Fertigation: interaction of water and nutrient management in almonds – monitoring water use (ET), stress & yield impacts

(Joint project with Shackel: Advanced sensing & management technologies in specialty crops: case studies of water & N in almonds under normal & resource-limited conditions.
Brown: Development of a Nutrient Budget Approach To Fertilizer Management In Almond)

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Funding: **California Almond Board**

Introduction

Competition for fresh water in California has increased dramatically over the last 30 years. Municipal and environmental water demands over this period have increased by 2 million ac-ft (MAF) per year, while water exports to agriculture have declined by nearly the same amount. Ag has made up the difference by fallowing acreage, pumping more groundwater and increasing water use efficiency.

Almonds have been one of the bright spots in this setting as worldwide markets have expanded to keep pace with higher yields due to improved irrigation and production practices (Figure 1) that have maintained price and profitability for the grower.

Improved varieties, planting, pruning and pollination practices have all contributed to this increase, but some of the most significant yield increases have been realized through the use of micro-irrigation, fertigation and improved understanding of the water use (ET) potential of these trees. In an era when regulators are stressing water conservation it is essential to scientifically document this high ET requirement that was not supported by almond research done 15 years ago (Figure 3).

Objectives

- Determine actual almond ET under truly non-stressed conditions using 3 different methods.
- Determine if differential fertilizer regimens, micro irrigation system type (drip vs. microsprinkler) and yield result in differential rootzone soil moisture, tree stress (SWP) and tree ET.

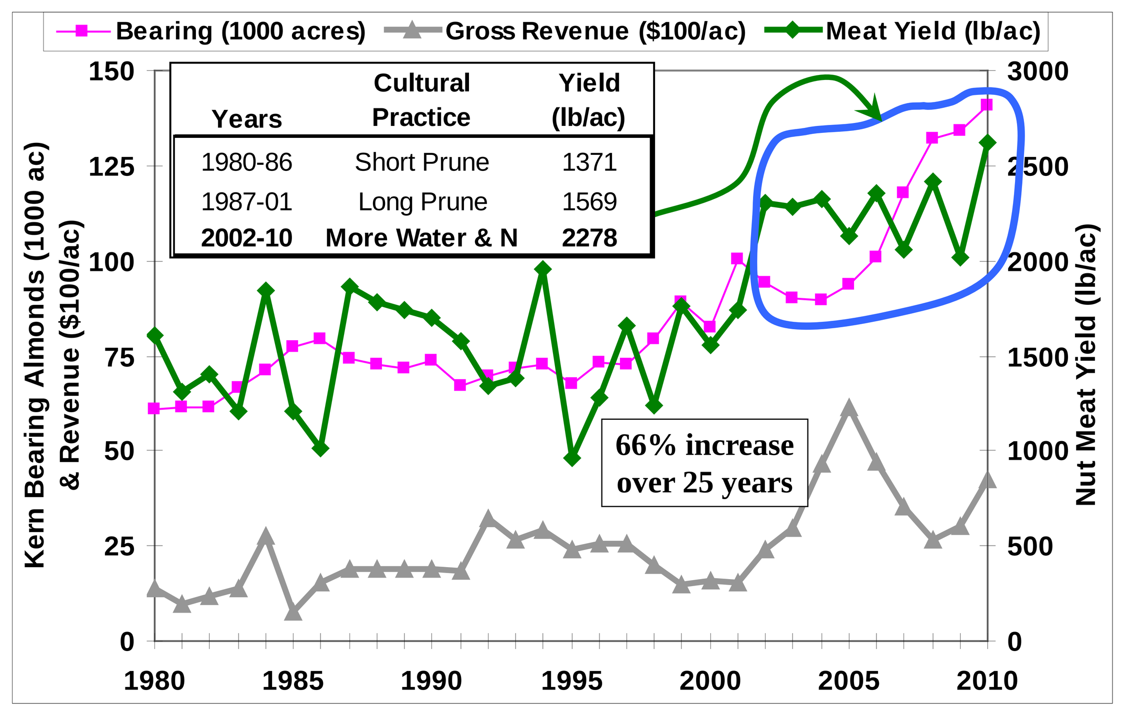


Fig 1. Changes in Kern almond acreage and yield, 1980-2010.

