SUBSURFACE DRIP IRRIGATION, DEFICIT IRRIGATION STRATEGIES, AND IMPROVED VARIETIES TO IMPROVE ALFALFA WATER USE EFFICIENCY UNDER DROUGHT CONDITIONS

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Non Technical Summary
Alfalfa is the fourth highest economic value crop in the U.S. and 48% of the nation's alfalfa hay is produced under irrigated conditions. However, rapidly diminishing water resources threaten this productive sector. Deficit irrigation strategies are needed to adjust to periodic droughts while sustaining yield, and to improve alfalfa varieties and irrigation methods to sustain production under water deficits. Our first objective is to develop deficit irrigation strategies to conserve water under drought conditions. Secondly, we will quantify the interactions between variety and irrigation strategy and assist in developing new germplasm adapted to periodic water deficits. Thirdly, we will document the practicality and performance of Subsurface Drip Irrigation (SDI) in controlled studies, and on farmers' fields. Lastly, we will conduct extension activities and outreach to improve farmer expertise in water management, SDI, and specifically how to deal with periodic water limitations. Field trials are planned for El Centro and Davis, CA, and outreach activities are planned for Arizona, New Mexico, and California. This project meets AFRP and NIFA goals of improving yields through better water management, improving persistence under drought, and breeding to address abiotic stresses. The ability of alfalfa growers to cope with water stress is highly relevant to the need to sustain forage production in a water-limited future, especially given the vagaries in water availability and increased drought severity expected due to climate change.

Animal Health Component

Research Effort Categories

Basic
20%

Applied
80%

Developmental
80%

80%
**Classification**

Knowledge Area
202 - Plant Genetic Resources; 205 - Plant Management Systems; 203 - Plant Biological Efficiency and Abiotic Stresses Affecting Plants; 111 - Conservation and Efficient Use of Water;

Subject Of Investigation
1640 - Alfalfa; 0210 - Water resources;

Field Of Science
1070 - Ecology; 1060 - Biology (whole systems); 1081 - Breeding;

**Keywords**
drought
extension
forages
genetics
medicago sativa
profitability
water

**Goals / Objectives**
Alfalfa is often the largest water user in most western states, and may be most affected by water deficits caused by climate change, water transfers to cities, environmental demands for water, or periodic droughts. Additionally, there is a strong need to develop improved technologies of irrigation, specifically Subsurface Drip Irrigation (SDI), along with development of appropriate varieties for water deficits. The goal of this proposal is to ensure the sustainability of alfalfa production in the western U.S. through 1) characterizing deficit irrigation strategies, 2) developing the capability for subsurface drip irrigation, and 3) evaluating current, and developing future, alfalfa varieties and germplasm which are compatible with drought and deficit irrigation strategies, and in particular the use of SDI. Specific objectives are to: 1. Identify and evaluate the technical and economic viability of deficit irrigation management practices that can optimize alfalfa forage production while conserving water under limited supply. 2. To quantify alfalfa cultivar interactions with deficit irrigation practices in terms of yield response and persistence, and to develop new alfalfa germplasm with improved yield potential for deficit irrigated environments. 3. To document the performance, water savings, and yield response of alfalfa grown under Subsurface Drip Irrigation (SDI) on Farmers Fields and in controlled studies. 4. To conduct extension activities on water management, SDI, and to develop a `learning network for irrigation management and use of SDI in alfalfa.

