YIELD OF SPRING, SUMMER, AND FALL SEEDED ANNUAL FORAGES UNDER SEASONAL DEFICIT IRRIGATION

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ABSTRACT

In order to mitigate the negative impact of drought and irrigation water shortage on forage production in Pacific Northwest, we need search and revisit alternative forage options. Due to its high management flexibility and low seed and establishment cost, annual forages especially small grains can be seeded in spring, summer, or fall for forage production under limited irrigation water resources. We conducted three research trials from 2016 to 2020 in Eastern Oregon, focusing on seasonal deficit irrigation effects on annual forage yield. The three research trials are: 1) spring seeded full season annual forages, 2) summer seeded late season annual forages after winter triticale harvested as hay, and 3) fall seeded annual forages. Four seasonal deficit irrigation treatments are: full season irrigation from May 1 to September 15 (W1), late-season deficit irrigation from May 1 to August 1 (W2), mid-season and late-season deficit irrigation from May 1 to June 15 (W3), and no irrigation under dryland (W4). Twenty spring seeded full season annual forage species yielded on average 8.35, 8.30, 5.75, and 4.00 Mg/ha under W1, W2, W3, and W4, respectively. Irrigation after August 1 is not necessary to achieve the highest forage yield for these 20 evaluated annual forage species. Pearl millet, foxtail millet, sorghum-sudangrass, oat, and triticale produced approximately 5.00-6.00 Mg/acre under both W3 and W4. Summer seeding of annual forages as a cover crop after winter triticale is not recommended in a Mediterranean-like climate without adequate irrigation water after June 15 (W3 and W4). With irrigation until August 1 and September 15 (W2 and W1), summer seeded late season annual forage species produced 3.20 and 2.40 Mg/ha on average, respectively. Annual warm season grasses including sorghum-sudangrass, pearl millet, and foxtail millet had the greatest average yield (4.90 Mg/ha) among four groups of annual forages evaluated under W2. Seeding in mid-September or mid-October made little difference on all the winter species evaluated except annual ryegrass. Winter annual species produced 12.39 Mg/ha and seasonal deficit irrigation did not affect the yield level for all the species except annual ryegrass. In summary, annual forages have potential to augment the perennial forage shortage in the PNW with flexible planting dates and short growing seasons and matching species selection and/or cropping systems with available water will give annual forages more opportunity.

Key Words: Annual forages, seasonal deficit irrigation, small grains, cover crops

INTRODUCTION

Since the early 1900s, annual forages have been used as a supplement to deal with drought and perennial pasture shortage to avoid buying more expensive feed grain, thereby reducing cost (McCartney et al., 2009). Annuals offer an alternate forage option that shifts production to periods of feed shortage, like summer and autumn, and extend the grazing season beyond the normal perennial grazing season, thus grazing year-round can be achieved and profitability can be improved. Based on a study conducted in the Loess Plateau, a typical semi-arid region of China, annual forage-based systems had higher water use efficiency compared to alfalfa

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(Medicago sativa L.) (Jia et al., 2009). Compared to perennials, annual forages have more flexible planting dates (McCartney et al., 2008), enabling them to be used in variable cropping systems: spring seeding as a long season cover crop, late summer seeding after harvesting an annual crop or fall seeding as a winter crop.

With a Mediterranean-type climate, almost two-thirds of the precipitation in the PNW falls between October and March. From May to September, rainfall declines and is both sporadic and undependable. Therefore, irrigation during this period is necessary for most traditional forage production systems. Due to frequent drought and climate change, irrigation water is limited in PNW, especially for late season irrigation needs. Irrigation can be terminated at variable dates with different water rights that exist in certain states. For example, in Oregon, irrigation will be shut off earlier for junior users while senior users can keep irrigating without regard for the needs of other users when water is inadequate to satisfy the requirements of all water users. The research on forages response under variable irrigation cutoff seasons has been limited so far but one study conducted by Orloff et al. (2016) evaluated the tolerance of cool season perennial grasses under partial-season irrigation deficits in northern California and concluded that the average annual yield of perennial forages across three years was 11.3 Mg/ha for the full-season irrigation, 9.8 Mg/ha for mid-season cutoff (mid-July; before second cutting) and 6.9 Mg/ha for early-season cutoff (late May; before first harvest). Tall fescue had the highest yield under full-season irrigation while tall wheatgrass, intermediate wheatgrass and smooth bromegrass were the most drought tolerant when an early-season irrigation cutoff was applied.