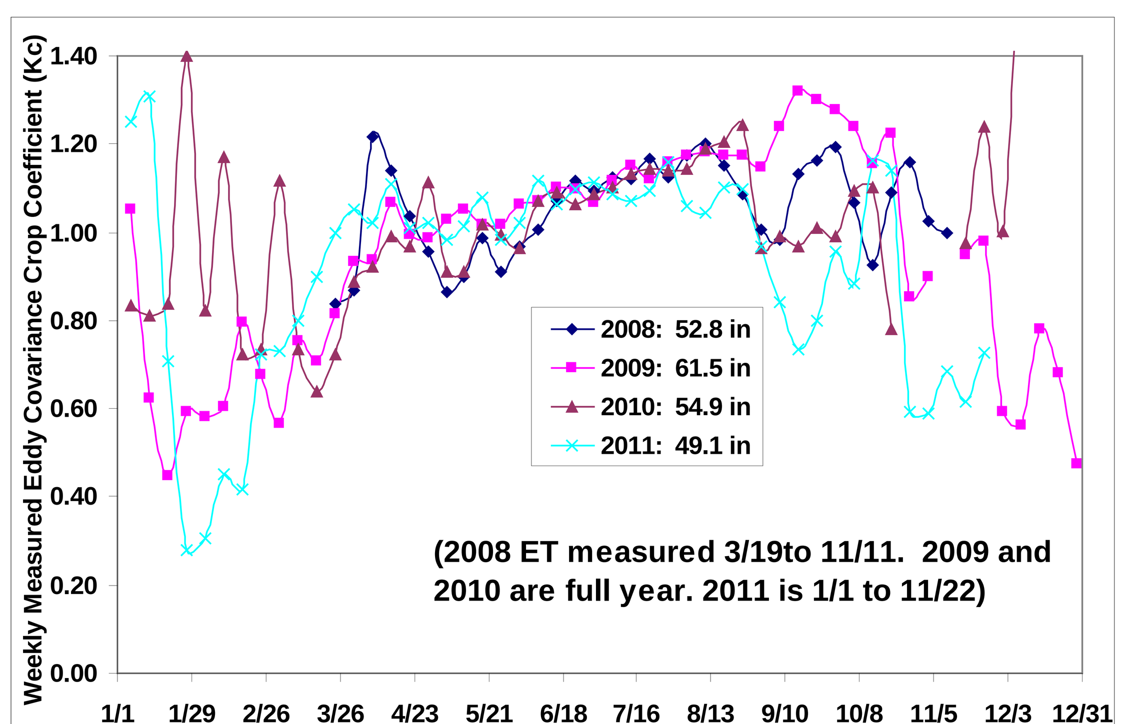


Fig. 2. Comparison of 4 years of mature almond crop coefficients (Kc) generated from EDDY COVARIANCE heat flux estimates of crop ET divided by the modified Penman ETo from the Belridge CIMIS station #146, 1.5 miles due west of orchard.

