SHORT-DURATION WATER STRESS DECREASES ONION SINGLE CENTERS WITHOUT CAUSING TRANSLUCENT SCALE

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Introduction

In earlier trials we have shown that onion yield and grade are very responsive to careful irrigation scheduling and maintenance of optimum soil moisture (Shock et al. 1998b, 2000). Using a high-frequency automated drip-irrigation system, the soil water tension at 8-inch depth that resulted in maximum onion yield, grade, and quality after storage was determined to be no drier than 20 cbars. It is not known whether short-term water stress, caused by irrigation errors, could result in internal bulb defects such as multiple centers and translucent scale. This trial tested the effects of short-duration water stress at different times early in the season on onion single centeredness and translucent scale.

Materials and Methods

Onions were grown at the Malheur Experiment Station, Ontario, Oregon on an Owyhee silt loam previously planted to wheat. In the fall of 2004, the wheat stubble was shredded, and the field was irrigated and disked. A soil analysis on September 14, 2004, showed a pH of 7.7, 2.4 percent organic matter, 36 ppm P, 764 ppm K, 4266 ppm calcium, 940 ppm magnesium (Mg), 3.1 ppm zinc (Zn), 15 ppm iron, 79 ppm manganese, 1.8 ppm copper, and 0.7 ppm boron (B). The soil was fertilized with 100 lb phosphate/acre, 400 lb sulfur/acre, and 4 lb Zn/acre, which were broadcast in the fall of 2004 after disking. The field was not fumigated nor bedded in the fall due to excessive moisture. In early March 2005, the field was moldboard-plowed, groundhogged, roller-harrowed, and bedded.

Onion seed was planted at 150,000 seeds/acre in 2 double rows, spaced 22 inches apart (center to center of double rows) on 44-inch beds on March 16, 2005. The 2 rows in the double row were spaced 3 inches apart. Drip tape (T-tape, T-systems International, San Diego, CA) was laid at 4-inch depth between the 2 double onion rows simultaneously with planting. The distance between the tape and the center of the double row was 11 inches. The 6-mil drip tape had emitters spaced 12 inches apart and a nominal flow rate of 0.22 gal/min/100 ft at 10 PSI.

Immediately after planting the onion rows received 3.7 oz of Lorsban 15G® per 1,000 ft of row (0.82 lb ai/acre), and the soil surface was rolled. The trial was irrigated for even stand establishment on April 13 and April 15 with a minisprinkler system (R10 Turbo

Rotator, Nelson Irrigation Corp., Walla Walla, WA). Risers were spaced 25 ft apart along the flexible polyethylene hose and hoses were spaced 30 ft apart. The water application rate was 0.10 inch/hour. Onion emergence started on April 17.

The experimental design had six irrigation treatments arranged in a randomized complete block with five replicates. The six drip-irrigated treatments consisted of five timings of short-duration water stress and an unstressed check. Two varieties ('Vaquero', Nunhems, Parma, ID and '6011', Global Genetics, Payette, ID) were split plots within the main irrigation treatment plots.

Each irrigation treatment main plot was 4 double rows by 60 ft and each variety subplot was 4 double rows by 30 ft. Each plot had a ball valve allowing manual control of irrigations. The water stress was applied by turning the water off manually to all plots in a given treatment until the average soil water tension at 8-inch depth for the treatment reached 60 cbars; at this point, the irrigation to all plots in that treatment was turned on again. Except for the unstressed check treatment, the onions in each treatment were stressed only once during the season. The five timings for the stress treatments were: two-leaf stage, four-leaf stage (water off May 27, water back on June 20), early six-leaf stage (water off June 13, water back on June 29), late six-leaf stage (water off June 20, water back on June 30), and eight-leaf stage (water off June 28, water back on July 11).

Soil water tension (SWT) was measured in each plot with four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co. Inc., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been previously calibrated to SWT (Shock et al. 1998a). The GMS were connected to the datalogger with three multiplexers (AM 410 multiplexer, Campbell Scientific, Logan, UT). The datalogger read the sensors and recorded the SWT every hour. The irrigations were controlled by the datalogger using a relay driver (A21 REL, Campbell Scientific, Logan, UT) connected to a solenoid valve. Irrigation decisions were made every 12 hours by the datalogger as follows: if the average SWT at 8-inch depth in the unstressed treatment plots was 20 cbars or more the field was irrigated for 4 hours. If the SWT was less than 20 cbars, the field was not irrigated. The pressure in the drip lines was maintained at 10 psi by a pressure regulator. Irrigations ended on September 5.

