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Improving Onion Yield and Market Grade by Mechanical Straw Application to Irrigation Furrows

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SUMMARY. Onion (*Allium cepa* var. *cepa* L.) is extensively grown under furrow irrigation in the western United States. Wheel compaction of furrows increases water runoff and erosion, and can lead to poor lateral water movement and reduced yields. We studied the effects of 560 to 800 lb/acre (630 to 900 kg·ha⁻¹) wheat straw mechanically applied to the bottom of irrigation furrows on yield and bulb size of sweet Spanish onions in commercial onion

fields in 1988, 1990, and 1991, and at an experiment station in 1991 and 1995. Furrows in commercial fields were either compacted with tractor wheels or not. In the commercial fields, straw application increased onion yield in plots with compacted furrows in 1988 and in all plots (with or without compacted furrows) in 1990. At the experiment station, straw mulch increased onion yield 64% in 1991, and 74% in 1995. Straw application primarily increased yields of jumbo (3 to 4 inches; 76 to 102 mm) and colossal (>4 inches; 10 cm) onions, whereas there was no effect on medium (2.25 to 3 inches; 57 to 76 mm) onions. We attributed yield improvements to decreased water runoff and increased lateral water movement and soil moisture.

Onion growth is very sensitive to water stress (Goltz et al., 1971; Miller et al., 1971), and the crop is commonly furrow irrigated in the western United States (Ells et al., 1986). In a recent study in eastern Oregon, yield of the onion cultivar 'Great Scott' decreased when soil water potential at 8 inches (20 cm) depth decreased below -0.2 bar (-20 kPa) (Shock et al., 1998). Onion requires intensive tractor-operated cultivation, which makes furrows subject to compaction by wheel tracks. This may increase water runoff and decrease lateral water movement. Onion growing on beds may not receive adequate water and thus not attain high yields when lateral water movement is restricted.

Small amounts of grain straw uniformly placed by hand in sloping irrigation furrows can decrease water runoff and increase lateral water movement (Berg, 1984; Brown, 1985; Brown and Kemper, 1987). Manual application of straw is, however, onerous and time

consuming. Commercial availability of equipment that mechanically applies straw mulch to the bottom of irrigation furrows has increased the interest in using the technique in onion fields. We (Shock et al., 1997) recently reported that mechanical straw mulching of irrigation furrows in onion plots substantially reduced soil erosion and surface water runoff. The objective of the present study was to assess effects of mechanical straw application in irrigation furrows on onion yield and bulb size.

Materials and methods

Five replicated trials were conducted between 1988 and 1995. The first three experiments were on-farm studies conducted within 18 miles (30 km) of Ontario, Ore., on commercial onion fields in 1988, 1990, and 1991. The other two experiments were conducted at the Oregon State University Malheur Experiment Station, 5 miles (8 km) southwest of Ontario in 1991 and 1995. All fields had silt loam soils. The slopes on commercial fields were 4% in 1988, 1% in 1990, and 1.5% in 1991, and at the experiment station were 3% in both years. Furrows were 44 inches (1.12 m) apart, and were 440 yards (400 m) long in commercial fields and 80 yards (72 m) long at the experiment station. Designated furrows in the on-farm experiments and all furrows at the experiment station were compacted by tractor wheel traffic. At the experiment station, sweet Spanish onion was seeded in April each year on rows 22 inches (56 cm) apart on furrow beds (each bed containing two onion rows) at 1.8 lb/acre (2 kg·ha⁻¹). The crop was thinned to one plant for every 4 inches (10 cm) of row during the last week of June. On-farm trials were planted to stand in late March to early April each year.

Treatments for the on-farm experiments were applications of 0 or 650 lb/acre (0 or 730 kg·ha⁻¹) straw in irrigation furrows, and two compaction levels (wheel traffic and nonwheel traffic furrows). At the experiment station, treatments were 0 and 800 lb/acre (0 and 900 kg·ha⁻¹) straw applications in 1991, and 0 and 560 lb/acre (0 and 630 kg·ha⁻¹) straw applications in 1995, with all furrows compacted by wheel traffic. Plots in all experiments consisted of two furrow beds, and each bed contained two rows of onion. A randomized complete block was used in each year, with four replications in all experiments except for on-farm experiments in 1988 and 1991 when 10 replications were used.