**Project Methods**
This project includes controlled field research studies, a genetics component, on-farm demonstrations, and surveys of farmers, and a significant outreach component. Objective 1. Identify and optimize deficit irrigation management practices. In this experiment, we will determine the impact of four deficit irrigation management practices under sub-surface drip irrigation method on forage yield of a set of commercial or near-release alfalfa varieties of
potential to be grown in the Southwest (Arizona, California, New Mexico). The irrigation treatments include: 1. Full Season-long Irrigation (supplying 100% of crop needs) 2. 75% of Full irrigation demand (supplying 100% of ETc through full irrigation until 75% of the seasonal ETc demand is satisfied, then full dry-down) 3. 75% of Full irrigation demand (supplying 100% of ETc through full irrigation until 50% of the documented ETc demand is satisfied, then applying lower amounts in increments, to satisfy 75% of seasonal ET for the remainder of the season) 4. 50% of Full irrigation (supplying 100% of ETc through full irrigation until 50% of the seasonal ETc demand is satisfied, then ceasing irrigation entirely for remaining of season). Trials will be set up in a randomized complete block design with a split plot restriction. Yields at each cutting will be measured using standard field experimental plot harvesters, adjusted for dry matter, and calculated on a field basis, as per standard protocols for variety trials. Soil moisture sensors will be applied to a representative variety in each irrigation system to measure soil moisture depletion in the various irrigation treatments. Applied water will be measured, and compared with ET estimates. High quality SDI tape will be installed at a single depth (8-12", depending upon soil type) at each site, and pressurized using infrastructure developed by UC. Spacing will be 36" with a single line under each variety, and emitter spacing will be as per recommendation of the Irrigation Specialist and industry representatives (e.g. 14"). Tracking of irrigation scheduling will be done through ET-based irrigation scheduling utilizing measurement-based Kc and the data from the California Irrigation Management Information System (CIMIS), weather stations located at both El Centro and Davis. Objective 2: To quantify variety interactions with deficit irrigation practices, and to select superior lines. Researchers Ian Ray, Charles Brummer, and Dan Putnam will assemble a set of approximately 15 released or near-released varieties or breeding lines which are appropriate for each area, noting that it is likely not advisable to test the same exact varieties in both locations (although there will be some overlap to allow comparison between sites). The choice of varieties will be dictated by an ideotype or a group of plant characteristics (Fall Dormancy being one important one), but also evidence for drought tolerance, salinity tolerance, and yield. The possibility of discrete disease and insect resistance packages necessary for specific irrigation treatments may also exist. Each of these germplasms will be grown under each irrigation treatment to understand the interaction between drought stress of various types, and variety. NMSU will provide seed of four elite alfalfa germplasms (the NMSU Melton cultivar, NM14BM1008251, NM14GTAF07235, and NM14HQ08196281) previously developed by two to four cycles of phenotypic recurrent selection for biomass productivity under deficit flood irrigation management. Three additional high performing germplasms (NM14MeltonHS1+, NM14MaloneHS3+, and NM14HQLS2+) derived from combined DNA marker assisted selection and phenotypic selection for drought resilience will also be provided. Fall dormancy ratings of these NMSU populations range from 6 to 8. Additional materials developed by the University of California or the alfalfa seed industry, including check cultivars possessing fall dormancy ratings of 5 to 8 at Davis and 7 to 9 at El Centro, will be evaluated. We will also utilize existing NMSU MAS-derived germplasms to develop new drought resilient populations with widely differing fall dormancies for future evaluation. Selection of Superior lines and marker assisted selection for varieties to perform under drought-resistant conditions. Breeding lines from NMSU and UC will be planted at the most severe deficit treatments (treatment 4 above) in swards to promote selection for drought resistance and adaptation to SDI conditions. See further details in the proposal. Statistical methods to examine the variety X deficit irrigation interaction, in addition to both yield and persistence under water deficits will be employed. Forage yield and irrigation data will be
analyzed by ANOVA to detect significant treatment differences associated with: (1) average forage yield losses over all populations, and individual accessions, resulting from each deficit irrigation treatment, (2) applied water use efficiency (i.e. biomass produced per unit of water applied) over all populations and individual accessions, within each irrigation treatment, and (3) yield stability of each population over the four irrigation treatments. Stand loss is a major risk of deficit irrigation practices, and these lines will be evaluated over the years of the study (should further funding be forthcoming) for stand persistence under the various irrigation treatments.

Objective 3. To document the performance, water savings, and yield results of alfalfa grown under Subsurface Drip Irrigation (SDI) on farmers fields and in controlled studies. The documentation of the value of SDI will be done in two ways A) Estimation of differences in yield and water use in a controlled study at one location (El Centro), and B) Documentation of the results of farmer experiences on-farm with SDI on their farms, using a `case study approach.

