FERTILIZER AND IRRIGATION CONSIDERATIONS FOR LOW DESERT SUDANGRASS BIOMASS PRODUCTIVITY AND NUTRITIONAL QUALITY

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ABSTRACT

Sudangrass thrives well in dry and hot regions. Accordingly, the Imperial Valley is one of the major Sudangrass-producing regions of California. While insufficient nitrogen (N) is a common yield-limiting factor for most crops, most growers of the low desert (the Imperial Valley) apply excessive amounts of N to sudangrass to maximize crop yield. However, high levels of N in Sudangrass may result in high nitrate tissue concentration and become toxic to livestock. Nitrogen availability for crop uptake may also depend on the level of irrigation water that moves N to crop root zones for uptake or leaches out of the crop field. This research is being conducted to assess the effects of supplemental fertilization and irrigation levels on biomass production and sudangrass hay quality. The research was conducted at the University of California Agriculture and Natural Resources (UCANR) Desert Research and Extension Center (DREC) in Holtville, California. One year of preliminary research suggests that sudangrass biomass yield is unaffected by irrigation or fertilizer levels within the tested treatment ranges. However, tissue nitrate concentration from all fertilizer levels was higher than a desirable nitrate level in sudangrass hay for livestock feed. Our research is in progress, but when completed, it is expected to help growers make management decisions on the best fertilizer and irrigation management for optimum sudangrass biomass and quality hay production in the low desert.

Keywords: Sudangrass, sudangrass fertilizing, sudangrass irrigation, biomass, forage toxicity

INTRODUCTION

The low desert, particularly the Imperial Valley, is California's major Sudangrass (*Sorghum Sudanese*) producing region. Sudangrass is a C4 grass that thrives well in the low desert. Sudangrass acreage in the Imperial Valley has ranged from 42,000 (1990) to 49,164 (2022) and generated $63.1M in revenue (*Dessert, 2022*). The recommended fertilizer for quality sudangrass production in the low desert is about 100lb N / acre as pre-plant and 50-60lb N / acre applied to the crop after each cutting (Bachie, 2021), with seasonal nitrogen (N) requirement of 320 to 400 lbs of N per acre throughout its growing season. In anticipation of maximizing hay production, growers of the low desert commonly apply large quantities of N fertilizers, varying from 150 to over 800 lbs N/acre during its growing cycle. With extensive root systems, sudangrass can effectively uptake and store excessive nitrogen concentrations in its tissue (Hirel et al., 2011). However, excessive amounts of N in tissue concentrations of hay become toxic to livestock, becoming unacceptable for export and hence causing diminished market value. Excess fertilizer supply could also result in erosion or leaching beyond crop root zones, causing environmental

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pollution and severe damage to ecological zones and aquatic life. Environmental pollution from excess fertilizer is exacerbated when eroded or leached due to excess irrigation water that carries (drains) contaminated water into the Salton Sea. This research project assesses the effects of supplemental fertilization and irrigation water on Sudan grass biomass and hay quality, ultimately addressing the best fertilizer and irrigation water amounts needed for optimum hay yield and quality. The study is being conducted at the UCANR Desert Research and Extension Center (DREC) in Holtville, California. This manuscript presents the preliminary findings of our trials.

DESCRIPTION

Three fertilizer rates (subplots): (1) Lower rate of 50 lbs of fertilizer N / acre at each cutting, (2) Higher rate conventional N fertilizer rates of 80 lbs of fertilizer N / acre, and (3) N fertilizer at successive cutting based on crop N needs. Fertilizers were applied as common pre-plant and as treatments following each crop cutting. The irrigation water treatments (main plots) are (1) 80% ET, (2) 100% ET, and (3) 120% ET. The treatments were laid out in a split-plot design with 4 replications. Gated pipes were used to control each irrigation treatment. Plant establishment was performed using sprinkler irrigation for all treatment plots. The soil of the experimental field was predominantly silty loam, although there are variations in depth. The soil is generally low in organic matter, nitrogen, and phosphorus but high in Potassium. The Soil was slightly alkaline.

RESEARCH FINDINGS (RESULTS)

Moisture sensors indicated variations in irrigation water availability following irrigation treatments. The soil water content (SWC) or soil moisture is the amount of water in the soil and influences plant growth, soil temperature, and transport of chemicals and nutrients. Total soil-water potential is defined as the amount of work done per unit quantity of water to transport isothermally and reversibly a quantity of water from a pool of water to the soil water (Haj-Amor and Anlauf, 2023). The 80%ET irrigation had relatively less soil water availability (higher soil water potential) over the growing period and may pose some crop water stress. Better water availability was in the 100%ET and 120%ET irrigation levels (Figure 1).

