University of California
Agriculture and Natural Resources

ANR Publication 8522 | July 2015
http://anrcatalog.ucanr.edu
UC PEER REVIEWED

DROUGHT TIP

Drought Strategies for Alfalfa

Alfalfa is well adapted to drought conditions and deficit irrigation strategies. When faced with a drought, alfalfa growers have the choice of

- reducing crop acreage ("triage," or elimination of irrigation on some fields)
- partial irrigations over the entire season ("starvation diet")
- full irrigations for portions of the season followed by complete dry-down ("cold turkey" midseason cutoff)

STEVE ORLOFF, University of California Cooperative Extension County Director and Farm Advisor, Siskiyou County; DAN PUTNAM, Extension Forage Specialist, Department of Plant Sciences, University of California, Davis; KHALED BALI, University of California Cooperative Extension County Director and Irrigation/Water Management Advisor, Imperial County

Summary

Yields will be affected in all cases, but some forage production can be sustained. We recommend a combination of triage and midseason cutoff strategies. Marginal stands can be abandoned and not irrigated or removed in favor of better stands during water shortages, depending on the economics of various crops. Due to the higher yields early in the season, midseason cutoffs are likely to maximize yield and water use efficiency and result in cost savings by eliminating one or more cuttings compared with a starvation diet strategy. Survival of alfalfa through drought periods depends strongly on the soil and the environment, but we have observed that alfalfa generally survives short-term periods of no irrigation and can recover upon rewatering to yield normally in subsequent years.

Introduction

Drought and diminished water supplies for irrigation affect many western states and can be especially acute in California. Periodic droughts are expected to be recurring issues in California and other irrigated areas. Inadequate water for irrigation has plagued nearly every alfalfa production region in the state at some time. Drought conditions often limit water supplies below those needed for maximum yield, forcing growers to make difficult decisions as to which crops they should irrigate. Strategies are needed to minimize economic losses during drought and lessen any long-term impacts.

Unlike many other perennial crops (orchards in particular), alfalfa offers a high degree of flexibility during droughts due to its ability to successfully survive severe irrigation deficits and produce some yield—a valuable attribute when deciding how to allocate scarce water.

The drought tolerance of alfalfa, as well as the pros and cons of irrigation strategies to deal with insufficient water supplies, are examined below.

Alfalfa's Characteristics with Regards to Water and Drought

In drought years when irrigation water supplies are tight, alfalfa is often the first crop people consider to deficit-irrigate. It is produced widely from one end of the state to the other, and it has been the single largest user of agricultural water of any crop in in California, accounting for approximately 16 percent use of applied water (DWR 2013).

The statewide high water demand of alfalfa should not be construed to mean that alfalfa is a "water waster." In fact, the water use efficiency (WUE), or the amount of crop produced per unit of applied water, is quite favorable for alfalfa compared with many other crops (Loomis and Wallinga 1991; Asseng and Hsiao 2000). The large quantity of water applied to alfalfa on a statewide basis is due mostly to the extensive acreage of the crop (historically, alfalfa has been the number-one acreage crop in California, between 900,000 and 1,000,000 acres) and its long growing season (from early spring to late fall, and all-year production in southern areas) compared with many other crops.

