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Rocio Reyes Esteves
Kansas State University, rocior@ksu.edu

Keith Harmoney
Kansas State University, kharmone@ksu.edu

Freddie R. Lamm
Kansas State University

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Deficit Irrigation Strategies for Subsurface Drip-Irrigated Alfalfa

R. Reyes Esteves, K.R. Harmony, and F.R. Lamm

Summary

This subsurface drip-irrigated study was conducted from 2020 to 2023 at the Kansas State University Northwest Research-Extension Center near Colby, KS, to evaluate five deficit irrigation strategies for alfalfa. The alfalfa crop was irrigated for the full growing season and harvested only from 2020 to 2022. Irrigation strategies focused on optimizing alfalfa production with a highly efficient Subsurface Drip Irrigation (SDI) system. Treatments were irrigated in a similar fashion (100% of Evapotranspiration (ET) minus Rain) through the first cutting. Following the first harvest, treatments were 1) Irrigate to replace 85% ET minus Rain; 2) Irrigate to replace 50% ET minus Rain between Cutting 2 and 3, then 85% ET - Rain; 3) Irrigate to replace 50% ET minus Rain between harvest 2 and 4, then 85% ET - Rain; 4) Irrigate to replace 70% ET minus Rain between harvest 2 and 4, then 85% ET - Rain; and 5) Irrigate to replace 25% ET minus Rain between harvest 2 and 3, then 85% ET - Rain. Average alfalfa forage dry matter yields varied across treatments (9.14 vs. 9.60 ton/a), while irrigation requirements varied by 20% (17.38 vs. 22.62 inches). Overall, the best treatments appeared to be treatments 2, 3, and 5, obtaining both good, reasonable yields and greater water productivity.

Introduction

Alfalfa offers high-energy feed for dairy cows and other livestock. This crop is also recognized for its high water-use efficiency. Subsurface drip irrigation (SDI) is an ideal technology for meeting crops' water demands (Reyes-Esteves & Slack, 2019). Alfalfa is also a very drought-tolerant crop due to its deep and extensive root system and its ability to go dormant and wait for water (Lamm et al., 2022). However, irrigation requirements for alfalfa are significant because of alfalfa's long growing season, so irrigation must be utilized efficiently in the Northwest Kansas region, where water is pumped from the declining Ogallala aquifer (Lamm et al., 2012). The first harvest (usually in the first week of June in the Central Great Plains) is the greatest and can be 30% to 40% of the annual yield. Generally speaking, irrigation management strategies deliberately allow for water deficits for alfalfa during the summer-fall period when forage yields and water productivity are significantly reduced. Results (2005–2007) from a subsurface drip irrigation field study of alfalfa at the Kansas State University Northwest Research-Extension Center near Colby, KS, indicated that alfalfa yields were not significantly affected by in-season irrigation levels (70%, 85%, or 100% replacement of ET minus precipitation) in a three-year study. Crop water use was significantly greater with increased irrigation, and crop water productivity generally was reduced with more irrigation. The lack of significant variances in alfalfa yield as affected by the irrigation regime can be

credited to the ability of alfalfa to explore the deep soil profile for water, the dormant-season application to reduce root intrusion and rodent damage, the precipitation that helped buffer water stress, and the efficient SDI application method that helped minimize water losses such as evaporation, runoff, and deep percolation (Lamm et al., 2012).

Experimental Procedures

A study area was identified, and alfalfa (Pioneer 54VR70) was planted on May 6, 2019, at a seeding rate of approximately 18 lb/a. Due to an insufficient and irregular stand, a second planting was interseeded at the same seeding rate on July 1, 2019. Hand-set sprinkler lines applied small irrigation events over approximately two weeks to ensure good alfalfa establishment. No study was done during this establishment year. The field study continued in 2020, 2021, 2022, and until the first 2023 harvest (no irrigation in 2023). Soil water access tubes for neutron probe readings were installed in April 2020, and since then, soil water content has been measured throughout 2020, 2021, and 2022 alfalfa seasons in 12-inch increments to a depth of 8 ft. Soil water content was measured after the first harvest of 2023. The focus of this study was to examine different strategies to withhold irrigation for alfalfa on a deep silt loam soil in semi-arid NW Kansas to utilize the rainfall water fully. A complete randomized block design was used to evaluate the five irrigation treatments with four replications per treatment. The irrigation treatments are listed in Table 1.

