Effects of Water Application Rates and Planting Density on Size Arrangements of Drip Irrigated Onions[1]

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ABSTRACT

Onions (Var. Texas Grano 502) were drip irrigated in December 1982 at the Fortuna Agricultural Research and Development Center to evaluate the effects of water application rates (wet = T1, moist = T2 and dry = T3) and various planting densities (S1, S2, S3 and S4) on crop performance. The evaluation characteristics were size arrangement and percentage distribution in each USDA size class, total solids percentage, defects percentage, onion volume, weight, density and commercial yield. The bulbs were significantly larger at 5% in T2 than in T1 and T3 in size classes X and XII. More than 50% of the onions were in size classes 1 to 5 and 16 to 19, respectively. Two rows of onions on both sides of the drip line yielded significantly more at the 5% level compared with the yield of one row on both sides of the drip line. The wet treatment outyielded the dry treatment at the 5% level. The yield differences were not significant at the 5% level between wet and moist treatments. The bulbs were heavier when plant spacing was increased from 7.5 cm to 15 cm.

INTRODUCTION

The consumption of fresh and processed vegetables in Puerto Rico increased from 38.6 kg/person in 1950–51 to 54.5 kg/person in 1981–82. The average vegetable consumption was 171.4 million kg, consisting of 52% fresh and 42% processed vegetables during the last 8 years. Out of 11,333 hectares cultivated to vegetables in Puerto Rico, 2,166 hectares were cultivated on the south coast in 1982–83. Annual per capita consumption of onions in Puerto Rico increased from 6.1 kg in 1972–73 to 8.2 kg in 1975–76. Puerto Rico imported 16,350 t of onions, mainly from the mainland United States in 1975–76 as against 35,754 t in 1981–82. The area planted, total onion production and the crop value were 34 hectares, 180 metric tons and $27,925 in 1981–82 as against 44 hectares, 251 metric tons and $313,637 in 1982–83.[3] The climatic conditions from November through March seem to be suitable for the production of quality onions in Puerto Rico (9, 10).

Bleasdale (1) found that reduction in planting distance from 45 to 30

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cm increased onion production by 10 to 30%. Increasing the number of plants/m^2 increased the number of commercial bulbs but reduced the yield. Frappel (2) found a 10% reduction in the yield when onions were planted in a 40 × 40 mm pattern as compared to that of a 360 to 40 mm planting pattern. Hatridge and Bonnet (7) showed that decreasing space between plants reduced bulb size. Mangual, Ramírez and Orengo (10) encountered significant yield increases when plant spacing was varied from 90 to 30 cm. Hall (6) indicated that 49% of the onion production in the USA was placed in storage before sale or processing and storage space was based upon onion bulk density of 640 kg/m^3. Goyal (3, 5) evaluated size arrangements of drip irrigated peppers and tomatoes. To what extent USDA grading standards (4, 8) may be applied to onions grown in Puerto Rico remains to be determined.

The objectives of this study were to evaluate effects of water application rates and planting density on yield, total solids, size arrangements, and fruit performance of drip irrigated onions (var. Texas Grano 502).

MATERIALS AND METHODS

This study was conducted at Fortuna Agricultural Research and Development Center, located on the semiarid southern coast of Puerto Rico. The soil belongs to the San Antón series with a pH of 7.9. Maximum, minimum, and average temperatures during the growing period were 16, 32 and 25° C, respectively. The seasonal rainfall and class A pan evaporation were 98.0 and 540.1 mm, respectively.

The crop was subjected to three water regimes (wet, moist and dry) based upon readings of tensiometers which were installed at 15, 30 and 45 cm below the soil surface to control the irrigation scheduling. The main treatments were replicated six times in a randomized split-plot block design. The subtreatments were one row of onions on both sides of the chapin biwall drip line[4] at 7.5 cm spacing down the row (S1 = 296,296 plants/ha); two rows of onions on both sides of the drip line at 7.5 cm spacing (S2 = 592,593 plants/ha); one row of onions on both sides of the drip line at 15 cm spacing (S_3 = 148,148 plants/ha); and two rows of onions on both sides of the drip line at 15 cm spacing (S_4 = 296,296 plants/ha). Plots consisted of three beds 90 cm apart and 12 m long; the center bed was harvested to obtain the experimental data.