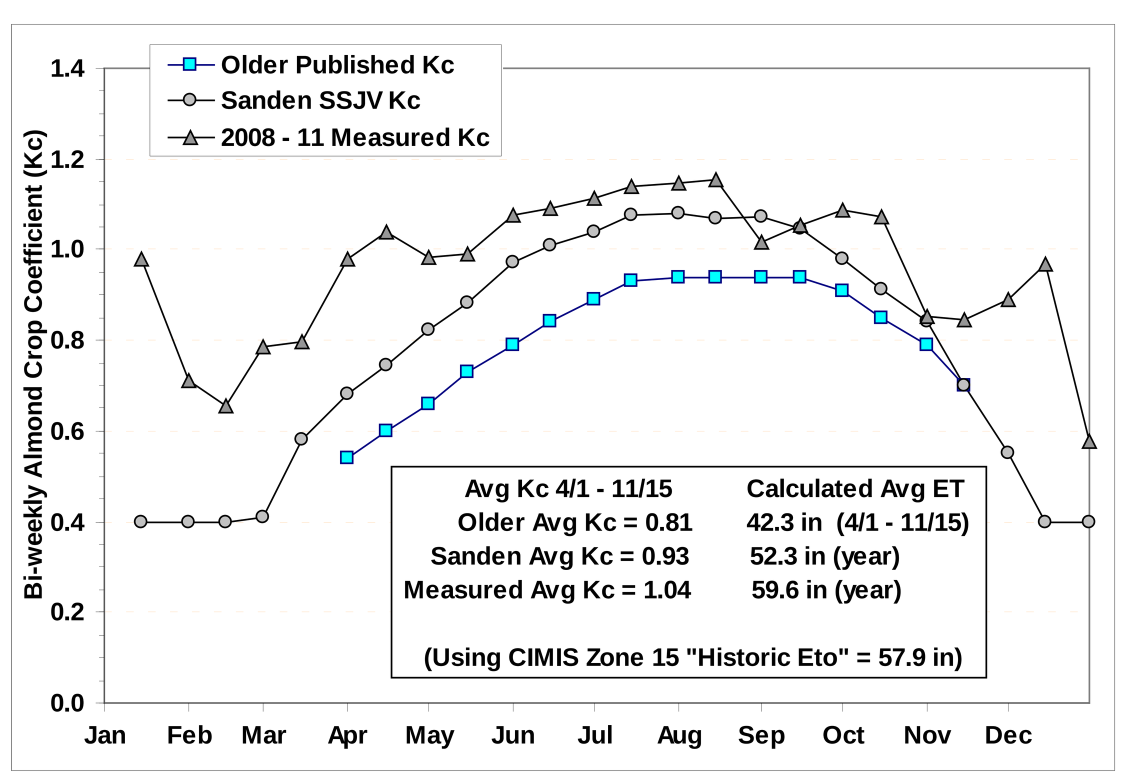


Fig. 3. Comparison of older published crop coefficients, Kc, for almonds to current practice (Sanden SSJV) and the average of actual 2008-2011 measured values.

Materials and Methods

Site Layout: A 9th leaf 150 acre almond orchard in NW Kern County with three 51 acre sets irrigated with microsprinklers (2 Fanjets @ 1.68 in/day irrigation) was selected for this trial starting February 2008. The eastern 2 sets are a uniform Milham Sandy Clay Loam. Past tissue tests showed uniformly low K levels, but yields which were fairly good (2400+ lb/ac). The eastern set was retrofitted with double-line drip applying 1.67 in/day irrigation. A total of 40 water monitoring sites (4 replications each treatment, 20 drip, 20 fanjet) have been established over 5 different fertility treatments (see Brown, et al for a fuller description).

FERTILITY TREATMENTS TO BE MONITORED WEEKLY FEBRUARY - NOVEMBER:

	N (lb/ac)	K (lb/ac)			N (lb/ac)	K (lb/ac)
1.	125	200		2.	200	200
3.	275	200	(Grower standard)			
4.	275	300		5.	350	200

(UAN32, K from base 125 lb/ac banded K2S04, balance KTS)

4 REPLICATED NEUTRON PROBE SOIL MOISTURE & SAMPLING SITES /TREATMENT
One 2 inch x 9 foot deep Class 125 PVC tube in middle of the emitter pattern, 40 sites total (20 each for microsprinkler and double-line drip)
Annual soil sampling to 9 feet @ 1 foot from neutron probe tube, Dec-Jan.

INTENSIVE SOIL WATER CONTENT MONITORING
4 additional access tubes installed at one of the high fertility sites to monitor water content change in all sectors of the wetted area.
1 site each for microsprinkler and drip systems

SOIL WATER TENSION MONITORING
1 replication of each treatment to be outfitted with Watermark blocks at the 18, 36 and 60 inch depths adjacent to the NP access tube
2 Irrometer loggers to be used to record readings @ 3 hour intervals

SOIL MONITORING FREQUENCY
All neutron probe sites and flow meters read weekly March - November

PLANT STRESS MONITORING
Weekly stem water potential (pressure chamber) May-October

METEOROLOGIC HEAT FLUX MONITORING for ET (continuous)
A sonic anemometer, net radiometer, high response air temperature thermocouples were installed above the canopy mid-March. In combination with soil heat flux plates and thermocouples installed at a 2 inch depth in 3 locations in the orchard floor these devices measure ET from the orchard by Eddy Covariance and Surface Renewal heat flux.