Evapotranspiration minus rain represents alfalfa's evapotranspiration water use by subtracting rainwater received for a given period. The hypotheses are that some of the treatments will allow irrigation water savings compared to Treatment 1 without significant yield losses. Every year, there were five alfalfa harvests, each about four weeks apart, beginning in June and ending in late October. In this region, the fifth harvest is typically delayed until the first hard freeze to allow the alfalfa to store winter reserves. During each harvest, samples were collected directly above each dripline and at a perpendicular distance of 30 inches from the 5-ft-spaced driplines. Samples have also been forwarded to a commercial lab to determine nutritional quality parameters.

Results and Discussion

Growing conditions were satisfactory for alfalfa production in those three years of the full alfalfa growing season. Precipitation during the April through October growing period was 10.87, 13.27, and 11.5 inches for 2020, 2021, and 2022, respectively, and was drier than the normal long-term average annual rainfall of approximately 18.8 inches and average long-term precipitation of approximately 16 inches during April through October, the typical active growing period for alfalfa.

Average alfalfa forage yields were 9.39 tons/a during the 2020-2022 study but varied between years (Figure 2). Yield differences between the irrigated strategies were minor, with the 2022 season having the lowest yield in comparison with the two previous years. The explanation of this is due to a lower initial available soil-water condition θ ($5.58 \text{ cm}^3 \text{ cm}^{-3}$). Initial available soil-water conditions θ in the soil profile were $11.05 \text{ cm}^3 \text{ cm}^{-3}$ and $7.06 \text{ cm}^3 \text{ cm}^{-3}$ in 2020 and 2021, respectively. Treatment 2 had the greatest yield (9.60 tons/a), and Treatment 5 had the lowest yield (9.14 tons/a) on average. Crop water productivity was greatest for Treatment 3, followed by treatments 5 and 2 (Figure 3). Due to the small overall yield differences for all treatments, Treatments 2, 3, and 5 appear to be the best balance between yield and water productivity.

See Figure 1 below for a graphical comparison between the full growing seasons' 2020-2022 yield measurements. Yield differences between treatments are likely affected by initial soil water conditions and rainfall.

Table 2 shows the irrigation amounts, annual yields, total crop water use, and the water productivity. Irrigation requirements varied between years; the most significant water requirement was for 2020 (20.28 inches), followed by 2022 (20.08 inches) and 2021 (18.67 inches).

Soil-water modeling utilizing HYDRUS-2D, model calibration and validation, and the writing of manuscripts have occurred and continue at this time. The effects of some of the deficit irrigation strategies may be exhibited in stand loss. Yield response is tied to climate, soil type, and the initial soil water condition in the profile. Still, this study will be useful for the Great Plains region, where more dairy producers want high-quality alfalfa grown with high-efficiency irrigation systems.

Acknowledgments

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Table 1. Five irrigation treatments for alfalfa study

Treatment	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
1	Replace 100% ET-Rain	Replace 85% ET-Rain	Replace 85% ET-Rain	Replace 85% ET-Rain	Replace 85% ET-Rain
2	Replace 100% ET-Rain	Replace 50% ET-Rain	Replace 50% ET-Rain	Replace 85% ET-Rain	Replace 85% ET-Rain
3	Replace 100% ET-Rain	Replace 50% ET-Rain	Replace 50% ET-Rain	Replace 50% ET-Rain	Replace 85% ET-Rain
4	Replace 100% ET-Rain	Replace 70% ET-Rain	Replace 70% ET-Rain	Replace 70% ET-Rain	Replace 85% ET-Rain
5	Replace 100% ET-Rain	Replace 25% ET-Rain	Replace 25% ET-Rain	Replace 85% ET-Rain	Replace 85% ET-Rain

Table 2. 2020-2022 alfalfa irrigation amounts, annual yields, total crop water use, and water productivity