A. Comparison of SDI with Check Flood. Controlled Study at UC Desert Research and Extension Center, El Centro. This involves establishment and data collection from field-level research studies on about 6 acres utilizing a Randomized Complete Block Design to compare check flood irrigation with two depths (12” and 18”) of Subsurface Drip Irrigation (SDI). B. Case Studies of SDI. Eight SDI sites in different soil types and in different regions of California and Arizona will be monitored to ascertain the adaptability (2 sites in the low desert region, Blythe and El Centro, two sites in the Fresno-county area, and 2 sites in the Sacramento Valley region, and 2 sites in Arizona). The objective of this component is to determine the real-life value and adaptability of this technology to farming conditions, including costs and benefits, yield impacts and labor impacts. Objective 4. To conduct extension activities on water management, SDI, and to develop a `learning network for irrigation management and use of SDI in alfalfa. Our outreach and extension approach will utilize several different strategies. First, we will plan on a workshop in El Centro and Arizona to review irrigation management principles with farmers and farm workers, featuring communication of our research results (Feb-March, 2015). This will include field tours of research plots and SDI installations on farmers fields. Secondly, we will establish an on-line `learning network for growers to learn about irrigation practices utilizing SDI. This will feature grower `case studies of the growers we have interviewed and worked with in the field. These case studies will be available on-line. The variety X irrigation results will also be posted online. This will include a `blog opportunity (see the alfalfa blog at: http://ucanr.edu/blogs/alfalfa/) to discuss various successes of irrigation practices, and how growers are coping with water issues on their farms.

Progress 09/01/15 to 08/31/16

Outputs
Target Audience: The primary target audience of this project are growers and farm workers, alfalfa industry, public and private companies, but also policy makers. To deliver science-based knowledge and practical information resulted by the project to this large community, we held five educational workshops in California (San Diego), Nevada (Reno), Arizona (Maricopa), and Mexico (Mexicali- SanFelip); and five field days in UC facilities in Davis and El Centre to review irrigation management principles and practices utilizing SDI system for alfalfa production with our target audience. The results of integrating SDI technology and deficit irrigation strategies were discussed with the audience too. At each of the workshops, a large group of audience nearly 150 people was attended, and at each of the field days a medium group between 70 and 80 people. Changes/Problems: This project has been generally on schedule. This project funds numerous fields studies, two graduate students
and a Project Scientist. We have exceeded already our planned interviews and case study reviews of farmers practices (22 instead of 8), while we plan to continue this effort. The controlled studies have been on schedule and are underway, with data collection for year one and two complete (year three remain). One of the El Centro studies was not successful in year 1, but has been more successful in year 2. The PIs and the participants in this study (Project Scientist, Grad Student, and field staff) remain committed to this project. What opportunities for training and professional development has the project provided? Over the first and second year of the project, we held five field days the entire state of California (totally 12 presentations by the UCD alfalfa SDI team); five workshops in California, Reno, and Mexico (10 presentations by the UCD alfalfa SDI team); published four journal and conference papers, developed an educational blog entitle "UCD Alfalfa Subsurface Drip Irrigation Learning Network", prepared many field tour and field demonstration for the national and international visitors; and participated in many growers and professional meetings. This project has funded the support for James Radawich, MS student at UC Davis, who is now in the final year of his MS project based upon this funding. One NMSU Master of Science degree candidate (Lovepreet Singh) and three undergraduate students (Steven Smalley, under-represented minority; Micah Funk; Nathanael Emerick) were partially supported to conduct DNA marker genotyping, selection, and phenotyping of field research plots in support of their projected degrees in Agronomy, Genetics, and Plant and Environmental Sciences. How have the results been disseminated to communities of interest? We disseminated the results of project to alfalfa growers and industry, private sectors, academia, and public agencies through field days, workshops, conference presentations and extension publications, peer reviewed journal papers, blogs, and interviews with media. What do you plan to do during the next reporting period to accomplish the goals? The plan to do during the next reporting period to accomplish the goals and objectives of the project is: 1. Monitoring and collocation data from control studies at Davis and El Centro now in the third year of production. Some are in the 2nd year and some in the 1st year of data collection. 2. UC has 3 studies at Davis, 2 studies at El Centro and 1 study at Kearney Ag. Center on Drip Irrigation in alfalfa. These are partly funded by other sources, but will be harvested (6-10 times) in 2017. 3. NMSU will collect a third year yield data to monitor the long-term impact of different irrigation treatments on alfalfa variety productivity and yield stability. 4. Second year forage yield data for DNA Marker Assisted Selection field studies will be collected. 5. M.S. thesis defense for Lovepreet Singh will be completed, and he will present results at the 2016 ASA-CSSA-SSSA annual meetings. 6. MS Thesis defense for James Radawich will be completed in 2017 and he will attend the ASA meetings to present data. 7. We will Visit, interview, and survey of more alfalfa farms in SDI (statewide and other western states including Arizona), including some of the same farms and refine the case studies. 8. Working on economic analysis of alfalfa in drip with rotation with other crops. 9. Developing materials for the blog of Alfalfa Subsurface Drip Irrigation Learning Network. See recent blog on SDI and deficits: http://ucanr.edu/blogs/Alfalfa/ 10. Collaboration with private and public companies and organization involved in subsurface drip irrigation technology (developing, installation, operation). This includes Netafim and Toro, both of whom have been closely involved with the project. 11. Outreach to lawmakers and water experts planned for March, 2017. 12. Disseminating project outcomes through workshops, growers meetings, field days and other extension meetings and presentations/publications 13. Developing new research and extension proposal/s on the topic 14. Manuscript/s elaboration and submission 15. Draft and final project reporting to be completed in 2017-18.

