ONION RESPONSE TO LATE-SEASON WATER STRESS AT TWO PLANT POPULATIONS

Jose M. Pinto, Clinton C. Shock, Erik B. G. Feibert, and Lamont D. Saunders
Malheur Experiment Station, Oregon State University, Ontario, OR, 2013

Introduction

Split onion bulbs is a phenomenon where the bottom of the bulb splits open. Split bulbs can reduce onion crop marketable yields. Anecdotal evidence suggests that late-season irrigation interruptions can cause bulb splitting. Past research at the Malheur Experiment Station demonstrated the sensitivity of onion yield and grade to soil water tension (SWT) (Shock et al. 2000a). In many other countries onions are grown at higher plant populations than in the Treasure Valley. This trial tested the effect of late-season irrigation interruption on bulb splitting at two plant populations with two varieties.

Materials and Methods

Onions were grown in 2013 on an Owyhee silt loam. The field was planted to wheat in 2012. In the fall of 2012, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. A soil analysis taken in the fall of 2012 showed a pH of 7.3, 1.6% organic matter, and 22 ppm of phosphorus. Based on the soil analysis, 49 lb of phosphorus/acre, 200 lbs of sulfur/acre, and 1 lb of boron/acre were broadcast before plowing. After plowing, the field was fumigated with Vapam® at 15 gal/acre and bedded at 22 inches.

Seed was planted on March 13 in double rows spaced 3 inches apart at 9 seeds/ft of single row. Each double row was planted on beds spaced 22 inches apart. Planting was done with customized John Deere Flexi Planter units equipped with disc openers. Immediately after planting, the onions received a narrow band of Lorsban® 15G at 3.7 oz/1,000 ft of row (0.82 lb ai/acre), and the soil surface was rolled. Onion emergence started on April 4.

The field had drip tape laid at 4-inch depth between 2 pairs of double rows during planting. The drip tape had emitters spaced 12 inches apart and a flow rate of 0.22 gal/min/100 ft (Toro Aqua-Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

The experimental design was a split-split plot randomized complete block with six replicates. The two irrigation treatments were the main treatments and consisted of a non-stressed check and a late-season stress treatment. The stress treatment used a SWT of 20 cb until July 31, when temporary water stress was imposed. The main plots were 4 double rows wide by 54 ft long.

Two onion varieties ('Vaquero', Nunhems, Parma, ID and 'Swale', Seminis, Payette, ID) were planted as split plots within each main plot. Each variety split plot was divided into two plant population split-split plots (120,000 and 450,000 plants/acre). Variety split plots were 27 ft long and plant population split-split plots were 13 ft long.

On March 21, a mixture of humic acid (CHB Premium 6, BioGro, Mabton, WA, 5% humic acids, 6 gal/acre), phosphoric acid (NUE 0-30-0, Bio-Gro, 26 lb P/acre), and Avail® (Simplot, Caldwell, ID, 0.5% of the final volume) was sidedressed between the seed row and the drip tape at 3-inch depth.

On May 16, the population split-split plots were thinned by hand. The plots thinned to 120,000 plants/acre had onions thinned to 4.75 inches between plants in each single row. The plots thinned to 450,000 plants/acre had onions thinned to 1.4 inches between plants in each single row.

In order to monitor plant nutrient status, every 2 weeks, starting on May 22, bulbs from the border rows in each split-split plot of 10 cb treatment of Vaquero from the 450,000 plants/acre population were removed and the roots washed in deionized water. A sample consisting of a composite of roots from all replicates was sent to Western Labs (Parma, ID) for nutrient analysis.

Soil solution analysis is an estimate of the amount of each nutrient that the soil can supply to the crop per day. Soil solution analysis uses an extraction method that simulates the extraction capacity of plant roots. Every week starting on June 24, soil samples were taken from the same split-split plots as the root issue samples and were sent to Western Labs for soil solution analysis. Each sample consisted of a composite of 7 cores to 9-inch depth from border rows in each plot.

Nutrients were applied based on root tissue analysis and soil solution analysis (Table 1). Nutrients were injected into the drip irrigation system using an Ozawa Precision Metering Pump (Ozawa R and D, Ontario, OR).