Onion seeds (variety Texas Grano 502) were hand sown on metal flats 45 × 30 × 5 cm October 29, 1982, and the seedlings were planted in the field December 22, 1982. Dacthal W-75 was applied immediately after

[4] Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

planting at the rate of 8.9 kg/ha as a preemergent herbicide. Tok E-25 (nitrofen) at the rate of 4.5 kg/ha was used as a postemergent herbicide. The tensiometers were installed according to "Tensiometer installation guide" by Irrometer Company, Inc., Riverside, CA. Irrigation was applied when the soil moisture tension was 50 cbars, and terminated when the moisture tension dropped to 15 cbars.

Onions were harvested April 5, 1983. After being cured for 10 days, commercial onions were counted and weighed. For determination of average bulb size, weight, volume, density and percentage loss during curing, a subsample from each subplot was taken at the time of harvest. These samples were transferred to the Food Technology Laboratory for determination of total solids, percentage of loss during curing, average bulb size, weight, volume and density. The Archimedes principle was used to determine the average bulb volume. The bulb volume was also estimated on the assumption that the onion was a perfect sphere.

RESULTS AND DISCUSSION

Table 1 indicates size arrangements of drip irrigated onions (Var. Texas Grano 502) for three water application rates (T1 = wet, T2 = moist and T3 = dry) in S1, S2, S3 and S4 plots, respectively. On weight basis, there were no significant differences at the 5% level among subtreatments and main treatments in any USDA size classes 1 to 19, except sizes 10 and 12 for T1, T2, T3; sizes 5, 9, 11, 13, 15 and 17 for S1, S2, S3 and S4, respectively. The moist treatment caused heavier bulbs compared with those of the wet and dry treatments, respectively, in size classes 10 and 12. The bulbs were significantly heavier at the 5% level in subplots S3 compared with those of S1 in size class 5; in subplots S2 compared with those of S3 in size classes 9, 13, 15; in subplots S2 compared with those of S1 and S4 in classes 9, 15; in subplots S4 compared with those of S1 in size class 9. The total number of onions in all size classes indicated heaviest bulbs in subplots S3 as compared with those of S2 and S4.

On the basis of number of commercial bulbs, the differences were not significant at the 5% level among main treatments in all size classes and among subtreatments in size classes 1 to 4, 7, 10 to 14, 16, and 19, respectively. The number of commercial bulbs was highest at the 5% level in subplots S3 compared with that of S1, S2 in size classes 5, 6; in subplots S3 compared with that of S4 in size class 9; in subplots S4 compared with that of S2 in size class 8; in subplots S4 compared with that of S1, S2 and S3 in size class 17; in subplots S2 compared with that of S3 in size classes 9, 15; in subplots S2 compared with that of S1 in size class 18, respectively. The total number of commercial onions in all size classes was lowest at the 5% level in subplots S3 compared to that of S1 and S2.

TABLE 1.—*Effects of water application rates (T1, T2, T3) and planting density (S1, S2, S3, S4) on size of drip irrigated onions (var. Texas Grano). Date of transplanting: Dec 22, 1982. Date of last harvest: April 5, 1983*