**Impacts**

What was accomplished under these goals? Case studies of SDI: Case studies continued in AZ and CA over this period, to follow up on observation in year one. Often opinions changed over the 2-year period, as some growers continued to be enthusiastic while others
abandoned their SDI alfalfa fields due to gopher damage and low hay prices. Yield increases and gopher (rodent) issues were found by 100% of the growers as the most important advantage and disadvantage of the SDI system, respectively. All the growers who participated in the study believe that rodent damage is the main issue of alfalfa farms in SDI; and system maintenance is the largest disadvantage. System costs and smaller wetting pattern are other disadvantages. It seems that filtration, clogging due to iron bacteria and calcium precipitation, and root intrusions are not recognized as noticeable issues with the alfalfa growers. Part of the reasons may be that water supplies were of fairly good quality and these systems are relatively new. All the growers applied sprinkler or flood irrigation to establish more effective germination, whereas no one selected wetting up of the top soil for alfalfa germination as a disadvantage. Increasing crop quality, less applied water, and easier overall farming were found to be the most significant advantages of the SDI after yield increases. More rapid re-growing following harvest and good net benefits, better fertilizer management, fewer weeds or easier to control weeds, and less labor cost are the other advantages assessed by the producers. None of the responders found less energy consumed, less disease/fungus damage or easier to control as a benefit of SDI systems. Some found reduced weed infestation. Despite the fact that the alfalfa fields selected were relatively gopher-free fields, there are still some gopher problems at the all farms. According to the growers observations, gopher damage is most prevalent over summer and the same year-round. The growers combat gopher populations with integrated approaches by trapping (100% of the growers), baiting, using Aluminum phosphide and protect-T as burrow fumigation, and owl Boxes which are recognized as the most common tools used for effective management of pocket gophers in alfalfa fields with SDI. Flood irrigation is also used sometimes as a gopher controlling practice. We found that one of the key advantages of SDI systems, when properly spaced, is to improve distribution uniformity (DU) over both time and space. Check flood systems, especially, may have built-in problems with uniformity due to greater times available for water infiltration at the top vs. middle vs. bottom of the field, especially with long runs, sandy soils, or highly variable soils. This typically not much of a problem in SDI systems, which can apply very close to the same application rate throughout the entire field (although SDI systems must be designed for high DU). Well-tuned sprinkler systems also have this advantage over surface systems, but some sprinkler systems may have distribution problems depending upon the influence of wind, poor nozzling, and the design of the system. The spatial distribution of water in across the profile is likely especially an advantage of SDI for alfalfa given its highly distributed broadcast planting pattern. Better water distribution the entire system in SDI is as a result of better maintaining soil moisture over time. We measured soil moisture tension by WATERMARKS sensors in our alfalfa SDI and sprinkler trials over the season 2015. Both treatments were fully irrigated ET-based, while at the SDI field soil moisture has been maintained at more desirable level. Controlled UC Davis studies: In our study at UC Davis which tests the interaction between varieties and irrigation, the total alfalfa ET under full irrigation were 39.9 and 38.9 inches for the season 2015 and 2016, respectively, estimated using the Eddy Covariance and the Surface Renewal systems. The SDI system enabled a good match between water application and crop ET for the full irrigation treatment. The irrigation deficit treatments were II (25% deficit irrigation late season), III (25% continual deficit irrigation starting mid-year), and IV (50% deficit irrigation) over the irrigation season 2015 were 29.5, 30.4, and 19.0 inch, respectively; and 30.2, 29.1, 19.4 inch for the irrigation season 2016, respectively. The total crop water requirements between planting to the last harvest of growing season 2015 was estimated to be 52 inches, and for 2016 was estimated 42 inch. The soil moisture sensors demonstrated that soil water balance at the early season of both years were very similar; and the irrigation season started with a soil full profile. A total dry matter yields (averaged over 15 alfalfa varieties) of 10.2 and 8.5ton ac-1 were observed at the fully irrigated treatment over the season 2015 and 2016, respectively. A 20% yield reduction for the first season and 13% for the season second
were obtained for the 50% deficit irrigation scenario, mostly from the last four cuttings of the growing season, which were affected by severe water limitations. The slight yield reductions of 25% deficit irrigation regimes were very similar, averagely 4%. The averaged WUE value over all the 15 varieties with full irrigation was 0.21 ton ac-1 in-1. The results indicate that alfalfa WUE can be significantly affected by the different deficit irrigation regimes. However, the variety interaction in years 1 and 2 appeared to be non-significant.