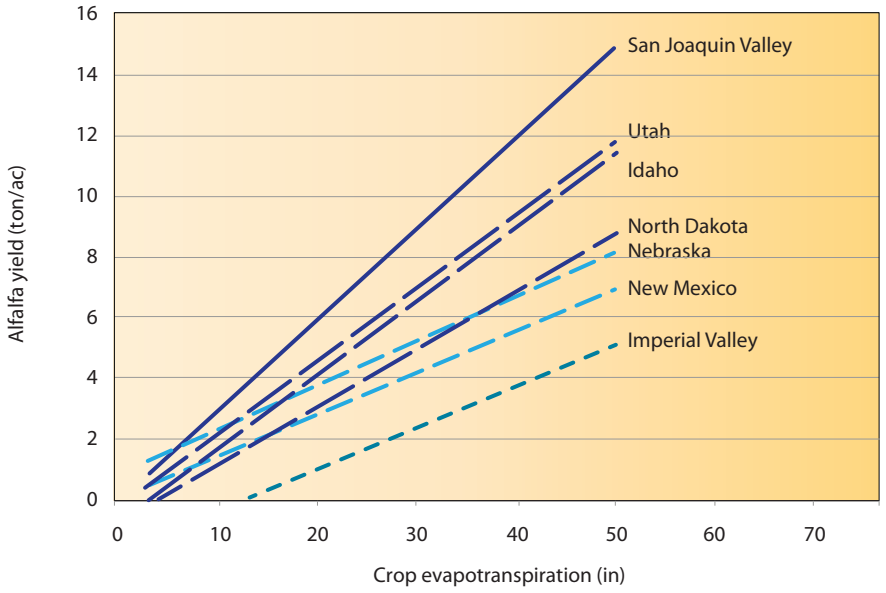

Figure 1. Relationship between alfalfa yield and evapotranspiration in selected western environments. *Source:* Hanson et al. 2009.

Relationship of Water to Yield

With alfalfa, unlike many other crops, nearly the entire aboveground biomass is harvested (a harvest index of nearly 100 percent), a factor that contributes to its high water-use efficiency. The accumulation of herbaceous dry matter in most crops during immature growth periods (before significant flowering or fruit or seed production) depends highly on continuous water availability because of high rates of evapotranspiration (ET). Since alfalfa forage is always harvested at an immature growth stage (before significant flowering or seed production), water is a key driving force for rapid vegetative growth. Therefore, alfalfa yield is directly related to ET and is reduced when less than the maximum potential ET is available to the crop (fig. 1).

Drought and Adaptation

Mature alfalfa is well adapted to drought conditions. The sensitivity of herbaceous growth to water deficits would suggest that alfalfa might be one of the worst crops to grow in a drought year. However, this is not the case. Compared with most other crops, alfalfa is actually relatively drought tolerant and has a high degree of flexibility with regards to irrigation needs. Alfalfa as a crop was developed more than 3,000 years ago in Central Asian regions that are characterized by long, hot summers and rainy winters (Lesins 1976), so it is well-adapted to periodic droughts. Additionally, since alfalfa is harvested from three to ten times in California, excellent growth and yield can be accomplished during one or two growth periods, while sacrificing yield during other harvest periods, a characteristic not generally available to other crops.

Because of its deep root system, alfalfa is able to access moisture low in the soil profile that is unavailable to most crops, especially other forage crops. Therefore, depending on the soil type

and environmental conditions, alfalfa growth can continue long after irrigation is terminated.

However, after soil moisture is depleted, the crop enters into what is commonly called a drought-induced dormancy (fig. 2). The plant limits its aboveground growth while storing energy reserves for rapid regrowth from buds when water becomes available (Sheaffer et al. 1988). This enables alfalfa to survive extended periods without irrigation.

This is not the case with many other crops. If irrigation water is withdrawn midseason from vegetable crops such as onions, tomatoes, potatoes, lettuce, etc., there may be nothing to harvest or the quality of the harvestable crop may be so adversely affected that it is unmarketable. Similarly, there may be no marketable crop to harvest with tree fruits or nuts, and the effect is likely to carry over into future years. Even the yields of many seed-producing agronomic crops such as wheat, corn, and sunflower can be highly subeconomic when irrigation water supplies are limited.

Figure 2. When exposed to severe soil moisture deficits, alfalfa can enter a drought-induced dormancy. Under most conditions, it will survive and resume growth when water becomes available again. *Photo:* R. Long.

Seedling alfalfa (alfalfa during its first 2 to 5 months of growth) is not as drought tolerant as is established alfalfa, so moisture stress at this time should be avoided. If soil moisture is inadequate during the establishment phase, excessive plant mortality and stand loss can occur. The alfalfa growth stage at which alfalfa can tolerate extended soil moisture deficits has not yet been well documented and depends on the production area and environmental conditions, including soil type, temperature severity, and the length of the drought period. However, anecdotal evidence suggests that alfalfa should have multiple stems and a well-established root system 3 to 4 feet deep before the onset of severe soil moisture stress.