The field had Prowl® (1lb ai/acre) broadcast on May 23 for postemergence weed control. Approximately 0.45 inch of water was applied through the minisprinkler system on May 24 to incorporate the Prowl. Goal® at 0.16 lb ai/acre, Buctril® at 0.16 lb ai/acre, and Poast® at 0.21 lb ai/acre were applied on May 27 for weed control. Due to high rainfall in April and May, Bravo® at 2.25 lb ai/acre was applied on May 20 for prevention of foliar fungal diseases.

Onion tissue was sampled for nutrient content on June 8. In each check plot, the roots from four onion plants from one of the border rows of variety Vaquero were washed with deionized water, bulked together, and analyzed for nutrient content by Western

Labs, Parma, Idaho. The onions in all treatments were fertilized according to the plant nutrient analyses. Urea ammonium nitrate solution at 60 lb N/acre, P at 10 lb/acre as phosphoric acid, K at 20 lb/acre as potassium chloride, and Mg at 5 lb/acre as Epsom salts (magnesium sulfate) were applied through the drip tape on June 15. Nitrogen at 40 lb/acre as urea ammonium nitrate solution was injected through the drip tape on June 20. A second tissue sample taken on July 11 showed the need for B. On July 14, B at 0.2 lb/acre as boric acid was injected through the drip tape.

Thrips populations were very challenging in 2005. Thrips were controlled with aerial applications of the following insecticides: June 16, Warrior plus Lannate®; June 24, Warrior®; July 10, Warrior plus Lannate; July 18, Warrior plus Lannate; July 26, Warrior plus MSR; August 3, Warrior plus Lannate; August 10, Warrior plus MSR; August 14, Warrior plus Lannate; August 20, Warrior plus MSR. Warrior was applied at 0.03 lb ai/acre, Lannate at 0.45 lb ai/acre, and MSR at 0.5 lb ai/acre.

On September 12 the onions were lifted to cure. On September 19, onions in the central 25 ft of the middle 2 double rows in each subplot were topped and bagged. The bags were placed into storage on September 22. The storage shed was managed to maintain air temperature at approximately 34°F. The onions were graded on December 8, 2005. Bulbs were separated according to quality: bulbs without blemishes (No. 1s), double bulbs (No. 2s), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small (<2.25 inches), medium (2.25-3 inches), jumbo (3-4 inches), colossal (4-4.25 inches), and supercolossal (>4.25 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.

After grading, 50 bulbs ranging in diameter from 3.5 to 4.25 inches from each subplot were rated for single centers and translucent scale. The onions were cut equatorially through the bulb middle and, if multiple centered, the long axis of the inside diameter of the first single ring was measured. These multiple-centered onions were ranked according to the diameter of the first single ring: "small doubles" have diameters less than 1.5 inches, "intermediate doubles" have diameters from 1.5 to 2.25 inches, and "blowouts" have diameters greater than 2.25 inches. Single-centered onions are classed as a "bullet". Onions are considered functionally single centered for processing if they are a "bullet" or "small double." The number and location of translucent scales in each bulb was also recorded.

The data were analyzed using analysis of variance and treatment means were compared using the protected least significant difference test at the 5 percent probability level, LSD (0.05). Treatment means were considered statistically different if the difference between means was equal to or greater than the LSD value for a characteristic.

Results

Excessive rainfall in April and May prevented water stress at the two-leaf stage.

Single Centeredness - Vaquero

Water stress at the four-leaf stage resulted in the lowest percentage of single-centered or functionally single-centered onions. Water stress at the six-leaf early or six-leaf late stages resulted in more single-centered or functionally single-centered onions than at the four-leaf stage, but less than the unstressed check (Table 1). Water stress at the four-leaf stage resulted in the highest percentage of blowout multiple-centered onions. Water stress at the eight-leaf stage did not result in fewer functionally single-centered bulbs than the unstressed check.

Single Centeredness - 6011

Water stress at the four-leaf or six-leaf early stages resulted in the lowest percentage of single-centered onions. Water stress at the six-leaf late stage resulted in more single-centered onions than at the four-leaf or six-leaf early stages, but less than the unstressed check. Water stress at the four-leaf or six-leaf early stages resulted in the lowest percentage of functionally single-centered onions. Water stress at the six-leaf late and eight-leaf stages did not result in fewer functionally single-centered bulbs.

Single Centeredness - Variety Average

Compared to the unstressed check, water stress resulted in decreasing percentages of single-centered and functionally single-centered bulbs in the following order of timing: six-leaf late, six-leaf early, and four-leaf stage.