Controlled NMSU Studies: Objective 1. Forage yield of 24 elite alfalfa varieties were evaluated at Las Cruces, NM in 2015 and 2016 under control (C) management, flood irrigated every 14-days; deficit (D) management irrigated every 28-days; and early termination (ET) management, irrigated for only the first half of each growing season. Relative to the C treatment, average yield reductions of 44% and 39% were observed in the D and ET treatments, respectively. However, applied water use efficiency (i.e. yield per mm of water applied) was similar among the three treatments. A variety performance trial at Tucumcari, NM was planted in spring 2016 under sprinkler irrigation with municipal waste water, and forage yield data were collected. Objective 2A: Quantify alfalfa variety interactions with deficit irrigation practices. Nonsignificant variation among alfalfa varieties in the C and ET treatments in 2016 limited our ability to detect variety by irrigation treatment interactions in 2016 and across years. This interaction was significant in 2015, but primarily reflected variety performance differences based on three harvests for the ET treatment, versus six harvests for the C and D irrigation treatments. A significant variety by year interaction was only detected in the ET treatment, and indicated that termination of irrigation during the second half of the 2015 growing season impacted the relative performance of varieties in 2016 (post-stress) as compared to 2015 (pre-stress). Performance of varieties across irrigation treatments and years identified two commercial cultivars and four NMSU breeding lines that exhibited the best performance over all environments. Objective 2B: Develop new drought resilient alfalfa germplasm. Three field studies were planted in October 2015 to evaluate 30 newly developed elite dormant, semidormant, and nondormant alfalfa populations developed by DNA marker assisted selection (MAS). Heavy rain destroyed one field study (semidormant elite) and new seed was regenerated for those 12 populations during 2016. Forage yield data from the nondormant and dormant elite populations were collected over six harvests under deficit irrigation management in 2016. Five of eight elite nondormant MAS-derived populations exceeded the yield of the elite base population by 1 to 20%. All eight elite dormant MAS-derived populations outperformed the elite base population by 8 to 43%.

Publications

- Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Putnam, D., Montazar, A., Bali, K., Zaccaria, D. (2016). Alfalfa production progress under subsurface drip irrigation. 2016. Drought and water conservation workshop, Mexicali- SanFelip, Mexico, April 15.