USDA[1] bulb size class	Number (%) and average weight of onions (g)[2]																					
	T1 = Wet								T2 = Moist								T3 = Dry					
	S1		S2		S3		S4		S1		S2		S3		S4		S1		S2		S3		S4	
	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.	No.	Mean wt.
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	528.7
2	—	—	1	527.5	2	522.1	1	576.9	1	489.9	1	446.8	2	531.3	1	554.3	—	—	2	490.7	—	—	—	—
3	1	457.8	1	249.9	1	537.0	—	—	1	464.9	1	417.2	—	—	2	485.8	1	589.2	—	—	2	449.6	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	499.9
5	—	—	1	447.4	3	525.8	1	437.0	—	—	—	—	3	477.5	4	451.3	1	430.8	1	414.1	1	432.6	—	—
6	5	390.9	5	394.1	11	360.6	10	396.7	5	368.9	6	363.5	9	382.0	7	370.8	3	364.5	2	364.3	9	379.4	6	402.5
7	4	318.7	8	307.8	3	300.9	9	311.6	5	309.8	7	320.1	11	310.4	8	308.2	9	339.8	4	302.1	8	336.3	5	312.5
8	6	272.4	8	266.6	10	266.3	17	267.3	9	257.8	8	247.2	8	259.5	10	257.9	13	283.9	7	269.0	12	276.2	18	269.9
9	13	222.4	19	231.2	6	240.2	14	216.2	14	222.3	13	226.9	18	199.7	8	229.2	10	213.1	12	229.8	15	219.1	7	209.0
10	15	175.6	12	180.1	11	187.8	18	176.9	14	179.5	17	193.2	15	177.8	13	175.1	10	175.7	12	170.7	15	179.7	12	172.0
11	14	130.1	14	138.3	15	137.2	14	154.0	10	148.5	15	148.5	18	130.9	16	129.2	15	114.4	13	145.3	12	133.4	12	145.5
12	8	91.2	7	107.7	9	111.4	1	111.4	7	116.1	11	109.5	7	110.2	12	109.3	8	111.0	11	109.4	6	105.0	5	114.8
13	7	77.2	10	89.5	15	80.3	6	87.4	8	80.9	9	82.5	3	76.9	9	74.6	10	78.7	14	85.8	12	44.1	9	86.7
14	9	53.0	5	60.9	5	60.9	3	56.2	4	61.9	3	57.0	2	59.2	6	62.1	5	58.2	8	58.0	3	54.2	3	57.3
15	12	40.4	6	42.2	3	44.3	3	43.1	8	44.4	7	49.1	2	44.3	1	43.0	12	47.3	6	42.7	2	45.0	10	43.7
16	1	25.2	1	24.4	2	25.3	2	26.4	3	27.9	3	33.9	1	29.0	1	33.9	1	21.9	3	29.8	2	27.5	5	29.7
17	3	15.7	2	16.7	3	18.4	—	—	1	16.9	1	17.1	1	18.6	—	—	1	14.3	2	16.9	1	21.6	5	18.3
18	1	14.9	—	—	—	—	1	24.8	1	11.9	—	—	—	—	2	10.5	—	—	3	10.3	—	—	—	—
19	1	3.4	—	—	1	6.3	—	—	1	9.3	1	5.1	—	—	—	—	1	4.8	—	—	—	—	1	11.6
Sample size	29	4072.9	27	4552.3	21	3637.5	22	4310.0	28	4320.2	28	4983.3	16	3313.4	23	4242.2	20	3281.5	29	4171.6	17	3228.8	28	4232.6
Mean size, g	—	140.4	—	168.6	—	173.2	—	195.9	—	154.3	—	177.9	—	207.1	—	184.4	—	164.0	—	143.8	—	189.9	—	151.2

[1] USDA bulb size classes, 1–19 are based on bulb diameter of 4.75, 4.50, 4.25, 4.1875, 4.125, 4.00, 3.75, 3.50, 3.25, 3.00, 2.75, 2.50, 2.25, 2.00, 1.75, 1.50, 1.25, 1.00 and 1.00 inch, respectively.

[2] Water application rates were based on tensiometers at 15, 30 and 45 cm depth in the T1, T2 and T3 treatments, respectively. Subtreatments were S1 = one row of onions on both sides of drip line at 7.5 cm spacing down the row; S2 = two rows of onions on both sides of drip line at 7.5 cm spacing; S3 = one row of onions on both sides of drip line at 15.0 cm spacing; and S4 = two rows of onions on both sides of drip line at 15.0 cm spacing.

Table 2 reveals onion performance for three main treatments (T1, T2 and T3) and four subtreatments (S1, S2, S3 and S4). The variation in water application rate and plant density did not affect the percentages total solids, percentage of defective onions and onion bulk density based upon laboratory samples. The number of marketable bulbs was higher in the wet treatment at the 5% level compared with that of the moist treatment. The wet treatment outyielded the dry treatment at the 5% level. The average bulb weight was not significantly different at the 5% level in the T1, T2 and T3 plots. The number of marketable bulbs and yield were highest at the 5% level in the S2 plots compared with those of S1, S3 and S4 plots; in the S1 plots compared with those of S3 and S4 plots; and in the S4 plots compared with those of S3 plots, respectively. The average bulb weight was highest at the 5% level in S3 plots compared with that of S1, S2 and S4 plots; in S4 plots compared with that of S2 plots; and in S1 plots compared with that of S2 plots, respectively. The marketable yield (t/ha) for the T1, T2 and T3 treatments, was 23.0, 22.9 and 22.2 in the S1 plots; 28.4, 24.9 and 24.5 in the S2 plots; 16.2, 15.7 and 12.9 in the S3 plots; 20.3, 16.9 and 16.6 in the S4 plots, respectively.

The average percentage total loss between April 22 and May 13, 1983, was 10.6, 10.7 and 10.2 in the wet, moist and dry treatments; and 9.5, 11.9, 12.2 and 8.3 in the S1, S2, S3 and S4 plots, respectively, when the onion samples were stored at ambient conditions. These values were not statistically different at the 5% level. Seasonal water applications per hectare were 288, 236 and 189 mm for the wet, moist and dry treatments, respectively, equivalent to 28.8, 23.6 and 18.9 cm-hectare for the wet, moist and dry treatments, respectively. Eighty-six percent of the water was applied during the first three-fourths of the growing season.