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To prepare straw suitable for mechanical application, wheat from a weed free field was cut at 8 to 10 inches (20 to 25 cm) length during wheat harvest with a cylinder type combine, and was baled and stored dry. Straw was then applied to the bottom of furrows using a Hobson Mulching System mechanical straw applicator (Hobson Manufacturing Inc., Keizer, Ore.). Half of the straw was applied before the first irrigation, and the remainder was applied after all cultivations in June. Splitting straw mulch application allowed cultivation for weed control.

Uniform and effective weed control was obtained by a combination of herbicides, cultivation, and hand weeding. Chemical weed control included a combination of the foliar active herbicides bromoxynil at 70 g/acre (175 g·ha⁻¹), oxyfluorfen at 22 g/acre (56 g·ha⁻¹), and fluazifop at 85 g/acre (210 g·ha⁻¹) in 12 gal/acre (108 L·ha⁻¹) of water. Onion maggot was controlled by banding ethion at 3 lb/acre (3.36 kg·ha⁻¹) before onion emergence. When needed, onion thrips were controlled by aerial applications of cypermethrin at 3.6 g/acre (8.8 g·ha⁻¹) in 5 gal/acre (42 L·ha⁻¹) of water. Onions were fertilized in June with 178 lb/acre (200 kg·ha⁻¹) N as slow release fertilizer at the experiment station; different N rates were applied on growers' fields depending on soil test.

All plots received 14 to 17 irrigations during each season. Irrigation duration in furrows with and without straw was identical and was adequate to allow the water to move laterally past the onion plants on the top of the beds in all rows. Water inflow and outflow for each furrow during each irrigation were measured in the 1991 and 1995 research at the experiment station, and water infiltration was calculated for all plots (Shock and Shock, 1997; Shock et al., 1997).

Onions were lifted with a rod weeder in September and left on the soil surface until they were hand topped. Onions were then graded using a Kerian Speed Sizer (Kerian Machines Inc., Grafton, N.D.) into medium (2.25 to 3 inches; 57 to 76 mm), jumbo (3 to 4 inches; 76 to 102 mm), and colossal (>4 inches) classes, and weighed. Few onions were smaller than 2.25 inches in diameter, and they were discarded. Data were analyzed as complete randomized blocks, and treatment means were compared using Fisher's protected LSD.

Results

Straw mulch did not affect onion yield in 1988 when the irrigation furrow was not compacted by the wheel track (Table 1). When the furrow bottom was compacted by the wheel track, straw mulch increased onion yield by ≈30%.

The increase in total onion yield was through increase in production of jumbo onions, whereas straw did not affect the yields of medium and colossal onions.

In 1990, straw mulch increased onion yield 24% in furrows with no wheel track and 38% in wheel track furrows (Table 1). The yield increase was through improvements in colossal onion yield, while straw mulch did not affect yields of medium and jumbo onions.

Straw mulch did not affect onion yield when grown on a commercial field in 1991 (Table 1). However, in the experiment conducted at the experiment station in that year, straw mulch increased onion yield 64%. The effect was through increases in both jumbo and colossal onions, whereas straw mulch decreased the yield of medium onions. Similar results were obtained in 1995 when straw mulch increased onion yield 74%.

Straw mulch reduced water runoff substantially and more than doubled infiltration (Table 2). Straw mulch also increased both irrigation efficiency and water use efficiency (Table 2).

Discussion

The sensitivity of onion growth and yield to soil water stress has been well documented (Goltz et al., 1971; Hegde, 1986; Kruse et al., 1987; Miller et al., 1971; Shock et al., 1998). Results of the present study indicate that straw

Table 1. Effects of mechanical application of straw mulch to irrigation furrow bottoms, with and without wheel compaction of furrows, on onion yield and market grade in five experiments.