Table 1. Nutrients applied (lb/acre) through the drip tape. All nutrients were applied based on root tissue analysis, except as indicated. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013.

Date	N	P	K	B	Ca	Mg	Cu
28-May	40						
10-Jun			20	0.2	3.5		
20-Jun	20		20	0.2			
3-Jul	20		20				
18-Jul		5	20			5	
25-Jul							0.1*
30-Jul							0.7*
1-Aug	20		20			5	
16-Aug		10	20				
19-Aug						5	
Total	100	15	120	0.4	3.5	15	0

* based on soil solution analysis

Onions were irrigated automatically to maintain the SWT in the onion root zone below the target for each treatment (Fig. 1). Soil water tension was measured in each 450,000 plant/acre split-split plot in the Vaquero split plot in each main plot. Soil water tension in each split-split plot was measured with four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model

200SS, Irrometer Co., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 410 multiplexer, Campbell Scientific, Logan, UT). The datalogger read the sensors and recorded the SWT every hour. The datalogger made irrigation decisions every 12 hours. The irrigation decisions were based on the average SWT of the four GMS in each plot. The irrigation durations were 8 hours, 19 minutes (0.45 inch of water). The temporary water stress was started on July 31, and was imposed by withholding irrigations until the SWT in each plot reached 60 cb. Then irrigations were restarted and ran continously until the SWT reached 20 cb, at which point the automatic irrigation schedule was resumed. The water stress period was ended on August 12 for four plots and on August 17 for the last two plots. The irrigations were controlled by the datalogger using a controller (SDM CD16AC controller, Campbell Scientific, Logan, UT) connected to a solenoid valve in each main plot. The water for the drip system was supplied by a well that maintained a continuous and constant water pressure of 30 psi. The pressure in the drip lines was maintained at 10 psi by pressure regulators in each plot. The automated irrigation system was started on July 9. Prior to July 9, irrigations were run manually based on sensor readings.

Irrigations for the whole trial were terminated on September 3. Onion evapotranspiration (ET_c) was calculated with a modified Penman equation (Wright 1982) using data collected at Malheur Experiment Station by an AgriMet weather station. Onion ET_c was estimated and recorded from crop emergence until the onions were lifted.

The onions were managed to avoid yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. Roundup® at 1 lb ai/acre was broadcast on April 2 prior to onion emergence. On May 3, Goal Tender® at 0.06 lb ai/acre (4 oz/acre), Buctril® at 0.25 lb ai/acre (16 oz/acre), and clethodim at 0.19 lb ai/acre (12 oz/acre) were applied for weed control. On May 26, Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre) was applied for weed control. On June 10, Goal Tender at 0.09 lb ai/acre (6 oz/acre), Buctril at 0.31 lb ai/acre (20 oz/acre), and clethodim at 0.25 lb ai/acre (16 oz/acre) were applied for weed control. For thrips control, the following insecticides were applied: Movento® at 5 oz/acre on May 23 and 31; Agri-Mek® at 16 oz/acre on June 14, 27, and July 4; Radiant® on July 12; and Lannate® on July 18 and 24.

The onions were lifted on September 10 to field cure. Onions from 9 ft of the middle 2 rows in each split-split plot were topped by hand, bagged, and placed in storage on September 19. The storage shed was ventilated and the temperature was slowly decreased to maintain air temperature as close to 34°F as possible. Onions were graded out of storage on November 25.

During grading, all bulbs from each split-split plot were counted. Split bulbs were counted and weighed. Bulbs were then separated according to quality: bulbs without blemishes (No. 1s), double bulbs (No. 2s), bulbs infected with neck rot (*Botrytis allii*) in the neck or side, plate rot (*Fusarium oxysporum*), or black mold (*Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading.

Treatment differences were compared using analysis of variance (ANOVA) and regression analysis. Means separation was determined using Fisher's least significant difference test at the 5% probability level, LSD (0.05).

Results

Soil water tension over time oscillated around the target for each treatment (Fig. 1). The amount of water applied with irrigation at 20 cb paralled crop evapotranspriation (ET_c), which totaled 35.3 inches for the season (Fig. 2, Table 2).