Translucent Scale

There was no significant difference between treatments in the percentage of bulbs with translucent scale. The percentage of bulbs with translucent scales was small from all treatments. Previous research has shown that factors other than water stress can cause translucent scale, such as prolonged field curing and high artificial drying temperatures (Solberg and Boe 1997).

Yield and Grade

The interaction effects of stress treatment and variety were not statistically significant, so the stress treatment effects are discussed in terms of the variety averages. Total and marketable onion yield were reduced substantially by water stress at the eight-leaf stage (Table 2). Reductions in supercolossal onion yield resulted from water stress at the four-leaf, six-leaf late, and eight-leaf stages. Reductions in colossal onion yield resulted from water stress at the six-leaf early, six-leaf late, and eight-leaf stages.

Variety Comparison

Variety 6011 had more single-centered and functionally single-centered onions than Vaquero. Vaquero had more pronounced reductions in single centered and functionally single-centered onions in response to water stress than 6011. Vaquero had higher total and marketable yield than 6011. Variety 6011 had higher colossal onion yield than

Vaquero. It is possible that the lower yield of 6011 observed in this trial was associated with onion thrips pressure.

Discussion

In 2003, water stress at the four-leaf and six-leaf early stages resulted in significantly lower single-centered and functionally single-centered bulbs than the unstressed check (Shock et al. 2004). In 2004, water stress did not affect onion single centeredness (Shock et al. 2005). Both average maximum air and 4-inch soil temperatures during the stress treatments were higher in 2003, lower in 2005, and lowest in 2004 (Table 3). The lack of response of single centeredness to water stress in 2004 could be related to the lower temperatures during the water stress treatments. Water stress alone during a period of cool and overcast or rainy weather might have a smaller effect on stopping onion growth than stress during warmer, drier weather. The clear response of single centeredness to water stress in 2005 is somewhat surprising, because temperatures were only slightly higher than in 2004 and substantial precipitation occurred in 2005 (Table 4). The precipitation during the stress treatments in 2005 explains the longer duration of the stress treatments than in 2004 and 2003. At each stress timing, more days of water stress were required for SWT to reach 60 cbars in 2005 than in 2004 or 2003 (Fig. 1, Tables 3 and 4). The longer stress periods in 2005 also resulted in a longer period of SWT above 40 cbars in 2005 than in 2003 and 2004. The longer duration of stress in 2005 might explain why stress at the six-leaf late stage had an effect on single centeredness in 2005 and not in 2003 and 2004. Also, the longer duration of stress in 2005 might explain the effect of stress on yield. Prior work has shown that extended SWT drier than 20 cbars reduces onion marketable yield (Shock et al. 2000). The effect of stress on yield was more pronounced at the eight-leaf stage, which is the beginning of bulb growth.

The 2003 and 2005 results show that onions are more susceptible to producing multiple centers when stressed at the four-leaf and six-leaf early stages than later at the six-leaf late and eight-leaf stages. Over the 3 years, the four-leaf and early six-leaf stages occurred from late May through June.

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Table 1. Onion multiple-center rating and translucent scale response to timing of water stress for two varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2005.

Water stress timing	Blowout*	Intermediate double†	Small double‡	Bullet§	Functionally single centered bullet + small double	Translucent scale
	----------	----------	----------	%	----------	----------
			Vaquero			
Check, no stress	2.4	1.6	10.0	86.0	96.0	0.0
2-leaf stage	3.3	2.0	8.7	86.0	94.7	0.0
4-leaf stage	24.4	16.8	22.0	36.8	58.8	0.0
6-leaf early stage	6.0	12.4	17.6	64.0	81.6	0.4
6-leaf late stage	4.0	8.8	20.4	66.8	87.2	0.4
8-leaf stage	0.5	1.0	10.5	88.0	98.5	1.0
Average	7.3	7.7	15.5	69.6	85.0	0.3
			6011			
Check, no stress	2.0	0.0	6.4	91.6	98.0	0.0
2-leaf stage	6.0	0.0	9.3	84.7	94.0	0.7
4-leaf stage	8.4	4.0	18.0	69.6	87.6	0.4
6-leaf early stage	7.6	10.4	18.0	64.0	82.0	0.4
6-leaf late stage	2.0	6.8	12.4	78.8	91.2	0.8
8-leaf stage	1.2	0.4	13.6	84.8	98.4	1.6
Average	4.4	3.9	13.2	78.5	91.7	0.6
			Variety average			
Check, no stress	2.2	0.8	8.2	88.8	97.0	0.0
2-leaf stage	4.7	1.0	9.0	85.3	94.3	0.3
4-leaf stage	16.4	10.4	20.0	53.2	73.2	0.2
6-leaf early stage	6.8	11.4	17.8	64.0	81.8	0.4
6-leaf late stage	3.0	7.8	16.4	72.8	89.2	0.6
8-leaf stage	0.9	0.7	12.2	86.2	98.4	1.3
Average	5.8	5.8	14.3	74.1	88.4	0.5
LSD (0.05)						
Treatment	4.1	3.8	5.0	6.6	5.8	NS
Variety	NS	2.0	NS	3.3	3.5	NS
Treatment X variety	5.0	4.9	NS	8.1	8.6	NS