Irrigation treat- ment	Irrigation amount	Dry matter yield	Water use	Water productivity
	inches	ton/a	inches	ton/a-inch
2020 crop yield				
1	22.50	10.09	40.19	0.2511
2	20.40	10.05	38.83	0.2588
3	18.95	9.81	37.19	0.2638
4	21.00	9.66	39.07	0.2474
5	18.55	9.68	37.18	0.2604
Mean	20.28	9.86	38.49	0.2563
2021 crop yield				
1	21.55	9.70	40.60	0.2390
2	18.80	9.84	36.87	0.2668
3	16.95	9.51	34.25	0.2778
4	19.60	9.60	37.67	0.2550
5	16.45	9.36	34.09	0.2749
Mean	18.67	9.60	36.70	0.2627
2022 crop yield				
1	23.80	8.91	35.75	0.2493
2	19.91	8.91	33.04	0.2698
3	18.29	8.71	30.37	0.2871
4	21.24	8.62	33.56	0.2569
5	17.15	8.38	29.72	0.2822
Mean	20.08	8.71	32.49	0.2691
Mean 2020 to 2022				
1	22.62	9.56	38.84	0.2464
2	19.70	9.60	36.25	0.2651
3	18.06	9.35	33.93	0.2762
4	20.61	9.29	36.77	0.2531
5	17.38	9.14	33.66	0.2725
Mean	19.68	9.39	35.89	0.2627

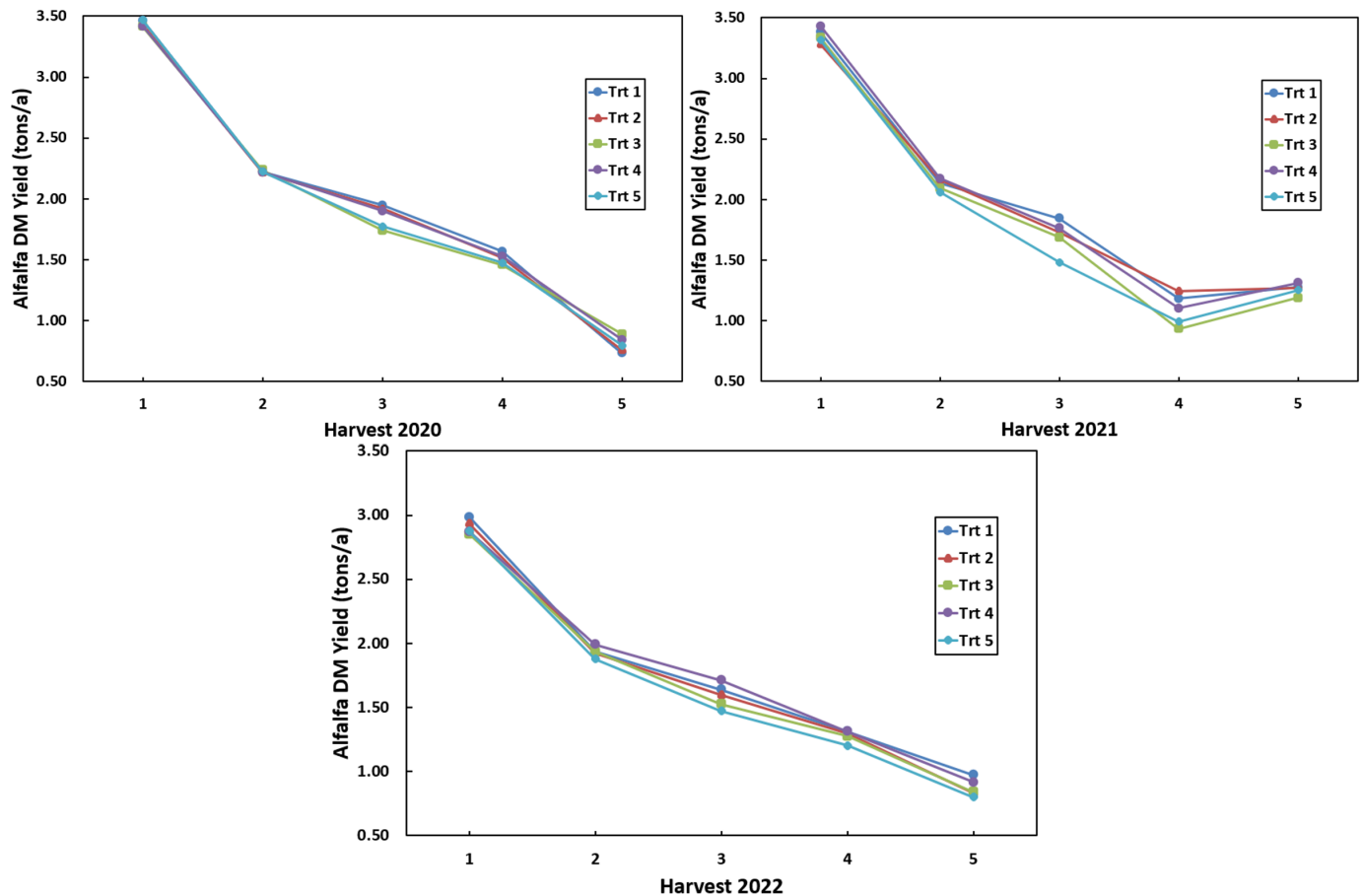


Figure 1. Comparison between 2020, 2021, and 2022 Dry Matter Yield (tons/a) in every harvest