Plant Population Effects

The plots thinned to 120,000 plants/acre actually contained close to 130,000 plants/acre and the plots thinned to 450,000 plants/acre actually contained close to 330,000 plants/acre. Averaged over varieties and treatments, marketable yield, supercolossal yield, colossal yield, and jumbo yield were higher with the 130,000 plants/acre population (Table 3). Total yield, medium yield, small yield, total rot, and bolting were higher with the 330,000 plants/acre population.

Water Stress Effects

Averaged over varieties and plant populations, total yield, marketable yield, and jumbo yield were reduced by late-season water stress (Table 3). Averaged over varieties, total rot was reduced by late-season water stress only for the 330,000 plants/acre population.

Both the percentage and yield of split bulbs was very low in this trial. For Vaquero at the 330,000 plants/acre population, the percentage of split bulbs was increased by water stress. For Swale at the 330,000 plants/acre population, both the percentage and yield of split bulbs were decreased by water stress.

Bulb Single Centers

Averaged over treatments and varieties, the 330,000 plants/acre population resulted in higher single-centered and functionally single-centered bulbs than the 130,000 plants/acre population (Table 4). Averaged over populations, water stress resulted in lower single-centered and functionally single-centered bulbs for Swale. Averaged over treatments and varieties, the 330,000 plants/acre population resulted in a higher percentage of tops down on July 25.

Discussion

This study agrees with a previous study at the Malheur Experiment Station that showed that late-season increases in irrigation criterion from the ideal of 20 cb reduced marketable yield, but did not significantly reduce storage rot (Shock et al. 2000b). In Shock et al. (2000b), the plant population was approximately 120,000 plants/acre. In our study, total rot was reduced by late-season water stress only for the 330,000 plants/acre population.

The results of this study agree with another study at Malheur Experiment Station (Shock et al. 2006) that tested the effect of single episodes of a 60-cb water stress at different timings of onion development. They found that water stress at 4- to 6-leaf stages (May through June) caused decreases in single centeredness, but not at the 8-leaf stage (late June to early July). In the present study water stress in August did not decrease single centeredness for Vaquero (the same variety tested in Shock et al. [2006]), but slightly decreased single centeredness for Swale.

References

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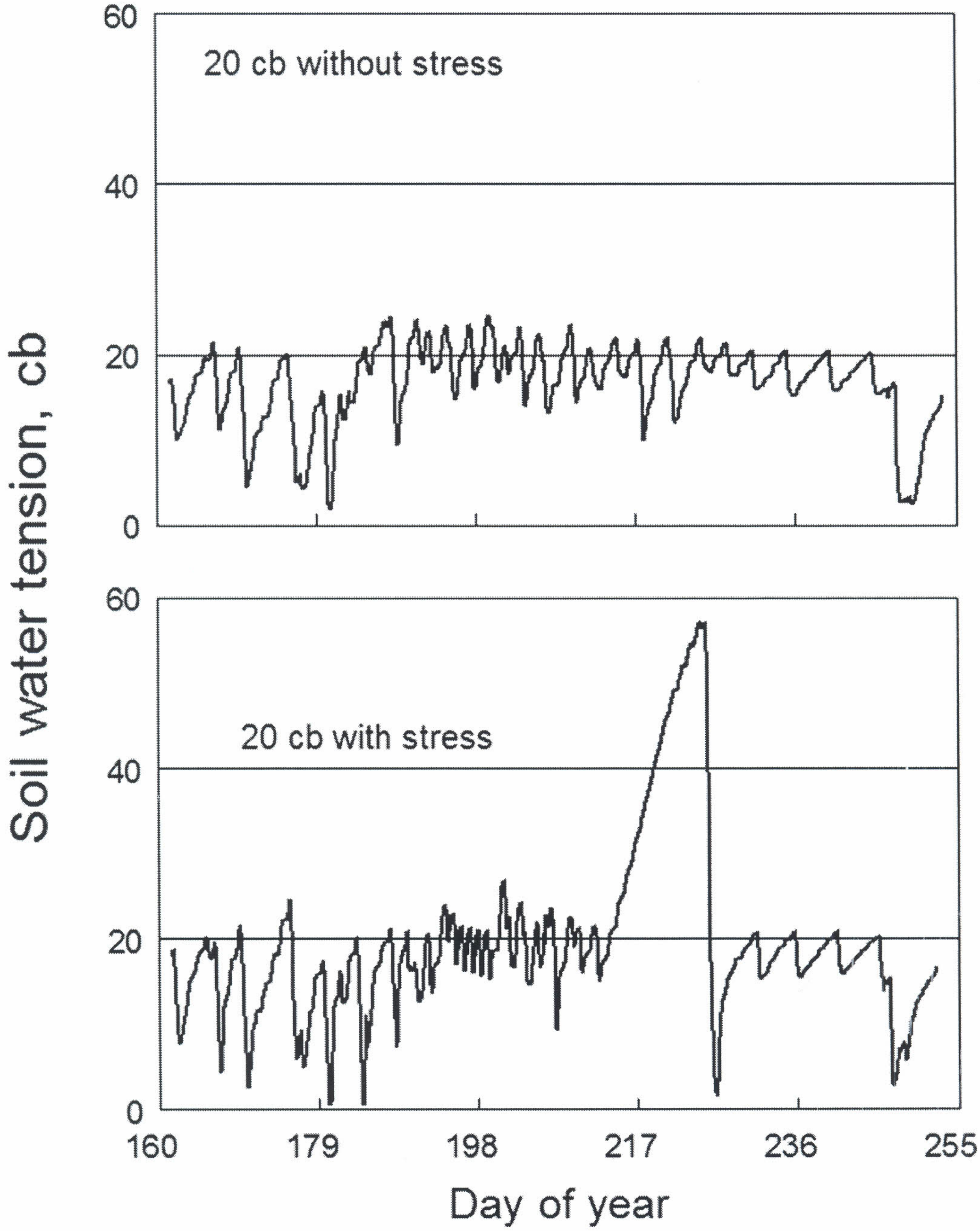