*Blowout: diameter of the first single ring >2¼ inches.
†Intermediate double: diameter of the first single ring 1½-2¼ inches.
‡Small double: diameter of the first single ring <1½ inches.
§Bullet: single-centered.

Table 2. Onion yield and grade response to timing of water stress for two varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2005.

Water stress timing	Total yield	Marketable yield by grade					Bulb counts >4¼ in	Nonmarketable yield		
		Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in		Total rot	No. 2s	Small
	---------- cwt/acre ----------						#/50 lb	% of total yield	-- cwt/acre --	
Vaquero										
Check, no stress	732.7	689.1	2.7	23.9	584.0	56.3	36.0	4.6	0.0	11.7
2-leaf stage	667.4	644.1	1.9	19.6	600.3	59.5	42.0	0.9	1.5	11.7
4-leaf stage	661.7	632.3	0.0	10.7	519.4	102.2		2.0	0.0	16.4
6-leaf early stage	651.9	621.8	0.0	5.6	550.2	66.0		3.0	0.9	10.1
6-leaf late stage	694.4	664.8	0.0	10.7	588.2	65.9		2.5	1.0	11.7
8-leaf stage	539.7	503.9	0.0	0.0	380.8	123.1		3.3	0.0	18.1
Average	661.6	629.2	0.7	11.6	538.3	78.6	38.0	2.8	0.5	13.2
6011										
Check, no stress	598.9	574.5	2.6	58.4	472.0	41.5	37.2	2.4	0.7	10.4
2-leaf stage	614.6	603.2	3.1	77.0	479.9	43.1	50.4	0.7	1.1	8.0
4-leaf stage	548.9	517.9	0.0	57.7	406.4	53.8		2.9	0.0	15.8
6-leaf early stage	593.6	568.9	0.9	35.7	481.5	50.8	51.5	2.3	0.0	10.9
6-leaf late stage	598.2	553.1	0.0	30.7	468.3	54.1		5.8	0.0	11.0
8-leaf stage	444.0	421.1	0.0	7.6	347.6	65.8		2.1	0.0	14.2
Average	562.9	535.3	1.0	42.2	440.0	52.1	46.4	2.9	0.3	12.0
Variety average										
Check, no stress	655.5	620.7	2.6	41.2	528.0	48.9	36.4	3.5	0.4	11.1
2-leaf stage	658.1	642.2	2.5	48.3	540.1	51.3	46.2	0.9	1.3	9.8
4-leaf stage	605.3	575.1	0.0	34.2	462.9	78.0		2.5	0.0	16.1
6-leaf early stage	622.8	595.4	0.5	20.6	515.9	58.4	51.5	2.6	0.4	10.5
6-leaf late stage	646.3	608.9	0.0	20.7	528.3	60.0		4.1	0.5	11.4
8-leaf stage	486.6	457.9	0.0	4.2	362.4	91.3		2.6	0.0	15.9
Average	611.4	581.4	0.8	27.2	488.2	65.1	42.2	2.8	0.4	12.6
LSD (0.05)										
Treatment	59.0	56.7	2.5	16.6	55.9	17.9	NS	NS	NS	3.7
Variety	38.7	35.2	NS	11.2	32.9	10.1	NS	NS	NS	NS
Treatment X variety	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