Plants have developed different mechanisms to adapt to drought, namely, drought escape, drought avoidance, and drought tolerance (Basu et al., 2016). Drought escape occurs when plants complete their life cycle before the onset of drought. They can form rapid phenological development involving producing a minimal number of seeds before soil water scarcity happens. Most annual forages fall into this category. Inducing developmental plasticity is another way annuals use to escape drought. Plants reduce their growth when water is scarce while they can have indeterminate growth during wet seasons. Drought avoidance is defined as the ability of plants to maintain higher tissue water content when soil water content is reduced. This is achieved by minimizing water loss and maximizing water uptake. Drought avoidance is the main mechanism that sorghum-sudan and alfalfa adopt to resist drought. Sorghum-sudan and alfalfa have the ability of deep rooting and produces high proportion of roots in the subsoil, thus presenting greater drought resistance than other species when water stress occurred. Drought tolerance is when plants are able to endure low tissue water content through adaptive traits like adjusting osmotic potential to maintain cell turgor. Hasanuzzaman et al. (2019) pointed out that barley can maintain a low content of organic osmolytes (Na^+, K^+ and Cl^-) for osmotic adjustment to endure low tissue water content. Therefore, we want to test diverse annual forage species including small grains under seasonal deficit irrigation in eastern Oregon to explore forage production alternative systems under drought and limited irrigation water.

MATERIALS AND METHODS

The trials was conducted at the Oregon State University Eastern Oregon Agricultural Research Center (EOARC) at Union, OR, USA (45°12'23.6" N, 117°52'37.7" W, elev. 853 m) from 2017 to 2020. The climate in the region is Mediterranean-like characterized by wet and cool to cold winters and dry and warm to hot summers. The long-term (1994-2019) average annual precipitation in the region is 434 mm (17"). Approximately 70% of the annual precipitation occurs from October to March and 25% from April to June in low intensity (< 2-3 mm h-1) and low volume (10-20 mm per event), which renders July through September the driest period. A randomized complete block split-plot design with four replications was used for the trials. The whole plot was seasonal deficit irrigation treatments while the subplot was annual forages. Four seasonal deficit irrigation treatments were: full season irrigation from May 1 to September 15 (W1), late-season deficit irrigation from May 1 to August 1 (W2), mid-season and late-season deficit irrigation from May 1 to June 15 (W3), and no irrigation under dryland (W4). Irrigation was applied every Friday unless prohibited by other management practices through solid-set 12-m (40') handlines with R33LP rotator (Nelson Irrigation Corporation, Walla Walla, WA) setting 0.9-m (3') aboveground. Irrigation amount for each irrigation event was based on the actual accumulated evapotranspiration (ET) between irrigation events of alfalfa stand in Imbler, OR within 40 km from the study site (https://www.usbr.gov/pn/agrimet/agrimetmap/imboda.html). We applied 734, 437, 134, and 0 mm irrigation water yearly averaged over four growing seasons for W1, W2, W3, and W4 treatments, respectively. The rainfall and alfalfa ET in the same period were 85 and 826 mm, respectively. Twenty annual forage species were seeded in spring and summer and ten annual and biennial forage species were seeded in fall.

RESULTS

Yield generally decreased as water stress increased for spring seeded full season annual forages. In 2017, the forage yield averaged over all species was 7.8, 7.4, 4.3, and 2.5 Mg/ha under W1, W2, W3, and W4, respectively. In 2018, the forage yield was 8.9, 9.2, 7.2, and 5.5 Mg/ha under W1, W2, W3, and W4, respectively. However, no significant difference was observed between W1 and W2 treatments in both years. The detailed species differences are listed in Table 1. Under W1 and W2, annual warm season grasses besides teff yielded higher than the other forage groups. However, under W3 and W4, both annual warm and cool season grasses besides teff and annual ryegrass yielded higher than the other forage groups. For annual warm season grasses, teff yielded less under W1 than other species in this group and its yield decreased sharply under severe seasonal deficit irrigation. Proso millet is the earliest maturing species in annual warm season grasses. Its yield was less than most producing species in this group. Under adequate irrigation, pearl millet and foxtail millet could be a better choice while under severe irrigation water shortage, sorghum-sudangrass could be a better choice.