Figure 1. Soil water tension at 8-inch depth for onions irrigated at 20 cb without water stress and at 20 cb with temporary stress. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013.

Table 2. Total water applied (includes 1.5 inches of precipitation) from onion emergence to the last irrigation and average soil water tension. Evapotranspiration from emergence to lifting totaled 35.3 inches. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013.

Irrigation criterion	Total water applied	Average soil water tension
	inches	cb
20 cb	36.4	17.4
20 cb/stress	29.4	20.3
LSD (0.05)	NS	NS

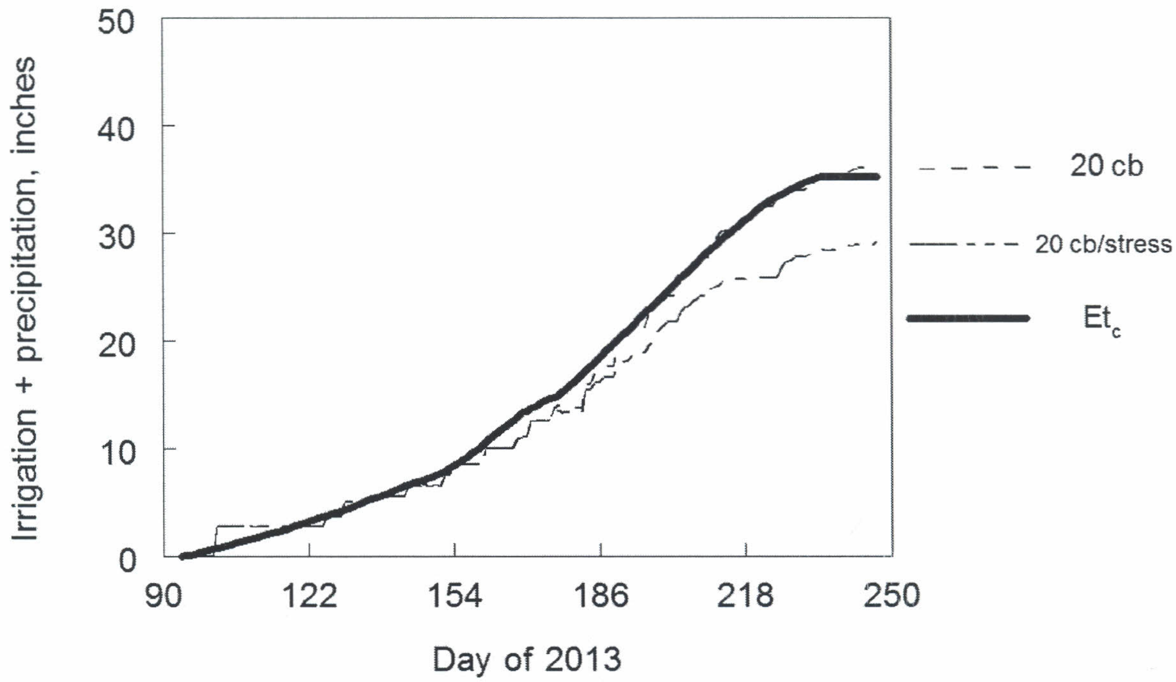

Figure 2. Water applied plus precipitation and evapotranspiration (Et_c) for onions irrigated at 20 cb without water stress and at 20 cb with temporary stress. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013.

Table 3. Onion yield and grade for two varieties under two plant populations in response to late-season water stress. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013.

		Plant population		Total	Marketable yield by grade						Bulb counts		Split bulbs		
Variety	Treatment	target	actual	yield	total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	>4¼ in	Total rot	% by no.	yield	Bolting
		--- plants/acre ---		---------- cwt/acre ----------							#/50 lb	% by yield	%	cwt/acre	%
Vaquero	20 cb	120,000	110,331	995.0	967.2	23.8	335.0	587.8	20.6	9.6	33.2	1.8	0.0	0.0	2.3
	20 cb/stress	120,000	153,179	958.7	901.8	10.7	263.7	512.0	115.3	53.1	36.0	1.6	0.0	0.0	0.9
		average	131,755	976.8	934.5	17.3	299.4	549.9	67.9	31.3	34.6	1.7	0.0	0.0	1.6
	20 cb	450,000	294,484	1196.6	922.5	0.0	23.5	616.0	283.0	154.8		10.2	0.0	0.3	9.5
	20 cb/stress	450,000	293,064	1046.9	837.3	0.0	6.0	490.1	341.2	170.0		3.9	0.1	1.5	9.7
		average	293,774	1121.7	879.9	0.0	14.8	553.1	312.1	162.4		7.0	0.0	0.9	9.6
	20 cb		202,408	1103.5	943.1	11.0	167.3	603.0	161.9	87.8	33.2	6.3	0.0	0.2	5.9