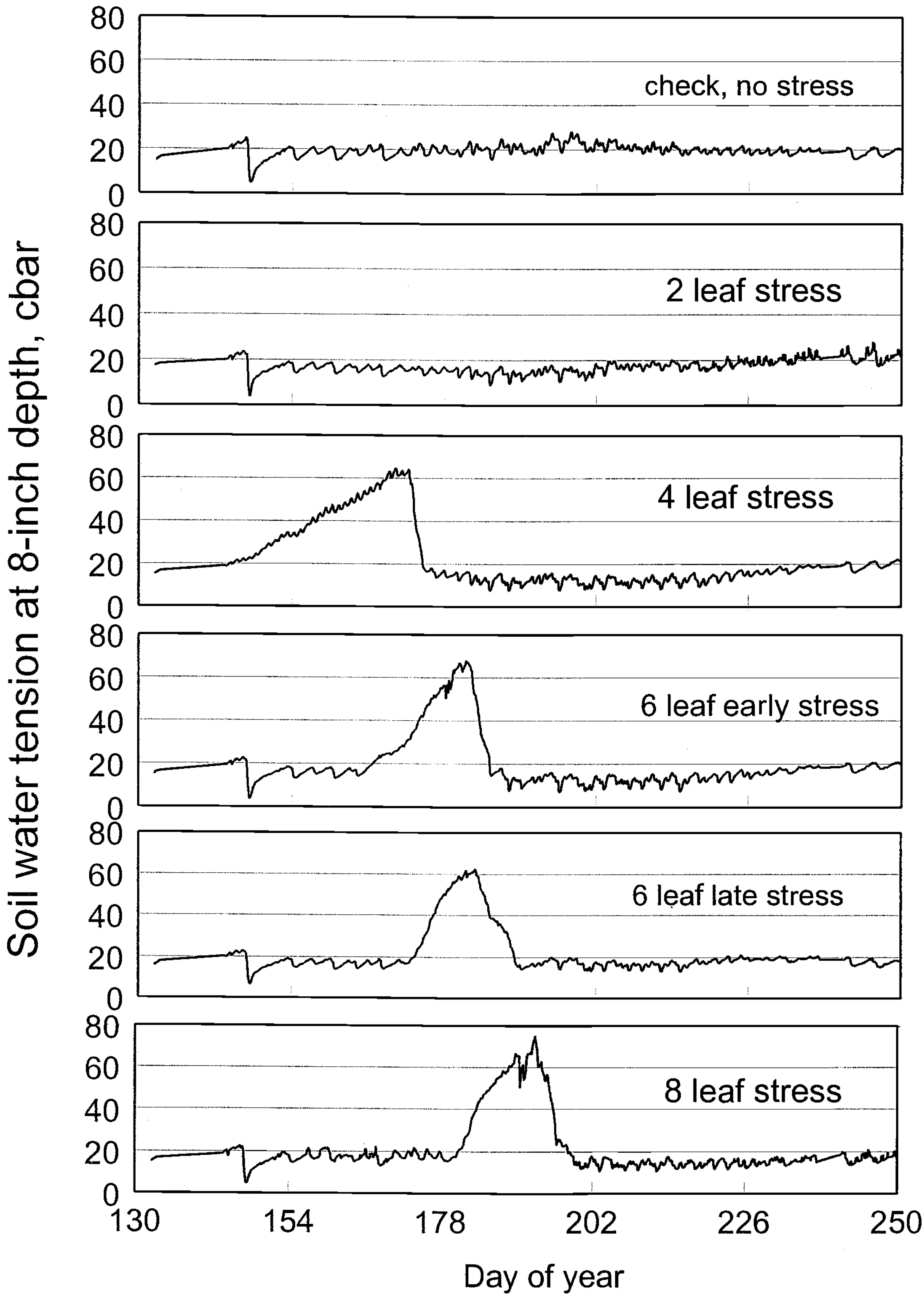

Figure 1. Soil water tension for onions irrigated at 20 cbars with an automated drip-irrigation system and submitted to short-duration water stress, Malheur Experiment Station, Oregon State University, Ontario, OR, 2005.

Table 3. Degree days (32-104°F), average maximum 4-inch soil temperature, and average maximum air temperature during stress treatments, Malheur Experiment Station, Oregon State University, Ontario, OR.

Water stress timing	Degree days from start to end of stress period			Average maximum soil temperature			Average maximum air temperature		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
	°F								
2-leaf stage		689			61.2			71.0	
4-leaf stage	272	259	432	70.0	63.5	66.6	85.8	74.5	76.5
6-leaf early stage	146	259	536	72.4	67.3	70.6	87.0	80.0	83.1
6-leaf late stage	182	146	340	72.8	66.4	72.2	92.0	76.4	85.6
8-leaf stage	137	218	437	73.0	71.5	72.9	94.0	87.3	86.0

Table 4. Length of stress treatments and precipitation during stress treatments, Malheur Experiment Station, Oregon State University, Ontario, OR.

Water stress timing	Length of stress			Length of time soil water tension above 40 kPa			Precipitation		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
	days			hours			inches		
2-leaf stage		28			372			1.70	
4-leaf stage	8	10	24	147	179	392	0.00	0.55	0.93
6-leaf early stage	5	9	16	145	177	230	0.23	0.02	0.68
6-leaf late stage	6	5	10	91	123	213	0.00	0.00	0.22
8-leaf stage	4	6	13	113	229	290	0.01	0.26	0.38