Considering Resource Limitations and Economics of the Farm

The strategy that is best for dealing with a water shortage depends on the individual farming operation, economics, and crops produced, as well as the local site conditions. In particular, the source, cost, and availability of water over time are the most important considerations. There is no single best strategy for all situations.

The most economical approach for dealing with an irrigation water shortage may be dictated by water availability, the price of the water, and the value of hay in the farming operation. Key considerations are

- Is water available season-long but at a reduced delivery rate?
- Is water available only in the spring and then runs out?
- What is the severity of the irrigation water shortfall?
- Is there potential to use saved water on other more drought-sensitive crops or to transfer conserved water to other regions to meet existing water transfer agreements?
- Is there a more precise method of water application that enables lower application rates (e.g., sprinkler or drip)?
- Can recycled water (drainage, municipal wastewater, dairy water) be used to replace fresh water sources?
- What is the economic value of different crop options deserving water?

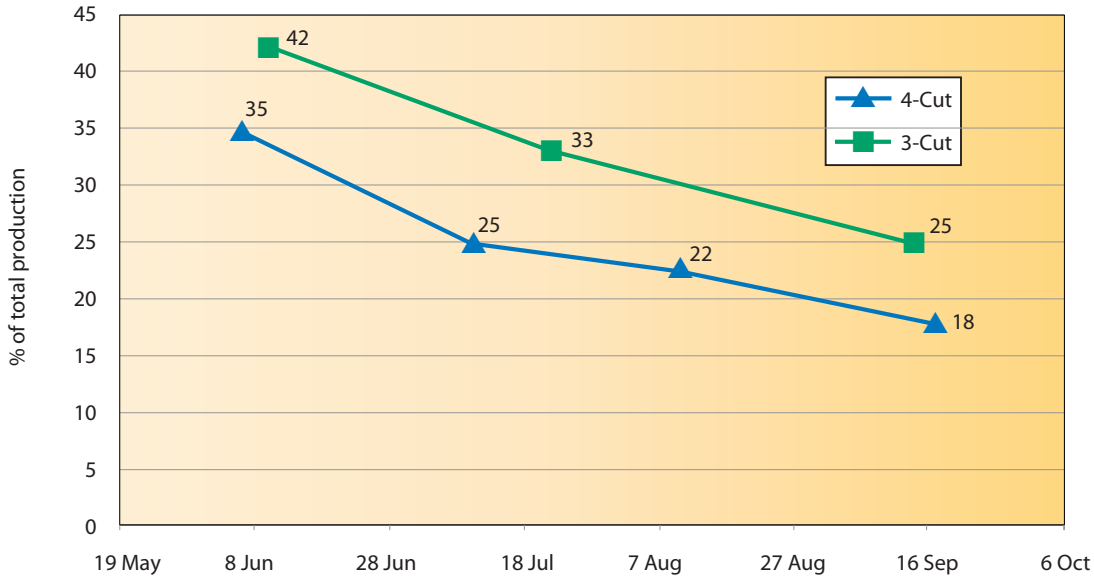

Figure 3. Percentage of total seasonal production that occurs at each cutting with 3- and 4-cut schedules in the intermountain area of California.