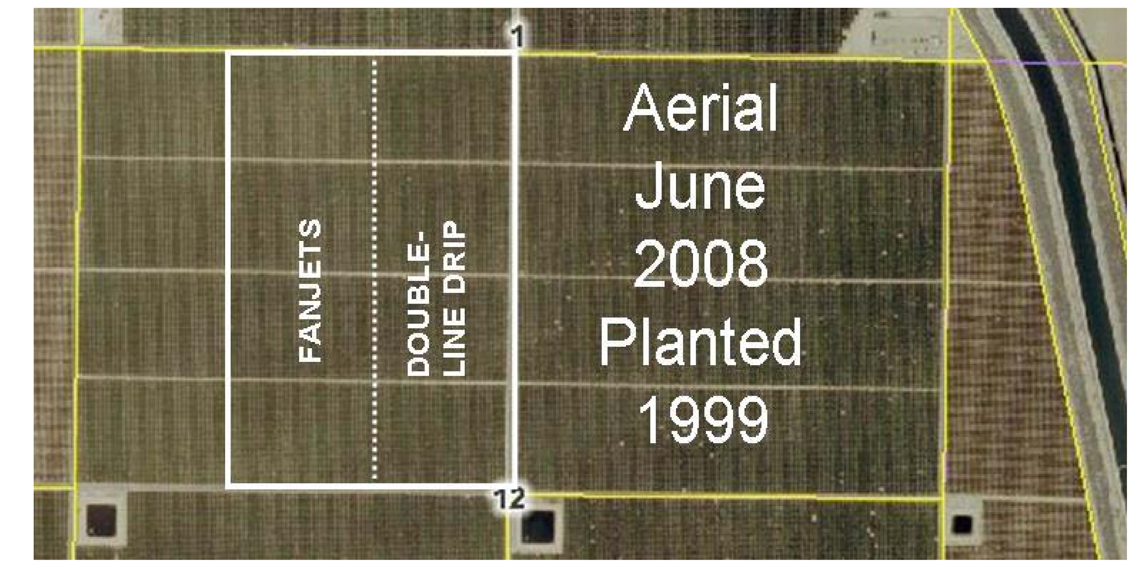
Results and Discussion

Bagged stem water potential (SWP) values over four years were less negative (less stress) for the double-line drip compared to the fanjet due to decreased surface evaporation. SWP was less (more stress) than the moderate stress level of -12 to -14 bars for one week in July and two separate weeks during harvest in 2009. Substantial hull rot still occurred. In 2010 and 2011 we applied deficit irrigation from early July to Monterey harvest cutoff in an attempt to reduce hull rot in both Nonpareil and Monterey. SWP did not decrease to -15 to -18 bars until 60% of available soil moisture to 6 feet was depleted as of mid August. Hull rot was still significant in both fanjets and drip (average SWP -15.0 and -11.6 bars, respectively, with some stressed trees reaching -20 bars). Average stored soil moisture started the season about 90-95% of field capacity and slowly declined; averaging 59% for the season as ET slightly exceeded irrigation. Net water use efficiency is 93 to 95%.

No statistical difference was seen in individual tree ET due to N rate or yield. Average tree ET estimated by applied water and water content depletion (neutron probe method) was virtually the same (except for some pressure differences in 2010) as that estimated by meteorological energy balance (eddy covariance and surface renewal. Figure 3 and Table 1). The average measured seasonal Kc value was 1.05, with peak season values reaching as high as 1.18. N fertilizer rates were just starting to impact yield in 2009, but there is no correlation with crop load/kernel yield and tree ET for all sites in this study (Figure 5).

Conclusions

More water likely went to actual transpiration in the Drip than the Microsprinkler – as indicated by less negative SWP. Almond ET is much greater than earlier published values and can exceed 52 inches/year, but individual tree ET above 52 inches does not consistently result in higher yields (Figure 5).