	20 cb/stress		211,464	995.4	874.9	6.3	156.4	502.9	209.4	101.8	36.0	2.6	0.0	0.8	5.3
	average		206,936	1049.5	909.0	8.6	161.8	552.9	185.6	94.8		4.4	0.0	0.5	5.6
Swale	20 cb	120,000	127,431	990.3	963.6	7.6	159.2	762.7	34.1	11.1	35.0	1.6	0.1	1.8	2.6
	20 cb/stress	120,000	130,033	932.8	887.6	2.9	90.7	740.3	53.7	24.9	38.5	2.0	0.1	0.8	3.2
		average	128,732	961.5	925.6	5.2	125.0	751.5	43.9	18.0		1.8	0.1	1.3	2.9
	20 cb	450,000	331,838	1121.9	882.8	0.0	1.9	408.4	472.5	201.0		3.6	0.1	4.0	8.4
	20 cb/stress	450,000	347,749	1003.3	740.1	0.0	0.0	264.0	476.1	252.1		1.1	0.0	0.0	7.2
		average	339,794	1062.6	811.5	0.0	1.0	336.2	474.3	226.6		2.3	0.1	2.0	7.8
	20 cb		253,219	1071.3	913.8	2.9	62.4	544.7	303.9	128.0	35.0	2.8	0.1	3.0	5.7
	20 cb/stress		238,891	968.0	813.9	1.4	45.4	502.2	264.9	138.5	38.5	1.6	0.0	0.4	5.2
	average		246,055	1019.6	863.9	2.2	53.9	523.4	284.4	133.2		2.2	0.1	1.7	5.5
Average	20 cb	120,000	117,456	992.8	965.5	16.4	255.1	667.3	26.7	10.2	33.6	1.7	0.1	0.8	2.5
	20 cb/stress	120,000	142,496	946.7	895.3	7.1	183.9	617.4	86.9	40.1	36.6	1.8	0.0	0.4	2.0
		average	129,976	969.8	930.4	11.8	219.5	642.3	56.8	25.2		1.8	0.1	0.6	2.3
	20 cb	450,000	314,406	1156.7	901.3	0.0	12.0	505.3	384.0	179.5		6.7	0.1	2.2	9.1
	20 cb/stress	450,000	322,892	1023.1	784.3	0.0	2.7	366.8	414.8	214.8		2.4	0.0	0.8	8.4
		average	318,649	1089.9	842.8	0.0	7.4	436.0	399.4	197.1		4.5	0.0	1.5	8.8
	20 cb		226,873	1087.4	928.5	7.0	114.9	573.8	232.9	107.9	33.6	4.6	0.1	2.2	9.0
	20 cb/stress		225,178	981.7	844.4	3.8	100.9	502.5	237.2	120.2	36.6	2.1	0.0	1.8	8.9
LSD (0.05)															
Treatment			NS	105.0	70.6	NS	NS	49.5	NS	NS	NS	NS	NS	NS	NS
Population			32,527	NS	44.2	6.6	45.9	48.8	59.1	29.2	NS	2.2	NS	NS	1.6
Variety X Population			NS	NS	NS	NS	64.9	69.0	83.6	41.3	NS	NS	NS	NS	NS
Treatment X Population			NS	NS	NS	NS	NS	NS	NS	NS	NS	3.1	NS	NS	NS
Treatment X Variety X Population			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.1	4.0	NS