For the summer seeded annual forages after winter triticale trial, winter triticale forage yield was not affected by irrigation treatments and averaged 9.90 Mg/ha across two years. Summer seeded annual forage species right after winter triticale did not germinate under W3 and W4 treatments in 2017 and yielded low (1.6 Mg/ha for W3 and 0.6 Mg/ha for W4 averaged over species) in 2018. No differences in yield were found between W1 and W2 for any species. The detailed species differences are listed in Table 2. Both warm season grasses and brasscias yielded above 4.0 Mg/ha under W1 and W2. Annual cool season grasses and annual legumes yielded less due to poor germination and growth in the late summer seeding.

Seeding winter annual forages in mid-September yielded 1.50 Mg/ha more than seeding in mid-October, mainly due to annual ryegrass good germination in the early seeding. For other winter annual species, seeding in mid-September and mid-October made little difference on forage yield. Averaged over seven species, two seeding dates, four irrigation treatments, and two growing seasons, winter annual forages yielded 12.39 Mg/ha. Seasonal deficit irrigation only affected annual ryegrass yield (Figure 1). Winter wheat and triticale yielded higher than other species under most irrigation treatments and growing years. However, annual ryegrass yielded the highest (14.89 Mg/ha) in one growing season under full season irrigation.

Table 1. The average yield of annual forage species under variable irrigation treatments in a spring seeded cropping system across 2017 and 2018 in Union, OR.

Species	Irrigation treatment				MSD ($p \leq 0.05$) among irrigation treatments
	W1	W2	W3	W4	
	Mg/ha				
Pearl millet	14.0 a†	14.0 a	7.3 abc	5.6 abc	3.4
Foxtail millet	12.8 a	12.9 ab	6.4 abcd	6.1 abc	2.5
Radish	11.9 ab	13.0 ab	11.7 a	7.2 ab	6.3
Sorghum-sudangrass	11.0 ab	11.6 abc	8.2 abc	8.0 a	3.0
Oat	10.7 abc	11.6 abc	9.0 ab	6.0 abc	1.5
Proso millet	9.0 bcd	9.7 bcd	7.2 abcd	5.1 abcd	2.2
Brassica hybrid	8.6 bcde	8.2 cde	6.9 abcd	6.1 abc	1.5
Barley	8.6 bcde	8.5 bcde	8.9 ab	5.9 abc	1.8
Annual ryegrass	8.5 bcde	8.2 cde	5.7 abcd	1.9 cd	1.5
Rape	8.0 bcde	7.2 def	4.0 bcd	5.2 abcd	4.2
Wheat	7.8 bcde	7.4 def	7.4 abc	4.7 abcd	1.6
Soybean	7.8 bcde	7.9 cde	4.4 bcd	2.4 bcd	1.8
Kale	7.8 bcde	7.7 cdef	7.3 abcd	3.1 bcd	3.9
Triticale	7.2 cde	7.5 def	6.6 abcd	4.4 abcd	2.7
Field pea	6.8 de	6.1 def	5.1 bcd	2.2 cd	3.0
Turnip	6.4 de	4.6 ef	4.9 bcd	3.3 bcd	1.9
Chickling vetch	6.3 de	6.2 def	4.2 bcd	3.0 bcd	1.8
Teff	5.4 de	5.9 ef	2.0 d	1.6 cd	3.5
Cowpea	5.4 de	6.1 def	3.7 cd	3.7 bcd	1.1
Crimson clover	5.2 e	3.6 f	1.2 d	0.8 d	1.3

† Means followed by the same letter within a column are not significantly different at the 0.05 confidence level. MSD, minimum significant difference. W1, full season irrigation; W2, late season cutoff; W3, early season cutoff; W4, no irrigation.

Table 2. The average yield of annual forage species under variable irrigation treatments in a summer seeded cropping system across 2017 and 2018 in Union, OR.