RESUMEN

En el Centro de Investigación y Desarrollo Agrícola de Fortuna se evaluó el efecto de diferentes niveles de riego (mojado—T1, húmedo—T2, seco—T3) y la densidad de siembra (S1, S2, S3, S4) sobre el desarrollo de la cebolla var. Texas Grano 502 regada por goteo durante diciembre de 1982. Los parámetros evaluados fueron la separación por tamaño y el porcentaje de distribución en cada una de las diferentes clases (USDA), porcentaje total de sólidos, porcentaje de desechos, volumen, peso y densidad de las cebollas y rendimiento comercial. Los bulbos fueron significativamente más grandes a un nivel de 5% en el tratamiento T2 comparado con los tratamientos T1 y T3 en las clases de tamaño X y XII. Más del 50% de las cebollas estaban entre las classes 6 a 12, en contraste con menos del 5% en las clases del I al 5 y del 16 al 19, respectivamente. El tratamiento de dos hileras de cebollas a cada lado de la línea de goteo contribuyó a un rendimiento significativamente mayor a un nivel de 5%

TABLE 2.—*Effect of water application rates (T1, T2, T3) and planting density (S1, S2, S3, S4) on performance of drip irrigated onions (var. Texas Grano)*

Planting density	Laboratory analysis (based on individual onions)								Based on plot sample		
	Moisture	Total solids content	With defects (based on number)	Onion volume, V		Average bulb weight	Bulk density, W/V		Marketable bulbs	Yield	Average bulb weight
				Calculated	Displacement method		Calculated	Displacement method			
Plants/ha	%	%	%	cm^3	cm^3	g	g/cm^3	g/cm^3	No/ha	tons/ha	g
					T1 = Wet						
S1 = 296,296	91.82	8.18	46	202.6	220.5	140.4	0.69	0.64	135,161	23.018	170.3
S2 = 592,592	91.69	8.31	43	248.5	194.7	168.6	0.68	0.86	193,823	28.366	146.4
S3 = 148,148	91.45	8.55	43	253.8	289.2	173.2	0.68	0.59	68,989	16.197	234.8
S4 = 296,296	91.68	8.32	46	291.5	243.4	195.9	0.67	0.57	111,210	20.317	182.7
					T2 = Moist						
S1 = 296,296	91.52	8.48	42	193.1	283.4	154.3	0.80	0.54	123,475	22.914	185.6
S2 = 592,592	91.83	8.17	37	242.9	208.9	177.9	0.73	0.85	166,154	24.929	150.0
S3 = 148,148	91.37	8.63	49	297.6	289.2	207.1	0.69	0.72	67,699	15.670	231.5
S4 = 296,296	91.88	8.12	35	268.9	260.4	184.4	0.69	0.71	92,004	16.947	184.2
					T3 = Dry						
S1 = 296,296	91.89	8.11	44	227.2	226.2	164.0	0.72	0.73	121,574	22.166	182.33
S2 = 592,592	91.82	8.18	40	201.2	186.1	143.8	0.71	0.77	182,645	24.516	134.20
S3 = 148,148	91.43	8.57	39	273.0	251.9	189.9	0.69	0.75	61,316	12.862	209.8
S4 = 296,296	91.96	8.04	44	231.9	223.3	151.2	0.65	0.68	90,737	16.583	182.8

[1] Water application rates were based on tensiometers at 15, 30 and 45 cm depth in the T1, T2 and T3 treatments, respectively. Subtreatments were S1 = one row of onions on both sides of drip line at 7.5 cm spacing down the row (296,296 plants/ha); S2 = two rows of onions on both sides of drip line at 7.5 cm spacing (592,292 plants/ha); S3 = one row of onions on both sides of drip line at 15.0 cm spacing (148,148 plants/ha); and S4 = two rows of onions on both sides of drip line at 15 cm spacing (296,296 plants/ha).

comparado con el de una sola hilera a cada lado. El tratamiento mojado propició rendimientos mayores comparado con el tratamiento seco a un nivel de 5%. Las diferencias en rendimiento no fueron significativas a un nivel de 5% entre los tratamientos mojado y húmedo. Los bulbos fueron más pesados cuando se aumentó la distancia de siembra de 7.5 cm. a 15 cm.

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