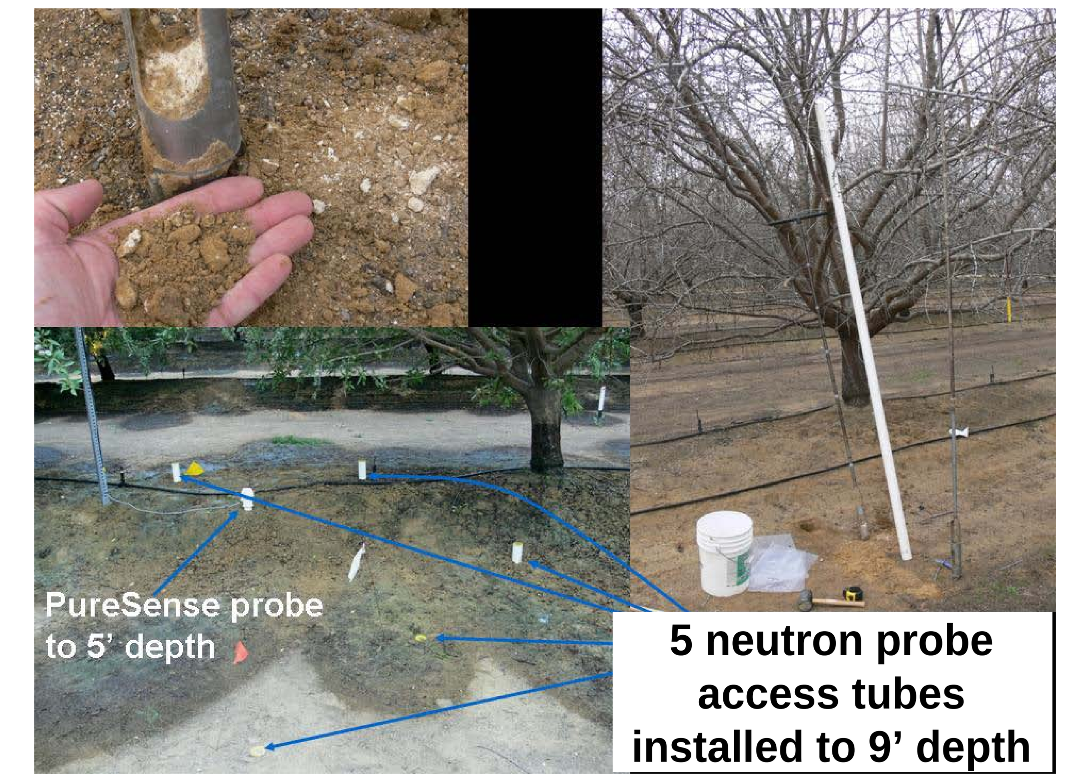


Fig 4. Layout of neutron probe tubes in intensive site.