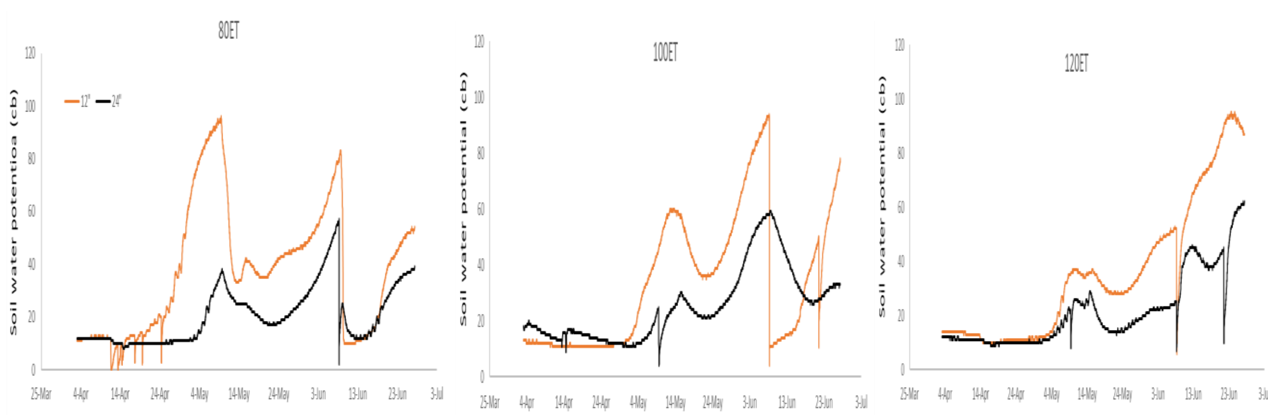

Figure 1: Soil water potential under the 3 irrigation schedules, 80%ET (left), 100%ET (middle), and 120%ET (right) at 12(red line) and 24 inches of soil depth (black line).

Sudangrass biomass production for the two subsequent cuttings was not significantly different (statistically) between fertilizer application rates (Pr > 0.8577) or irrigation treatments (Pr > 0.3411), although biomass yield at the third harvest was slightly higher for all fertilizer treatments under the 100ET and 120ET than the 80ET(Figure 2), suggesting that sudangrass responds to fertilizers at optimum (100ET) or higher (120ET) irrigation water than under slightly water deficient (80%ET) irrigation. However, the interaction between fertilizer and irrigation levels was insignificant (Pr > 0.6689). Mean biomass production over fertilizer levels or irrigation was not significantly different from each other (Figure 2). Since there are no biomass differences between fertilizer levels, there is no added NUE from supplementing higher fertilizer application beyond 50lb/ac after every cutting. Accordingly, our preliminary findings suggest that optimum sudangrass forage biomass production can be achieved at the lowest fertilizer supply (50lb/ac) after every cutting. Applying higher than 50 lbs of N per acre can be an economic loss since there is no additional biomass for the higher fertilizer levels.

Our finding also suggests that sudangrass can be transferred to 80%ET irrigation and produce hay biomass without significantly reducing yield. Since there was no considerable increase in sudangrass biomass with increased irrigation water level, the highest water use efficiency (WUE) is also achieved at slightly water-stressed conditions. In other words, higher WUE by sudangrass is achieved under slight irrigation water levels. Our preliminary finding needs to be confirmed with repeated evaluation of the treatments over subsequent years.

