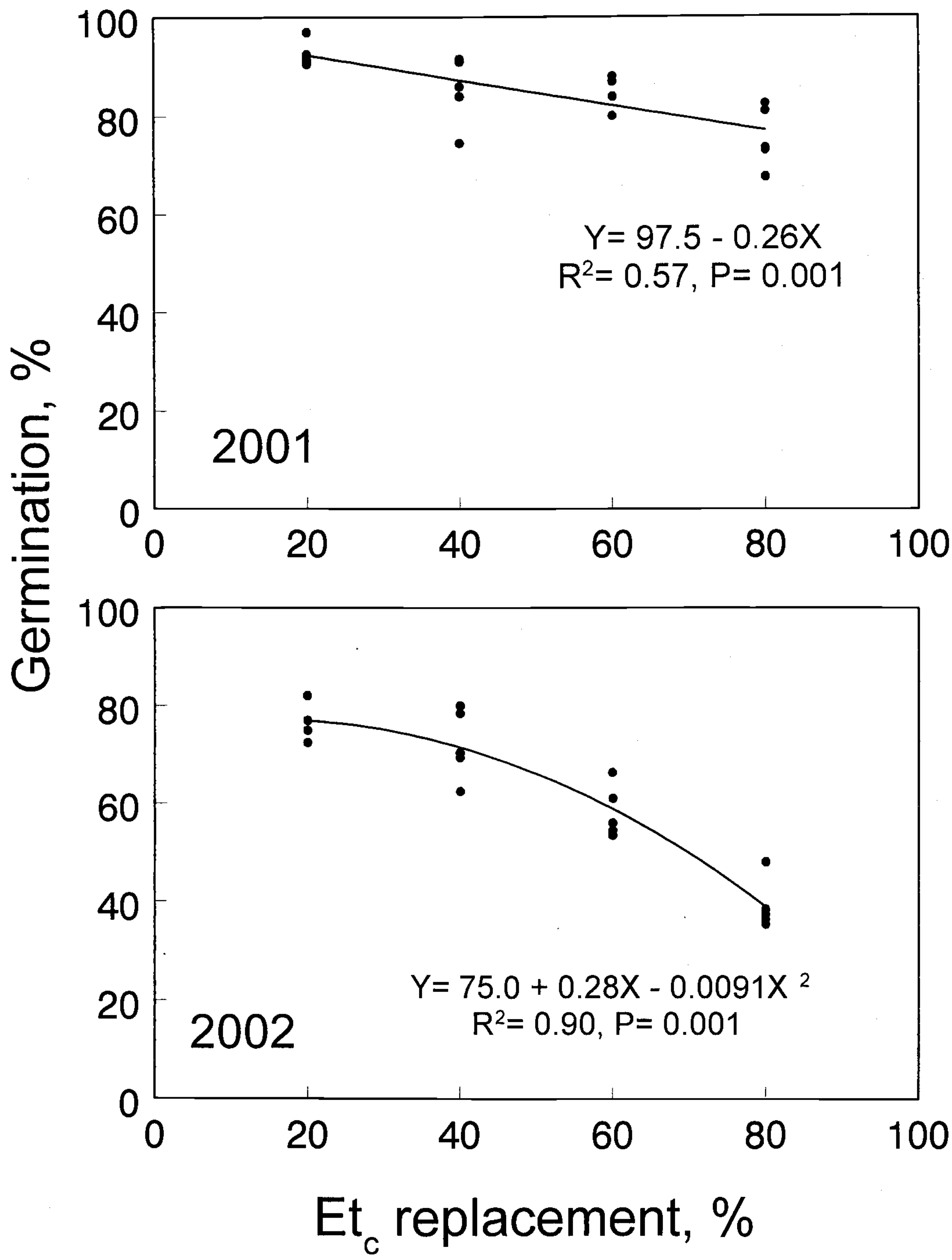

Figure 7. Effect of Et_c replacement strategy on seed germination averaged over two alfalfa varieties in 2001 and 2002, Malheur Experiment Station, Oregon State University, Ontario, OR.

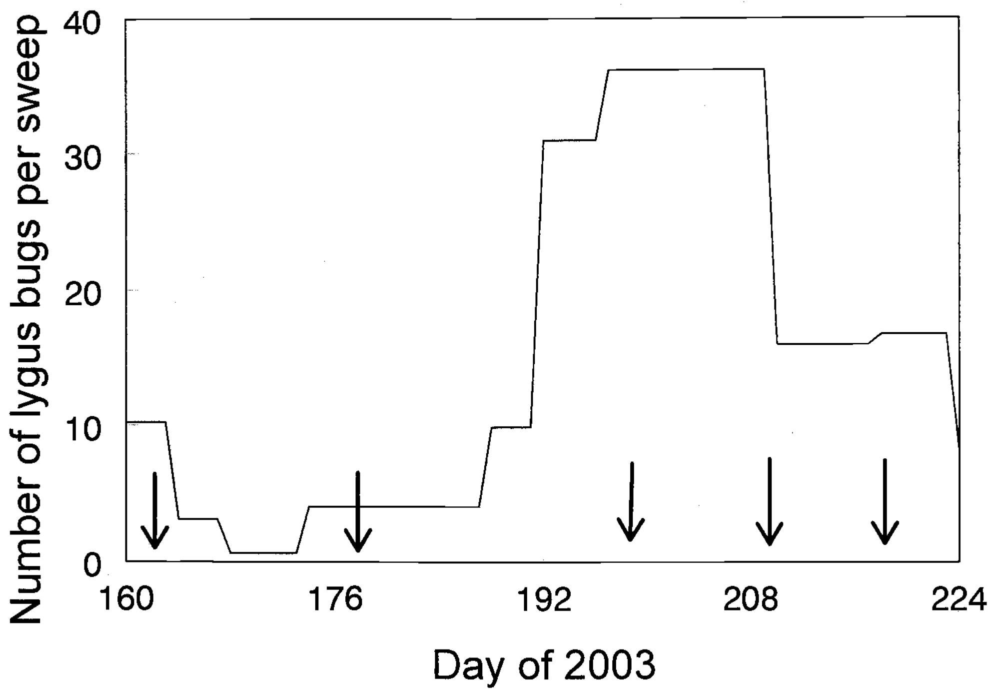

Figure 8. Alfalfa seed lygus bug population levels. Arrows denote insecticide applications. Malheur Experiment Station, Oregon State University, Ontario, OR.