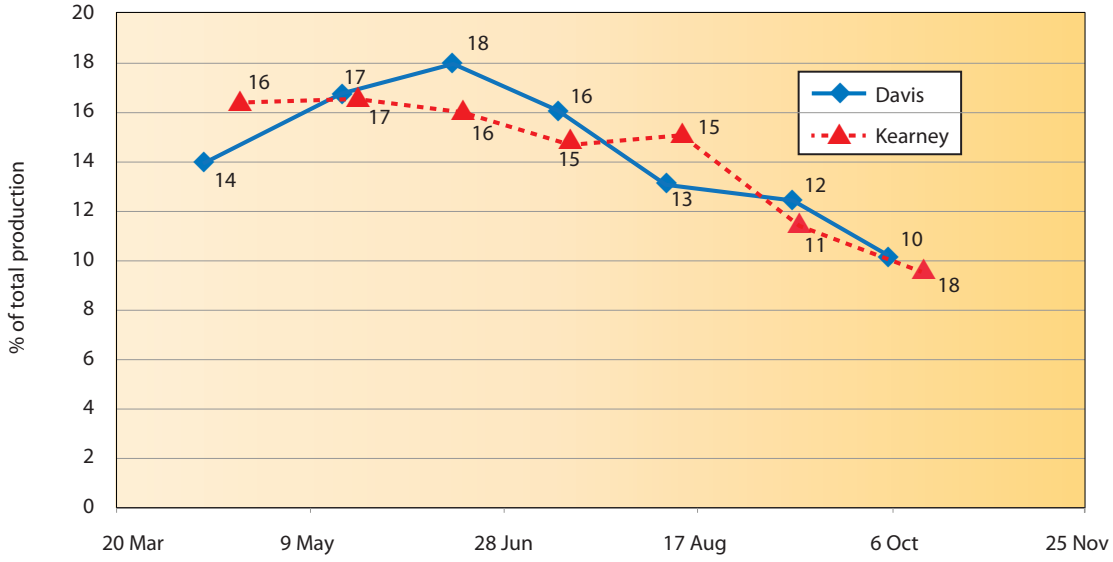

Figure 4. Percentage of total seasonal production that occurs at each cutting in Davis and at the Kearney Research and Extension Center in Fresno County.

- Is there sufficient groundwater available at a reasonable cost?
- What is the quality of water, and will salinity become an issue?

An analysis of the sources of water and economics will enable better decision-making on the optimal strategy for irrigating alfalfa.

Strategies for Deficit Irrigation of Alfalfa

The high flexibility of alfalfa to short-term water deficits is an important characteristic that should help growers and water managers cope with drought events. When faced with water quantities less than the potential seasonal ET needs of the crop, consider three basic strategies.

1. **Triage.** Reduce the irrigated acreage of alfalfa (cease irrigating some fields while fully irrigating others, or watering only some portions of fields).
2. **Starvation diet.** Deficit-irrigate the entire acreage during the crop season (less water per irrigation or fewer irrigations) so that less than the full potential ET is applied each growth period.
3. **Partial-season irrigation.** Fully irrigate all fields for the early cuttings, then cease irrigation partway through the season, when alfalfa ET demands are high. Resuming irrigation in the fall (summer deficit irrigation only) may be advised in some areas of the state, such as the Low Desert, to avoid stand loss.

In most cases, provided there is sufficient water available in early to midseason, a combination of triage and partial-season irrigation is the most appropriate. Partial-season irrigation may be the most economical choice for deficit irrigation of individual fields. Growers should ensure that fields have a full profile of water at the beginning of the season, calculate the water available, water fully to a midpoint in the season, then stop irrigation.

The reasons partial-season irrigation may be best are several-fold.

- Alfalfa exhibits superior yield early in the year. Figures 3, 4 and 5 show the percentages of alfalfa yields realized in the early cuts of the year. This is also a key period for high forage quality.
- Water may be more available or cheaper during early periods and less available or more expensive later on.