Location	Year	Field slope (%)	Wheel compaction	Straw mulch (lb/acre ^x)	Onion yield ^z (tons/acre ^y)			
					Total	Medium	Jumbo	Colossal
Commercial fields	1988	4	No	0	27.3 a	2.50	20.8 a	3.92
			No	650	26.7 a	2.45	19.1 a	5.13
			Yes	0	19.3 b	2.05	14.1 b	3.12
			Yes	650	24.8 a	3.03	19.0 a	2.81
	1990	1	No	0	39.0 c	2.85	20.29	15.8 c
			No	650	48.3 a	1.65	16.64	30.1 a
			Yes	0	30.9 d	2.19	17.48	11.2 d
			Yes	650	42.6 b	1.56	15.92	25.2 b
	1991	1.5	No	0	36.97	5.08	21.63	10.26
			No	650	36.22	5.35	21.10	9.77
			Yes	0	36.71	5.00	19.98	11.73
			Yes	650	36.71	5.58	21.50	9.63
Experiment station	1991	3	Yes	0	18.8 b	12.2 a	6.1 b	0.5 b
			Yes	800	30.8 a	9.5 b	17.2 a	4.0 a
	1995	3	Yes	0	18.1 b	10.0 a	8.1 b	0.0 b
			Yes	560	31.5 a	5.0 b	24.6 a	1.9 a

^zWithin each year, numbers in each column followed by different letters were significantly different at 0.05 level of probability, using Fisher's protected LSD. Medium = 2.25 to 3 inches (57 to 76 mm), Jumbo = 3 to 4 inches (76 to 102 mm), and Colossal = >4 inches (>102 mm).

^y1 ton/acre = 2.24 Mg·ha⁻¹.

^x1 lb/acre = 1.12 kg·ha⁻¹.

Table 2. Effects of mechanical application of straw mulch to irrigation furrow bottoms on water runoff, infiltration, irrigation efficiency, and water use efficiency of onion crop at the experiment station in 1991 and 1995.

Parameter ^z	1991			1995		
	No-straw	Straw	LSD _(0.05)	No-straw	Straw	LSD _(0.05)
Water applied (inches)	100	100	---	60	60	---
Water runoff (inches)	75	43	5	43	18	5
Water infiltration (inches)	25	57	6	17	43	5
Irrigation efficiency (%)	25	57	5	28	70	7
Water use efficiency ^y (lb onions/inches water applied)	935	1540	275	624	1160	95

^z1.0 inch = 25.4 mm.

^yDivide by 56 to convert to kilograms of onions per millimeter of water applied.

application to irrigation furrows can substantially improve onion yield. In addition to increasing yield, straw mulch increased the proportion of larger onions, which have higher market value. Other research (Drinkwater and Janes, 1955; Kruse et al., 1987) also indicate that irrigation increases onion yield through increases in jumbo onions.

Onion yield improvement by straw application to irrigation furrows is attributed to reduced water runoff and increased lateral water movement and soil moisture. The reported water infiltration in the present study includes the water that moves laterally into planting beds as a result of slow water movement at the furrow bottom. Reducing irrigation duration or rate to decrease water runoff in furrows without straw mulch causes inadequate lateral movement of water into planting beds.

Mechanical straw mulching of irrigation furrows of onion crop also has an important conservation value because it markedly reduces both soil erosion and irrigation water runoff (Shock and Shock, 1997; Shock et al., 1997). Synthetic materials such as polyacrylamide (PAM) control erosion and enhance water infiltration in irrigation furrows in onion fields, but a single application of straw mulch is apparently as effective as repeated application of PAM to reduce erosion and more effective than PAM to increase water infiltration and maintain soil water potential (Shock and Shock, 1997).

Investigation of onion yield in 1991 as a function of seasonal water infiltration indicated that smaller amounts of straw than 800 lb/acre (900 kg·ha⁻¹) applied in that year could have been sufficient for maximum yield (data not shown). Effective onion rooting depth is generally shallower than 2 ft (60 cm) (Drinkwater and Janes, 1955; Kruse et al., 1987), suggesting that deep water percolation may not be beneficial, but increasing lateral water movement to

maintain soil moisture at rooting profile can make more water available to onion. Effects of different rates of straw and irrigation durations on onion yield would depend on soil type and slope, and merit further investigation. Furrow spacing and plant position affects erosion from surface irrigation (Sojka et al., 1992). Effects of straw on onion yield and market grade under different planting conditions may be different and merit further investigation.

Conclusions

Results indicated that mechanically applied straw mulch to the bottom of irrigation furrows can significantly improve onion yield and bulb size, especially in wheel rows where the furrow bottom is compacted. The technique also decreases water erosion and runoff, and improves water use efficiency. Under furrow irrigation, it is generally not practical to leave residue on the surface before constructing the furrows. Commercial equipment is now available that allows banding a layer of straw in irrigation furrows after planting. Straw mulch applied using this system will not interfere with fertilizers and pesticides applied on planting beds because straw is banded only in irrigation furrows.

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