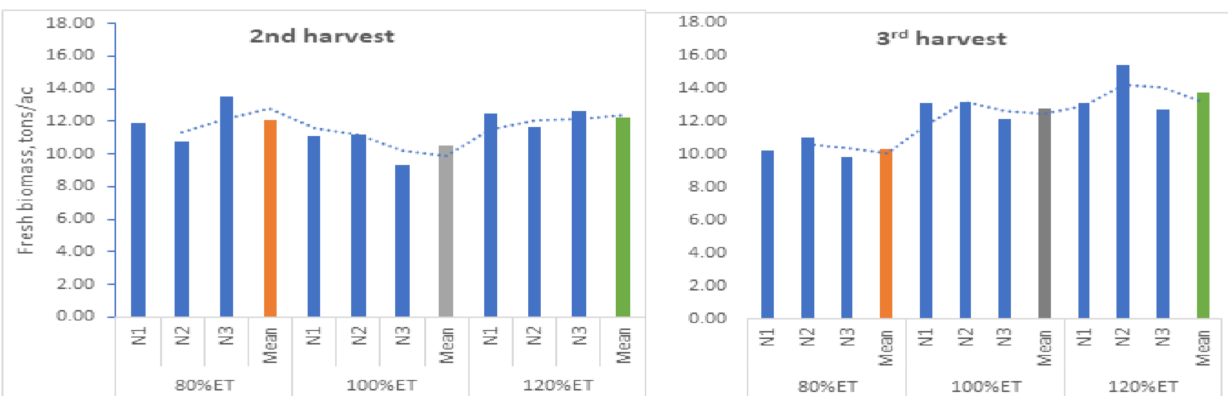

Figure 2: Fresh biomass, tons /ac of crops under 3 fertilizers (N1, N2, and N3) and 3 irrigation rates for the second cutting (left) and third cutting (right) with no significant biomass differences between fertilizer (Pr > 0.8577) or irrigation (*Pr > 0.3411*) treatments, or fertilizer * irrigation interactions (*Pr > 6689*).

Similarly, nutrient components of sudangrass did not vary largely (though no statistical analysis) among supplemental fertilizer levels or irrigation rates. The crop had consistent or linear relationships of crude protein, ADF, NDF, Ash, and TDN for all treatments with all nutrient components at desirable quantities. However, sudangrass produced under all fertilizer and irrigation treatments had elevated tissue nitrate-N (above 2000 ppm) and above possible acute toxicity levels for livestock (Figure 3). Scientists suggested that high fertilizer applications may promote luxury N consumption or uptake of nitrate by sudangrass tissue, causing more than normal tissue nitrate concentration and resulting in toxic nitrate and prussic acid levels. Drought conditions may also increase forage nitrate contents. Since all fertilizer levels produced hay that contained higher nitrate concentration than a desirable and healthy nitrate content of hay (Figure 4), it is suggested that no more than 50 lbs / N fertilizer per acre after every cutting is necessary to produce non-livestock toxic sudangrass hay. Forage tissue analysis did not find prussic acid, a potent livestock toxic compound in sudangrass hay, under any fertilizer level or irrigation water treatments.

Figure 3: Sudangrass Nitrate Composition

DISCUSSION AND CONCLUSION

Our findings suggest that an increased fertilizer supply of more than 50 lbs/ ac per cutting and higher irrigation levels beyond 80%ET do not necessarily increase forage biomass productivity in sudangrass. Many researchers showed evidence that there is little chance of yield increase at N applications greater than 70lbs / acre per growth period or 280lbs N / acre /year). Our findings show that the best nutrient use efficiency (NUE) and water use efficiency (WUE) based on biomass productivity were achieved at 50 lbs N per acre per cutting and 80%ET irrigation, respectively. Arregui and Quemada (2006) suggested that increasing nitrogen use efficiency (NUE) should be an agronomic, economic, and environmental priority for crop production. In many cases of crop yield analysis, nitrogen use efficiencies are typically less than 50%, indicating that 50% of applied N fertilizer is not used for increased crop yields. The portion of applied fertilizer N that plants do not take up may have been lost as surface run-off or leached below the root zone, contributing to environmental problems such as greenhouse gas emissions, eutrophication, and loss by leaching (Asghari and Cavagnaro, 2011) and may contaminate surface and groundwater. Nitrate (NO3-) and urea CO(NH2) are very soluble and can run off into the surface water or flow into the groundwater (Hirel, et al., 2011). Thus, using the optimum level of fertilizer that matches efficient crop nutrient use not only maximizes profitability or has economic benefits (Datta et al., 2018) but also helps farmers reduce the environmental impacts of food production.