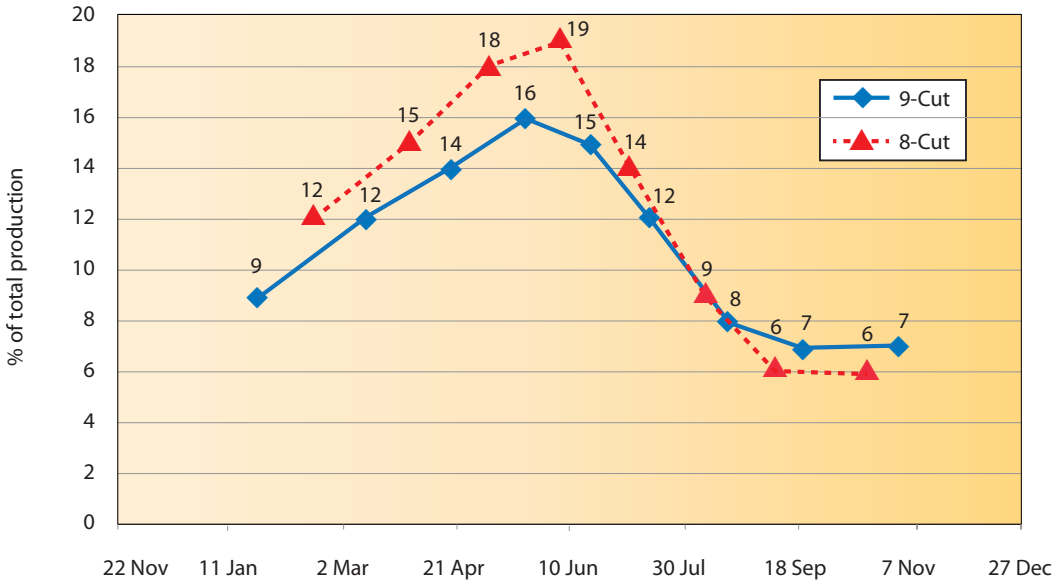

Figure 5. Percentage of total seasonal production that occurs at the Desert Research and Extension Center in Imperial County for 8 and 9 cutting schedules.

- A dry-down period of 2 to 3 months can save money on pest management requirements (for example, summer worm control) as well as harvesting costs.

Triage

Completely ceasing irrigation on some fields while fully irrigating other fields may make sense, especially if some fields are older, less productive, or are already near the end of their stand life. However, if there are no plans to remove an alfalfa stand, this approach is probably less viable unless the farm has other higher-value crops that are less drought tolerant or perennial tree crops that will suffer long-term yield loss if they do not receive full irrigation. There is a high likelihood of significant plant mortality in many alfalfa production areas if whole fields are left unirrigated for the entire growing season. However, this is likely to depend on soil type, residual moisture, and weather, since some fields have demonstrated the ability to survive the entire season without supplemental irrigation. The risk of plant mortality under drought conditions is the primary long-term risk of deficit irrigation, and it is discussed in more detail in the section "Effects on Stand Survival," below.

Starvation Diet

Deficit-irrigating all fields and applying less water than the alfalfa needs throughout the season is considered to be a less-viable option. This is because alfalfa yield increases with applied water in a linear fashion up to full-potential ET during each growth period (see fig. 1) (Carter and Scheaffer 1983; Schaffer et al. 1988; Hanson et al. 2007; Sanden et al. 2007). In other words, each additional unit of applied water produces the same increase in yield up to the point where full potential ET is applied. Applying less water during each growth period will result in a higher percentage of the water being lost to evaporation (especially with sprinkler irrigation) and low yields at each cut. Evaporation losses are true losses to the system and do not increase alfalfa yield; whereas water uptake and transpiration through the plant contributes to yield (Shewmaker and Neibling 2013). In addition, a lower yield over a larger acreage is less profitable than the same yield on fewer acres due to reduced harvest efficiency and perhaps increased costs associated with having to apply herbicides or insecticides to the entire acreage.

Partial-Season Irrigation

The best strategy for irrigating alfalfa when water supplies are insufficient is to fully irrigate the early-season cuttings and then cease irrigation partway through the season. This approach is often referred to as partial-season irrigation, early irrigation cutoff, or summer dry-down. This tactic has several advantages.

Effects on Yield

Spring and early-summer cuttings are typically the highest yielding. Depending on the production area, approximately two-thirds to three-fourths of the total annual production occurs by mid-July. Some alfalfa growth continues even after irrigation water is withdrawn, using stored soil moisture. Because yields are typically higher in spring and the ET rate then is less than in the summer, the applied water use efficiency (yield per unit of water) is greater in