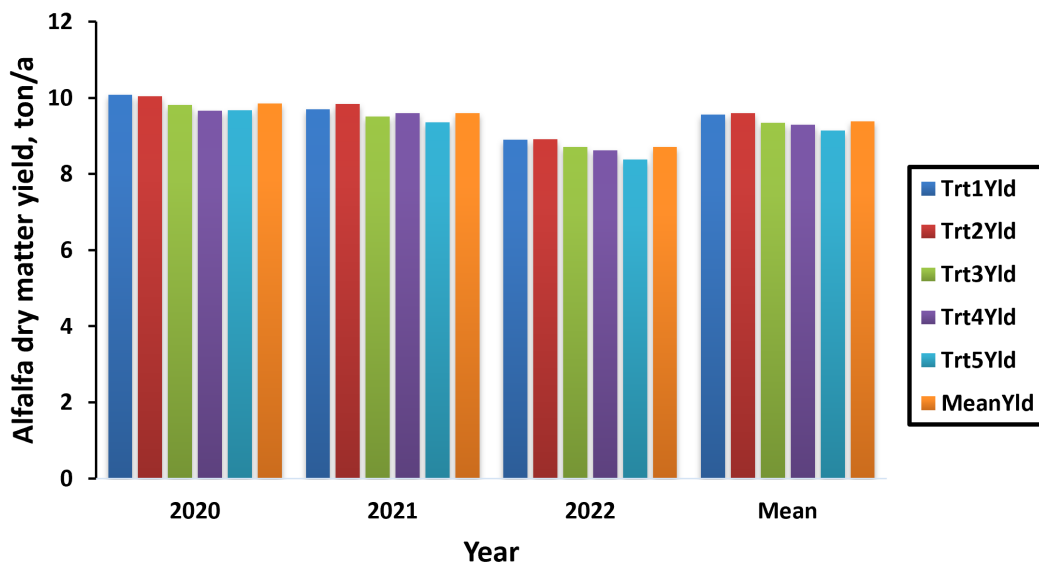


Figure 2. Alfalfa yields for the 2020-2022 seasons examining five different irrigation treatments

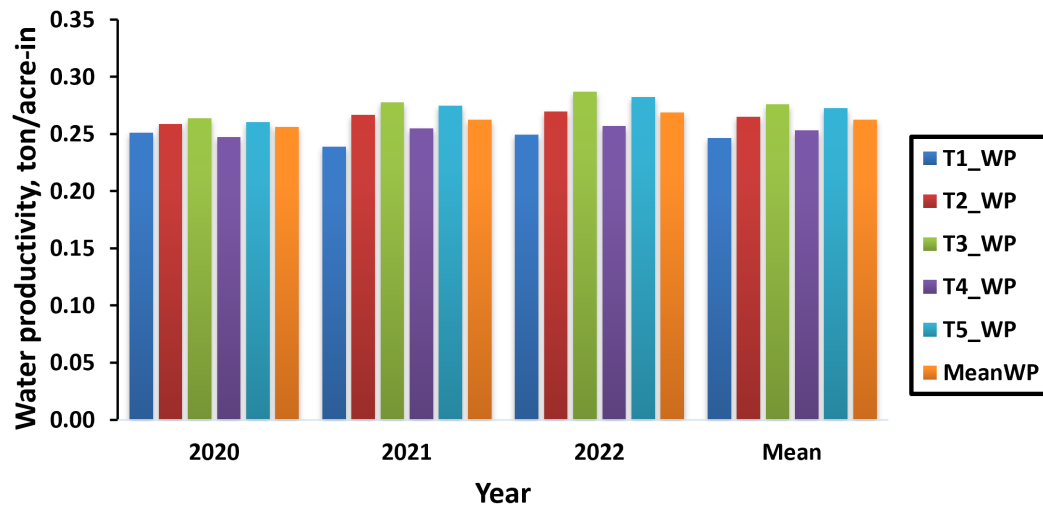


Figure 3. Alfalfa water productivity for the 2020-2022 seasons examining five different irrigation treatments