Species	Irrigation treatment			
	W1	W2	W3	W4
	——————————Mg/ha——————————			
Sorghum-sudangrass	11.4 a† A‡	8.8 a A	7.4 a A	2.3 a B
Radish	7.6 ab A	7.3 abc A	2.1 bcd AB	0.4 ab B
Pearl millet	7.6 ab A	5.1 abcde AB	2.0 bcd BC	1.0 ab C
Brassica hybrid	6.9 ab A	5.3 abcde A	2.2 bc B	0.8 ab B
Foxtail millet	6.9 ab A	7.6 ab A	1.8 bcd A	NA‡
Proso millet	6.7 ab A	5.8 abcd A	1.2 bcd B	0.4 b B
Oat	6.7 ab A	5.2 abcde A	1.8 bcd B	0.2 b B
Rape	6.5 ab A	6.7 abcd A	1.6 bcd A	0.9 b A
Kale	4.4 b A	5.4 abcde A	1.4 bcd A	0.9 ab A
Turnip	4.4 b A	3.4 bcde A	0.4 cd B	0.6 ab B
Chickling vetch	4.1 b A	4.3 bcde A	1.7 bcd AB	0.9 ab B
Soybean	4.0 b A	4.1 bcde A	3.1 b AB	1.3 ab B
Crimson clover	3.9 b A	3.0 cde A	0.6 cd B	0 b B
Field pea	3.7 b AB	4.2 bcde A	2.4 bc AB	0.6 ab B
Teff	3.6 b A	2.5 cde B	0.5 cd C	0 b C
Cowpea	3.3 b A	2.9 cde A	2.1 bcd AB	0.8 ab B
Annual ryegrass	3.1 b A	1.6 de AB	0.2 d B	0.2 b B
Wheat	2.4 b A	1.6 de A	0.5 cd A	0.8 ab A
Triticale	1.8 b A	1.7 de A	0.6 cd B	0.2 b B
Barley	1.7 b A	1.0 e AB	0.3 d AB	0.1 b B

† Means followed by the same lowercase letter are not significantly different within each column at the 0.05 confidence level. ‡ Means followed by the same capital letter are not significantly different within each row at the 0.05 confidence level. NA, not applicable; MSD, minimum significant difference; W1, full season irrigation; W2, late season cutoff; W3, early season cutoff; W4, no irrigation.

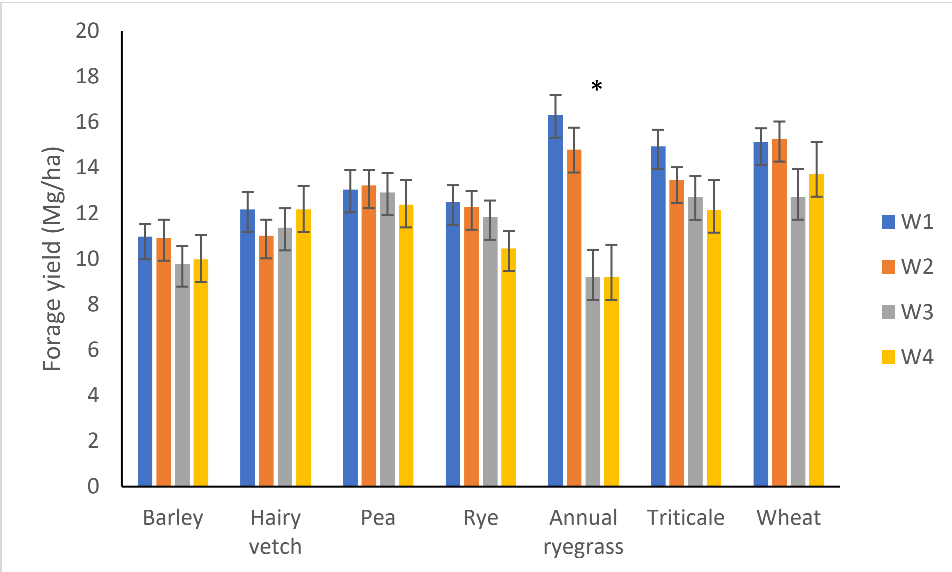

Figure 1. Forage yield of several winter annuals under four seasonal deficit irrigation treatments. * Means significantly different among irrigation treatments within species at the 0.05 confidence level. W1, full season irrigation; W2, late season cutoff; W3, early season cutoff; W4, no irrigation.

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