Table 4. Onion single-center ratings and maturity for two varieties under two plant populations in response to late season water stress. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013.

		Plant population	Multiple center			Single center		Maturity July 25	
Variety	Treatment	target	large	medium	small	functional[a]	single	tops down	dryness
		plants/acre	%						
Vaquero	20 cb	120,000	3.0	6.5	20.1	90.6	70.5	0.0	0.0
	20 cb/stress	120,000	4.5	7.2	18.4	88.4	70.0	0.0	0.0
	average	average	3.7	6.8	19.2	89.5	70.2	0.0	0.0
	20 cb	450,000	1.0	3.1	11.5	95.9	84.5	4.7	0.0
	20 cb/stress	450,000	0.0	1.4	6.6	98.6	92.0	8.8	0.5
	average	average	0.5	2.2	9.1	97.3	88.2	6.7	0.3
	20 cb		1.9	4.7	15.4	93.5	78.0	2.5	0.0
	20 cb/stress		2.2	4.3	12.5	93.5	81.0	3.5	0.3
Swale	20 cb	120,000	1.1	5.8	26.4	93.1	66.7	1.4	0.0
	20 cb/stress	120,000	2.2	6.7	24.7	91.1	66.4	0.0	0.0
	average	average	1.6	6.3	25.6	92.1	66.5	0.7	0.0
	20 cb	450,000	0.3	2.6	12.6	97.1	84.5	10.0	0.0
	20 cb/stress	450,000	0.8	3.5	17.7	95.7	78.0	20.0	0.0
	average	average	0.5	3.1	15.2	96.4	81.3	15.0	0.0
	20 cb		0.7	4.1	19.0	95.3	76.3	5.7	0.0
	20 cb/stress		1.5	5.1	21.2	93.4	72.2	8.0	0.0
Average	20 cb	120,000	2.0	6.1	23.3	91.8	68.6	0.8	0.0
	20 cb/stress	120,000	3.4	6.9	21.5	89.7	68.2	0.0	0.0
	average	average	2.7	6.5	22.4	90.8	68.4	0.4	0.0
	20 cb	450,000	0.6	2.9	12.0	96.5	84.5	7.4	0.0
	20 cb/stress	450,000	0.4	2.5	12.2	97.2	85.0	14.4	0.3
	average	average	0.5	2.7	12.1	96.8	84.7	10.9	0.1
	20 cb		1.3	4.4	17.2	94.4	77.2	4.2	0.0
	20 cb/stress		1.9	4.7	16.9	93.5	76.6	16.7	0.1
LSD (0.05)									
Treatment			NS	NS	NS	NS	NS	10.9	NS
Population			1.0	1.2	5.4	2.5	6.9	10.1	NS
Treatment X Population			NS	NS	NS	1.6	NS	NS	NS

[a] Single center plus small multiple center.