**Progress** 09/01/14 to 08/31/15

**Outputs**

Target Audience: Our primary target audience of this project are growers and farm workers, alfalfa industry, and public and private companies who are interested in irrigation management and alfalfa production. To deliver science-based knowledge and practical information resulted by the project to this large community, we held two educational workshops in California (Long Beach) and Arizona (Maricopa Agricultural Center), and two field days in UC facilities in Davis and El Centro to review irrigation management principles and practices utilizing SDI system for alfalfa production with our target audience. At the Long Beach’s workshop, a large group of audience nearly 150 people was attended, and at each of the other ones a medium group between 50 and 60 people. Changes/Problems: The research team decided to learn from deficit irrigation treatments in UC Davis trial during the first year of project and to start deficit irrigation in El Centre trail along with Davis trail starting in the second year (15-16). Therefore, we studied only the interaction of alfalfa varieties at a full irrigation treatment in UC Davis trial during the 2014-15 season--this data turned out to be very interesting, showing about 80% of full yields with 50% of the normal water use, and 95% of full yields applying 75% of full water. This should be quite interesting to farmers and regulators. So far, interactions between varieties and irrigation practices are not apparent, but it is only the first year of the study. In terms of the observations on farms in California (case histories) - this is a moving target - some of the farmers who were initially very enthusiastic about SDI in alfalfa have run into larger issues with rodent management - and some of them have abandoned fields due to excessive gopher damage. Therefore, we are working closely with Netafim and Certified Crop Advisors to 'professionalize' the gopher management issue - to make sure that farmers are able to adequately control these pests, since they (in some cases) completely destroy the ability to use SDI in alfalfa. Thus, the company has funded gopher management labor to characterize the costs involved, and we have installed a gopher fence to keep rodents out of these fields, to see if that is successful at improving the probability of success of SDI. It has been our observation that for many farmers, though they have good intentions, do not adequately control rodents, and they likely could be successful with the technique if they monetize the
rodent management so that it is actually accomplished. This is one advantage of our approach, which is to work directly with farmers and with companies who have an interest in this technology so that we can respond to the needs of the farmers to help solve their ongoing problems. The up-and-down of the alfalfa market tends has had an effect on the economics of SDI and other costs of production. This has been a down economic year for alfalfa - but the system still remains a viable economic possibility if some of these practical issues can be resolved. The yield advantages hold large interest for farmers who are willing to take a chance to develop the methods on their ranches. What opportunities for training and professional development has the project provided? Over the first year of project, we held two field days at the UC facilities in Davis and El Centro, one technical workshop for the western alfalfa growers, three technical presentations at Arizona alfalfa and forage crops workshop, and collaborated with USA Netafim Company in holding three field days statewide. An educational blog entitle "Alfalfa Subsurface Drip Irrigation Learning Network" was developed to provide the practical information on the potential for buried drip irrigation in alfalfa, advantages, issues, solution. In addition to the results of our research and extension programs, a set of the latest publications and presentations on this topic were also provided in this blog. The address of blog is http://ucanr.edu/sites/adi/. How have the results been disseminated to communities of interest? We disseminated the results of project to alfalfa growers and industry, private sectors, academia, and public agencies through field days, conference presentations and publications, peer reviewed journal papers, blogs, and interview with media. We provide Spanish-language at larger venues (Alfalfa Symposium) to reach our large Latino population. What do you plan to do during the next reporting period to accomplish the goals? In general, this program is working well, with very active field experimentation and outreach activities in 2014-15. From summer 2015-2016 we will continue with these trials at the given locations, and collect a second full year in 2016. This is a perennial crop, so longer-term field experimentation is required (2-4 years) before solid conclusions and recommendations can be made. We are collecting some very useful data on important subjects, especially the importance of field practices by farmers and the ability to deficit irrigate alfalfa varieties, as was seen in year 1. Due to the increased importance of the California and western drought conditions, more emphasis on so-called deficit irrigation strategies will be coming, with new trials (spacing and deficits) being implemented. We plan to put more emphasis on soil moisture monitoring (funding was inadequate in year 1 for this purpose). We have established a new spacing trial to examine drip tape spacing combined with deficit irrigation strategies (partial season dry down, with irrigation applied at 40-60-80 and 100% of full irrigations). The plan to do during the next reporting period (2015-2016) to accomplish the goals and objectives of the project is: 1. Monitoring and collocation data from controlled studies at Davis and El Centro 2. Improved soil moisture monitoring in these trials to better characterize water use. 3. Visit, interview, and survey of more alfalfa farms in SDI (statewide and other western states including Arizona) 4. Working on economic analysis of alfalfa in dip with rotation 5. Developing case studies 6. Developing materials for the blog of Alfalfa Subsurface Drip Irrigation Learning Network 7. Collaboration with private and public companies and organization involved in subsurface drip irrigation technology (developing, installation, operation) 8. Disseminating project outcomes through workshops, growers meetings, field days and other extension meetings and presentations/publications 9. Developing new research and extension proposal/s on the topic 8. Manuscript/s elaboration and submission 9. Draft and final project reporting