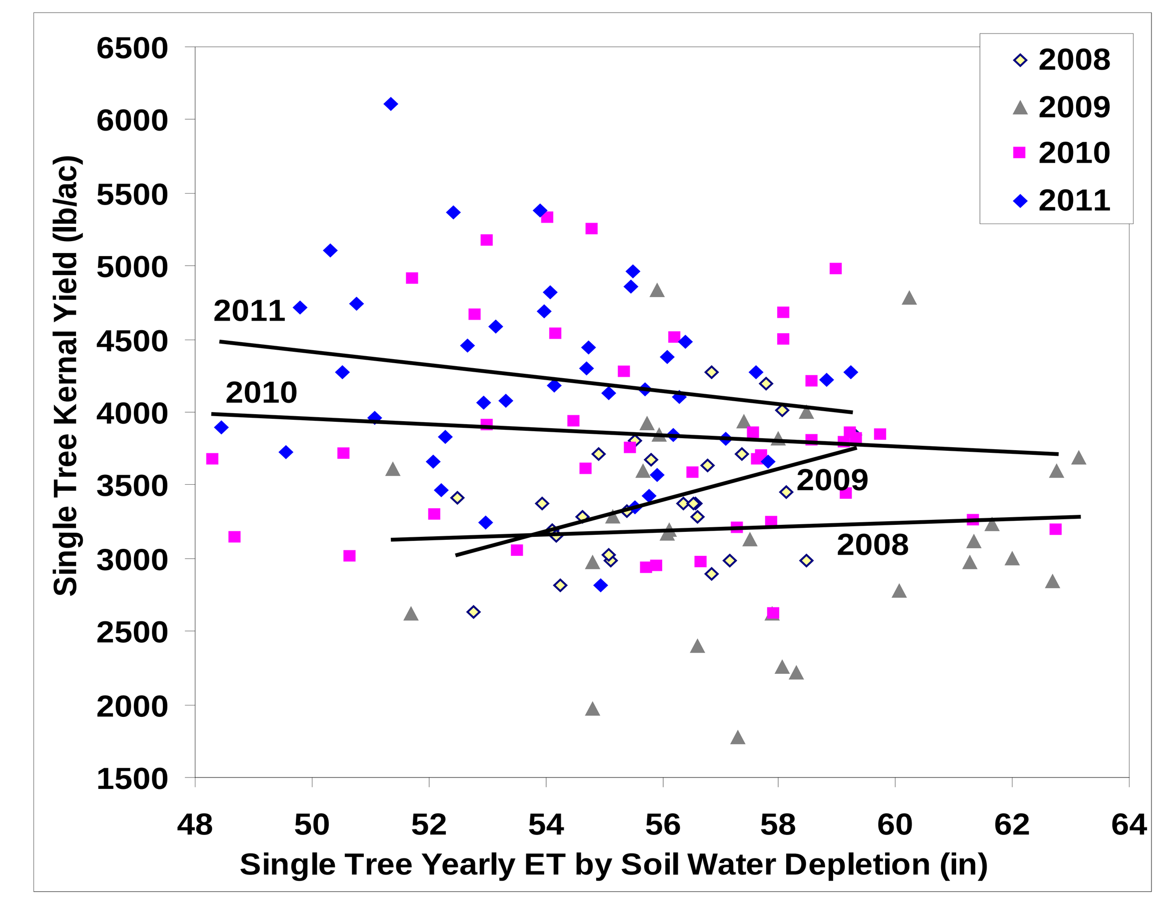


Fig 5. Yield variation as a function of tree specific ET estimated by weekly measurements of applied water and soil water content change.

Table 1. Seasonal averages and totals for SWP, soil moisture, irrigation, ET and yields by N-K rate for 2010 and 2011.

2010 Treatment (N-K lb/ac)	Stem Water Potential (bars)		Soil Water Content to 9 feet (in)		Cumulative Neutron Probe ET (in)		SWP-NP Tree Kernel Yield (lb/ac)		Whole Plot Kernel Yield (lb/ac)	
	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet
125-200	-9.8 a	-11.1 a	15.9 ab	14.4 a	56.8 a	55.5 a	3565 a	3280 a	3320 a	3108 a
200-200	-9.7 a	-11.9 b	17.2 b	15.1 a	57.0 a	54.4 a	3779 ab	3591 ab	3397 a	3294 ab
275-200	-9.7 a	-12.5 b	17.7 b	16.2 a	56.6 a	55.0 a	4266 bc	3914 bc	3974 b	3679 bc
275-300	-10.1 a	-12.1 b	16.7 ab	14.5 a	57.5 a	55.1 a	4069 cd	3804 bc	4143 b	3502 abc
350-200	-9.7 a	-11.9 b	14.6 a	15.3 a	56.4 a	55.0 a	4717 d	4165 c	4252 b	3923 c
AVERAGE	-9.8	-11.9	16.4	15.1	56.9	55.0	4079	3751	3817	3501
LSD 0.05	*0.5*	*0.6*	*2.5*	*2.9*	*3.7*	*3.3*	*457*	*415*	*431*	*528*

2011 Treatment (N-K lb/ac)	Stem Water Potential (bars)		Soil Water Content to 9 feet (in)		Cumulative Neutron Probe ET (in)		SWP-NP Tree Kernel Yield (lb/ac)		Whole Plot Kernel Yield (lb/ac)	
	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet
125-200	-9.3 b	-10.3 a	17.1 ab	15.5 a	53.8 a	54.7 a	3917 a	3659 a	3653 a	3798 a
200-200	-9.5 a	-10.4 a	17.5 ab	15.5 a	53.7 a	53.4 a	4034 a	3951 ab	4123 ab	4012 a
275-200	-9.3 b	-10.5 a	19.4 b	18.0 a	54.1 a	54.2 a	4621 b	4365 bc	4670 bc	4416 b
275-300	-9.3 b	-10.4 a	17.6 ab	16.1 a	54.6 a	53.7 a	4586 b	4702 c	4886 c	4447 b
350-200	-9.0 c	-10.5 a	15.3 a	16.5 a	55.2 a	52.8 a	4596 b	4273 bc	4854 c	4476 b
AVERAGE	-9.3	-10.4	17.4	16.3	54.3	53.8	4351	4190	4437	4230
LSD 0.05	*0.2*	*0.2*	*2.7*	*2.9*	*4.0*	*2.9*	*539*	*472*	*557*	*313*