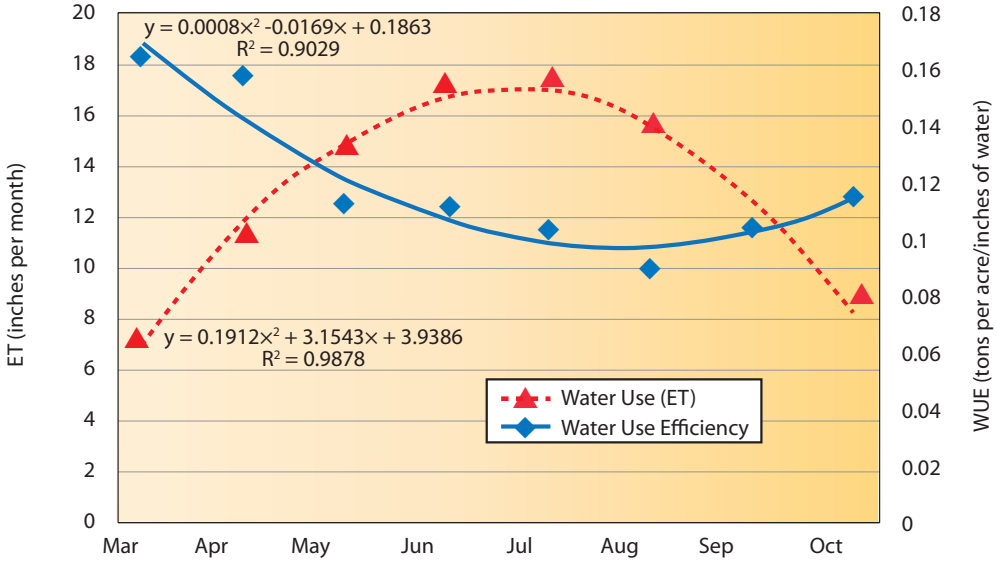

Figure 6. Changes in alfalfa water use (ET) and water use efficiency (WUE) over the growing season in the Sacramento Valley, CA.

spring than in midsummer or fall (fig. 6). In addition, spring growth can use stored soil moisture from winter and spring rains, further augmenting the spring yield of alfalfa per unit of applied irrigation water. For these reasons, if water supplies are low and the grower is forced to deficit-irrigate, returns should be higher when the crop is fully irrigated in the spring than when the water is applied later in the year. Yield during a deficit irrigation year is obviously reduced, depending on the duration of the deficit irrigation period and site conditions, but income is obtained from the higher-yielding and higher-quality first cuttings of the year.

Influence on Quality

Alfalfa forage quality (digestibility and protein content) is also higher in spring than in summer and therefore can yield a higher price. Quality can also be somewhat higher under deficit irrigation conditions due to a higher leaf-stem ratio (Carter and Sheaffer 1983).

Effects on Stand Survival

The long-term effect of drought on stand survival and the productivity of the field for subsequent years is the highest risk of deficit irrigation strategies for growers. An alfalfa grower may be willing to forgo irrigation for part of a season if forced to do so or if the water is needed for other crops or other uses, provided there would be no long-lasting deleterious effect on the alfalfa.

Alfalfa stand damage in response to deficit irrigation depends on soil characteristics and other factors. In the majority of cases we have observed, alfalfa fully recovers without any reduction in stand density and returns to full production after irrigation or rainfall replenishes soil moisture. However, this is not the case for all fields and all locations. Alfalfa survivability after drought strongly depends on the environment (including length of the growing season, soil type and depth, depth to the water table, and soil salinity), duration of the drought period, and perhaps even the alfalfa variety. The intermountain area has a shorter growing season and is cooler than other parts of California and is therefore least likely to see a lasting negative effect from deficit irrigation. In addition, dryland alfalfa is produced in the intermountain and coastal areas, an indication that alfalfa can survive extended periods without irrigation in that environment. However, stand loss has been observed even in the intermountain area when alfalfa was irrigated only part of the year during the seeding year and the subsequent year.

Stand loss has also been observed in commercial fields where irrigation water was withdrawn for most of the year. Alfalfa plants died in areas of the field with shallower soil where the alfalfa plants were weakened and likely had lower stored carbohydrate root reserves.

The ability of alfalfa crop to survive water deficits depends on

- length of drought
- soil conditions (water-holding capacity)
- variety
- rooting depth (young versus older stands)
- environmental effects (salinity, temperature)

In most cases, alfalfa will survive dry-down periods, but the stand can be damaged in some regions depending upon these factors.