**Impacts**

What was accomplished under these goals? During the first year of this project, we 1) Established 2 new field trials at UC Davis and UC Desert Research and Extension Center, 2) Conducted interviews with more than 18 farms to characterize practices that work (and those that dont) for SDI in alfalfa, and 3) Delivered educational and extension programs on
SDI in alfalfa over multiple locations and in multiple methods. The major goal of this project is to fully evaluate, test and develop Subsurface Drip Irrigation (SDI) as a potential option for improved water management in alfalfa production. Specific objectives of the project are:

- to identify and evaluate the technical and economic viability of deficit irrigation management practices that can optimize alfalfa forage production while conserving water under limited supply;
- to quantify cultivar interactions with deficit irrigation practices in terms of yield response and persistence, and to develop new alfalfa germplasm with improved yield potential for deficit irrigated environments;
- to document the performance, water savings, and yield response of alfalfa grown under Subsurface Drip Irrigation (SDI) on Farmers Fields and in controlled studies;
- to conduct extension activities on water management, SDI, and to develop a `learning network for irrigation management and use of SDI in alfalfa. Accomplished under these goals: 1- Case studies on SDI: Both from a theoretical basis, and from our case studies, water management in alfalfa under SDI has the potential to significantly improve yields in alfalfa. In our survey of growers, alfalfa growers estimate that yields have been improved an average of 2.6 tons/acre compared with their check flood systems. The maximum hay yield values we observed in the case studies from fields in Imperial Valley and Kings County with an average of 14.5 ton ac-1. Our predictions indicates that the alfalfa yield required to justify the cost of SDI - modeled with hay prices between approximately $160 to $280/ton and investment costs in the $2,000 range- typically can be from between 0.5 ton ac-1 to 1.5 ton ac-1 (utilizing a 15 year infrastructure lifespan and a 6 year drip lifetime). This does not include other differences in costs between the system, such as labor, maintenance, gophers, etc. The key mechanisms for improvement in crop performance are likely due to 1) better distribution uniformity over space and time for both water and nutrient applications, 2) maintenance of optimum soil moisture supply to more closely match alfalfa ET, and 3) prevention of wetting-drying cycles which may result in stress during sensitive growth periods as well as lack of oxygen to root systems. Stand survival was improved with SDI. In general, growers are satisfied with their SDI experiences. The cost of SDI installations in alfalfa fields is clearly been an important disadvantage of SDI systems in alfalfa, and has been the key limiting factor to adaptation of the technique historically. However, these costs can be justified if yields are improved and/or price of the product is sufficient to cover costs. During the past 20 years, the industry has seen dramatic increases in the value of alfalfa hay, which exceeded $200/ton for the first time in 2007, and has been most frequently priced from $180 to over $300/ton during the past 8 years. This has fundamentally changed the cost/value equation for growers for SDI and other improvements. In our review of grower investment costs, these have ranged from a low of $800-$1,000/acre to nearly $3000/acre, with typical costs ranging between $1600-$2200/acre. Alfalfa growers demonstrate that rodent damage is the major concern for alfalfa growers who are using SDI. Despite the fact that the alfalfa fields selected were relatively gopher-free fields, there is still some gopher problems at the all farms. According to the growers observations, gopher damage is most prevalent over summer and the same year-round. The growers combat gopher populations with integrated approaches by trapping (100% of the growers), baiting, using Aluminum phosphide and protect-T as burrow fumigation, and owl Box which are recognized as the most common tools used for effective management of pocket gophers in alfalfa fields with SDI. Flood irrigation is also used sometimes as a gopher controlling practice. The results indicate that the