While hay quality grades are usually determined primarily by chemical analyses (such as crude protein, acid detergent fiber, neutral detergent fiber, TDN, nitrate, and prussic acid contents of a forage crop are important components of toxicity measures to livestock. In this study, there was a higher risk of accumulating higher nitrate nitrogen in the tissues of sudangrass, even at the lowest fertilizer treatment. All our fertilizer treatments resulted in elevating sudangrass nitrate concentration to higher than the possible acute forage toxicity level. Growers usually apply higher fertilizer rates than the levels we used for this project and, hence, are prone to producing a greater risk forage that may result in higher possibilities of losing substantial revenue because of poor hay quality. Nitrates accumulate in the lower portion of the sudangrass stem. Experts described hay with nitrate-nitrogen concentrations less than 1,200 PPM as generally safe and 1,200 to 2,300 PPM as potentially safe, particularly with pregnant livestock. Concentrations of above 2,300 ppm is often considered toxic and unsafe to feed to livestock. Hence, farmers should make efforts to grow sudangrass with less nitrogen fertilizer supply and meet the demands of the export market, which calls for a product with less than 2000 ppm of tissue nitrate. Our finding did not confirm the presence of prussic acid, but only high nitrate tissue concentrations. The absence of prussic acid in our samples is probably due to the samples taken directly from the field, likely not undergoing a substantial enzymatic transformation of plant cell nitrate to prussic acid, which may occur during an extended curing time. The absence of prussic acid in our preliminary trials cannot be conclusive until the final evaluation of the project findings with subsequent trials. Our next sampling will consider extended curing for prussic acid analysis. Although tissue nitrate concentrations in sudangrass may have increased due to N fertilizer applications, fertilizers may not be the only cause of high tissue nitrate accumulation.

In summary, higher supplemental fertilizer levels and over-irrigations within our treatment levels did not affect biomass production and the nutritive quality of sudangrass. Our findings are in parity with researchers who showed that over 50% and up to 75% of the N applied to crop fields in most intensive agricultural production systems are not necessarily used by the plant but lost by leaching or erosion out of the crop root zones (Asghari and Catanzaro, 2011). Mineral N, especially nitrate (NO_3^-) and urea $CO(NH_2)_2$, are very soluble and can run off into the surface water or flow into the groundwater (Hirel et al., 2011, Prakash et al., 2005), causing contemporary challenges (Fixen and West, 2002). Among the many suggested management practices to mitigate environmental N contamination are enhanced-efficiency fertilizers (such as slow - and controlled-release), nitrification inhibitors, and urease inhibitor fertilizers (Cassman, et al., 2002). Wang and Alva (1996) observed large reductions in N leaching in sandy soils amended with slow-release fertilizer. Prakash et al. (2005) also observed reduced N leaching losses with the use of NBPT-coated urea as compared to urea alone. Leaching and erosion factors were not sampled during this phase of our trial but will be incorporated in the upcoming data collection. Understanding the release of plant-available nitrogen (N) from organic fertilizers is critically important to achieve high N use efficiency (NUE) and minimize environmental loss.

Some researchers suggested that tissue nitrate accumulation and prussic acid levels are normally highest in lush regrowth following heavy fertilization with nitrogen, crops stunted by moisture stress, or a higher irrigation rate that increases fertilizer distribution for crop uptake. Sorghum-family forages accumulate nitrates when there is plenty of soil nitrogen but insufficient water or sunlight that drives plant cell growth. When sorghum-family forages are cut for hay, prussic acid dissipates as the hay dries. Hence, hays are safe to feed once bales have reached the stable storage phase (Cassida, 2012). All sorghum family plants can also cause prussic acid or cyanide poisoning in livestock as they contain a secondary compound called dhurrin, cyanogenic glycoside which is enzymatically converted to toxic prussic acid (also called hydrocyanic acid) in wilting forage (Cassida, 2012). Sudangrass tissue nitrate levels in hay may also be reduced by swathing sudangrass at 6 to 8 inches height (nitrates accumulate in lower stem of sudangrass), swathing in the afternoon or early evening, allowing plants to metabolize stem nitrates to protein, avoiding additional fertilizer applications during drought years, diluting high nitrate feed with low nitrate feed, avoiding feeding any feed with > 1.5% NO_3 content to pregnant cows, split applications of fertilizer (McGuir, 2003), and adapting cattle to high nitrate feeds over time. Growers should monitor their sudangrass plant (testing the lower stem for nitrate during summer) and watch for water-stress conditions. Our findings are from a one-year trial. Therefore, further study is necessary to effectively determine the benefits of fertilization practices and stress sudangrass relative to the yield or revenue due to reduced irrigation water supply. When completed, the project is expected to develop information and tools on Sudan grass N and water use and develop best resource management practices. Best resource management for optimum, economical, and safe crop productivity will be disseminated to growers, farm managers, irrigators, farm workers, and stakeholders for implementation.

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