Method of deficit irrigation and cutting schedule may affect stand loss

An advantage of full irrigations followed by a dry-down is its effect on root health. Fully irrigated fields with high yields and long cutting schedules early in the year are more likely to have better root growth than fields under continuous water stress throughout the year. A full water profile early will tend to result in deep rooting patterns, whereas continual water stress is likely to result in less root growth and less ability to sustain droughts. Longer cutting schedules are recommended during deficit irrigation practices in order to benefit root health.

Losses are greatest in Low Desert regions

The greatest injury from partial-season irrigation has occurred in the Low Desert of California, likely due to the length of the growing season, the extremely high temperatures, and lack of sufficient moisture in the root zone. In general, alfalfa grown on medium-textured soils has fared the best after a period of no irrigation, whereas stands have been lost on sandy soils or very heavy, cracking clay soils under extreme heat. This is believed to be due to the hydraulic conductivity of the soils or the speed at which water can travel through the pore spaces in soils to the plant roots. Many areas of the Low Desert have a relatively high water table or a perched water table that contributes to the water needs of the crop (Bali et al. 2001), which can help the alfalfa survive drought provided the hydraulic conductivity allows for sufficient upward movement of water. Additionally, the physical cracking of heavy clay soils results in root injury, loss of fine root hairs, and more rapid desiccation.

Figure 7. Five-year-old alfalfa variety trial after 2 years of drought conditions, 2013 and 2014 (Western Fresno County, CA). Alfalfa has a remarkable ability to survive long droughts due to its deep roots and ability to enter into a drought-induced dormancy. *Photo:* D. Putnam.

In sandy soils there is insufficient capillary movement of water upward from the water table to keep the plant sufficiently hydrated to be able to survive. In a heavy clay soil, the rate of upward movement is too slow. In medium-textured soil with a relatively shallow water table, alfalfa roots can use the water table to survive as long as the salinity of the root zone is less than 15 to 20 dS/m. Once root zone salinity is above this limit, alfalfa roots may not be able to extract water from the soil despite the relatively wet soil profile near the water table.

In most locations and under most conditions, alfalfa can tolerate long periods during the growing season without irrigation with no loss in plant density or yield reduction the following year. In over ten experiments conducted in the intermountain area and the Sacramento Valley, no loss in stand or yield occurred after a season of partial irrigation (Orloff and Hanson 2008; Orloff et al. 2005). An alfalfa variety trial (in progress) conducted in western Fresno County tolerated 2 years with no irrigation and recovered when irrigated in the fall of the second year (fig. 7).

Consider Mild Deficit Irrigation in a Dry Year

If the irrigation water shortfall is not too severe (e.g., 10 to 20 percent), a mild deficit irrigation strategy may be most appropriate. No irrigation application method is 100 percent uniform, and some portions of a field receive more water than others. To compensate for this nonuniformity and to ensure that nearly the entire field receives enough water to satisfy ET, it is ordinarily recommended that growers apply more than ET to make up for system inefficiencies. The amount needed to satisfy ET (net water application) is ordinarily divided by the application efficiency to arrive at the total amount of irrigation needed (gross water application). However, there are diminishing returns in terms of yield per unit of applied water when water is applied in excess of ET because some of the water is lost due to deep percolation or runoff. Ordinarily, this approach is accepted and is

the recommended practice. Growers are averse to seeing dry spots in a field, and their presence is generally considered to be a sign of improper irrigation management. However, in dry years when water is at a premium and supplies are insufficient, or when water is needed for other crops, it may be advisable not to apply enough water to fully compensate for nonuniformity and apply closer to the ET value. This will likely result in a few noticeable dry spots in the fields, but it could save water and improve overall water use efficiency. This approach is effective during water shortages; however, additional water should be applied in the future to compensate for the potential increase in salinity in the areas that experienced deficit irrigation.

References

Asseng, S., and T. Hsiao. 2000. Canopy CO_2 assimilation, energy balance, and water use efficiency of an alfalfa crop before and after cutting. Field Crops Research 67:191–206.

Bali, K. M., M. E. Grismer, and R. L. Snyder. 2001. Alfalfa water use pinpointed in saline, shallow water tables of Imperial Valley. California Agriculture 55(4): 38–43.

California Department of Water Resources (DWR). 2013. Statewide water balances, 1998-2010.

Carter, P. R., and C. C. Sheaffer. 1983. Alfalfa response to soil water deficits. I. Growth, forage quality, yield, water use, and water-use efficiency. Crop Science 23(4): 669–675.

Hanson, B., S. Orloff, K Bali, B. Sanden, and D. Putnam. 2009. Coping with low water years: What strategies can you use? Proceedings of the 39th Western Alfalfa & Forage Conference. UC Alfalfa Workgroup website, alfalfa.ucdavis.edu/+symposium/proceedings/2009/09-141.pdf.

Lesins, K. 1976. Alfalfa. In N. W. Simmonds, ed., Evolution of crop plants., New York: Longman Press. 165–168.

Loomis, R. S., and J. Wallinga. 1991. Alfalfa: Efficient or inefficient user of water. Proceedings of the 21st California Alfalfa Symposium. UC Alfalfa and Forages website, http://alfalfa.ucdavis.edu/+symposium/proceedings/1991/91-63.Pdf.

Orloff, S., and B. Hanson. 2008. Conserving water through deficit irrigation of alfalfa in the intermountain area of California. Forage and Grazinglands doi:10.1094/FG-2008-0421-01-RS. Copied from the website: http://www.plantmanagementnetwork.org/php/elements/sum2.aspx?id=6928

Orloff, S., D. Putnam, B. Hanson, and H. Carlson. 2005. Implications of deficit irrigation management on alfalfa. Proceedings of the 35th California Alfalfa & Forage Symposium. UC Alfalfa and Forages website, http://alfalfa.ucdavis.edu/+symposium/proceedings/2005/05-25.pdf.

Putnam, D. H. 2012. Strategies for the improvement of water-use efficient irrigated alfalfa systems. Proceedings of the 42rd California Alfalfa &Grains Symposium. UC Alfalfa and Forages website, http://alfalfa.ucdavis.edu/+symposium/proceedings/2012/12-04.pdf.

Sanden, B., D. Putnam, and B. Hanson. 2007. Forage production strategies with limited water supplies. Proceedings of the 37th California Alfalfa & Forage Symposium. UC Alfalfa and Forages website, http://alfalfa.ucdavis.edu/+symposium/proceedings/2007/07-20.pdf.

Sheaffer, C. C., C. B. Tanner, and M. B. Kirkham. 1988. Alfalfa water relations and irrigation. In A. A. Hanson, D. K. Barnes, and R. R. Hill Jr., eds., Alfalfa and alfalfa improvement. Madison, WI: American Society of Agronomy. 373–409.

Shewmaker, G., R. Allen, and H. Neibling. 2013. Alfalfa irrigation and drought. University of Idaho Alfalfa Irrigation and Drought Fact Sheet, http://www.extension.uidaho.edu/forage/Fact%20Sheets/Alfalfa%20Irrigation%20Facts%202013%20Final%5b1%5d.pdf.

This publication was written and produced by the University of California Agriculture and Natural Resources under agreement with the California Department of Water Resources (DWR). It is an update of Drought Tip 92-33, which was part of a publication series developed as a cooperative effort by the California DWR; University of California; USDA Drought Response Office and Soil Conservation Service; and the U.S. Department of the Interior Bureau of Reclamation, Mid-Pacific Region.

To order or obtain ANR publications and other products, visit the ANR Communication Services online catalog at http://anrcatalog.ucanr.edu/ or phone 1-800-994-8849. You can also place orders by mail or FAX, or request a printed catalog of our products from

University of California
Agriculture and Natural Resources
Communication Services
1301 S. 46th Street
Building 478 – MC 3580
Richmond, CA 94804-4600
Telephone 1-800-994-8849 • 510-665-2195 • FAX 510-665-3427
E-mail: anrcatalog@ucanr.edu

Publication 8522

ISBN-13: 978-1-60107-916-9

This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by ANR Associate Editor for Agronomy and Range Sciences Rachael Freeman Long.

pr-06/15-SB/CR