cost for repairing drip tapes and leak issues ranges from 10 to 100 USD ac-1 per year according to the location and rodent population (averagely $65 per year). Our observations have led us to believe that growers should try to retain other methods of water applications in their SDI installations, including the ability to flood irrigate, and/or sprinkle irrigate. Sprinkler irrigation is nearly universally recommended for stand establishment of alfalfa (as it is with flood systems), due to the need for small amounts applied to the surface and the need to prevent crusting. Drip lines buried 8-12" deep are not likely to supply this moisture uniformly to the soil surface for seedling growth. After establishment, an occasional flood
(or sprinkler) irrigation is likely to be beneficial on some soil types. Its purposes would be 1) to provide an initial full uniform soil water profile before significant growth to promote deep rooting patterns, 2) Improve crop growth between laterals, and 3) to control salinity. Key limitations of SDI methods include cost of installation, which must be justified by higher yields, maintenance and management of rodent damage and water quality limitations. System design and irrigation management require further optimization and research. Evolving recommendations for SDI in alfalfa include maintaining the ability to sprinkler irrigate for stand establishment, and an occasional flood irrigation (e.g. 2x per year) to assist in filling the soil profile, reducing gopher pressure, and to manage salt accumulation. Although one must be cautious about its limitations, the ability of SDI to achieve higher yields in practice should be viewed as an important strategy for increasing water use efficiency of irrigated alfalfa production systems. 2-Research Station Studies: The average hay yield of all the varieties over eight cuts in Davis for full irrigation treatment was 10.1 ton ac-1, which ranged from 8.1 ton ac-1 (variety of R510Hg812dt) to 12.0 ton ac-1 (variety of AFX149092). The overall water use efficiency of irrigation system for full irrigation treatment was about 0.21 ton ac-1 in-1. The results indicates that there is no significant hay yield decrease for the both 25% deficit irrigation scenarios (only about 5%), while for some varieties late-season dry down scenario works better and for some varieties mid-season deficit scenario. The WUE values increased to 0.28 and 0.33 ton ac-1 in-1 and yields were 95% and 80% of fully irrigated plots in the 75% and in the 50% irrigation treatments, respectively. High early-season productivity is a key reason for relatively low yield penalties at severe (50%) water cutbacks. Analysis of multiple-year variety trial results from our other variety trails in check flood irrigation entire the state support significantly higher WUE in early vs. late season production, due to higher yields in early cuttings combined with moderate water demand. The higher yields under SDI compared to conventional flood and sprinkler irrigation and lower water cost of hay production in deficit irrigation practices may enable to offset some adverse economic impacts of deficit irrigation. However, the seasonality of productivity of alfalfa which favors early, water-use efficient production enables deficit strategies to be developed for drought conditions under irrigation. Further work is needed to better understand the impacts of deficit irrigation on alfalfa yields and on plant stands over long-term period, as well as on forage quality, influence of varieties, and economic aspects related to production.

Publications


- Type: Conference Papers and Presentations Status: Published Year Published: 2015
  Citation: Putnam, D., Montazar, A., Ball, K., Radawich, J., Balwin, R., Zaccaria, D.
  (2015). Promises and pitfalls of adopting new technology: subsurface drip irrigation
  (SDI) in alfalfa. 2015 Western alfalfa & forage Symposium, Reno, Nevada, December
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  of Subsurface drip Irrigation, Western Alfalfa and Forage Symposium, Long Beach,
  CA, December 10-12.

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  Leinfelder-Miles, K. Klonsky, D. Stewart. Sample Costs to Establish and Produce
  Alfalfa Hay in the Sacramento and N. Delta using Sub-Surface Drip irrigation (SDI)
  IN UC Cooperative Extension. UC Davis Cost studies. (22 pages). See: