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FROM THE GROUND UP

Agronomy News

Crop Production with Limited Water

During years with low water availability, a number of management adjustments are needed to best utilize available water for crop production.

Recent near record snowfall in some areas of Colorado has greatly improved mountain snow pack conditions with NRCS SNOTEL sites reporting from 72 to 108 percent of average snow water equivalents, while other parts of the state have recently received much needed rain. These conditions in late March are certainly an improvement over our winter precipitation last year. However the other side of the water story is the record low reservoir levels, below average surface and subsoil moisture in many locations, and moderate to severe drought still lingering throughout Colorado. Adding to this water dilemma will be the curtailed pumping of many alluvial wells along the S. Platte River, sold or leased water rights to municipalities, and decreasing well capacities on the High Plains and San Luis Valley. So, Colorado producers are most likely going to face another year of growing crops with less water. The articles in this issue are intended to provide information on a variety of topics that affect crop production during a drought. Hopefully, more snow will continue to improve our snow pack this spring and our skies will bring timely rains this summer. If not, information on farming with less water should be useful, and remain so as drought is certain to hit our state again.

INSIDE THIS ISSUE

Colorado State University
Knowledge to Go Places

Understanding and Accounting for Crop Water Use

Water use is the driving force for plant growth and models using weather variables can estimate this use.

A familiar fact about western US irrigation is that agricultural crops account for 80 to 90 % of all water use. Two main factors account for this apparent anomaly. First, the amount of land area devoted to irrigated crops in this region is much higher than any other enterprise or activity requiring water. Second, actively growing plants use a lot of water. The purpose of this article is to first explain why plants use so much water and then to describe how we account for the amount of water crops are actually using.

The water requirement of irrigated crops varies widely depending on a number of factors. Crude studies conducted in the early 1900's using a diverse array of crops revealed that the amount of water used to produce a pound of dry matter varied from 300 to 1000 pounds. The plant tissue associated with each pound of plant dry matter contains only a little over four pounds of water. This amounts to less than 0.1 % of the total water requirement, assuming the best-case scenario of 300 pounds of water use per pound of dry matter. So where does the rest of the water go? The best answer is, "…into thin air." In other words, more than 99.9% of the total water requirement of an irrigated crop is consumed by evaporation (from water occurring on either soil or crop surfaces) and transpiration. Transpiration refers to the evaporation that occurs from water on internal plant surfaces. The combined water loss from the processes of evaporation and transpiration is called evapotranspiration or ET. The cumulative amount of ET for a crop over an entire growing season is roughly equivalent to that crop's seasonal water requirement.

For irrigated crops that reach complete ground cover for most of the growing season, most of the seasonal ET is from transpiration (Figure 1). Transpiration water losses from a crop that completely covers the ground are similar in magnitude to observed evaporation from the surface of an open water body of comparable area. Although transpiration losses are high, they are directly linked to crop growth and, therefore, yield. This is because the pathway for transpiration water losses in plants is the same one that allows for plant uptake of carbon dioxide, which is the raw material for photosynthesis. Both exchange processes occur through pores called stomates on the leaf surface. When soil water is not limiting, which is usually the case under irrigated conditions, stomates are fully open. When this condition exists, both transpiration and photosynthesis are occurring at maximum rates allowed by current conditions both internal and external to the plant. If soil water becomes limiting, stomates begin to close, limiting both transpiration water losses and photosynthesis.

A key ingredient of irrigation water management is the ability to estimate the magnitude of ET losses for any given set of conditions. The most important factors that have to be accounted for are: 1) the local weather conditions and 2) the cropping system for which estimates are needed (type of crop, planting date, etc.). Local weather conditions are important because ET is driven by weather

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FROM THE GROUND UP

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Understanding and Accounting for Crop Water Use (Continued)

factors that determine the drying power of the air. A branch of science known as agricultural meteorology has provided good insight into the variables that drive evaporation of water from soil and crop surfaces. We can accurately predict ET losses in a given area from measurements of four local weather variables; solar radiation, temperature, humidity, and wind. To be useful, these measurements have to be made under a standardized set of conditions. By convention, the variables are measured using instrumentation of specific design located within large areas devoted to stands of irrigated grass or alfalfa. The data from these measurements are then used in specially calibrated equations that accurately predict the daily rate of ET for these standardized conditions. The values obtained from this process provide standardized measurements of ET that are referred to as reference ET. The term, reference, refers to standardization of the entire process including type of crop used under the weather-monitoring instrumentation, the weather variables measured, and the calculations performed. When all these factors are accounted for, the ET of the reference crop, which is designated as reference ET, can be estimated with great accuracy. In most cases, reference ET values are generated on a daily basis. The specific calculations used are from a set of calculations known as combination equations. The common name of Penman is often used to refer to the equations used.

Reference ET (ETref) values apply to a specific reference crop grown (usually alfalfa or grass) under a set of local weather conditions. To be useful for other crops within the area in which the reference values were obtained, ETref values have to be adapted to fit these other crops. This is accomplished by adjusting the ETref values by use of a crop coefficient. Locally adapted crop coefficients are available for most kinds of crops that are likely to be grown in a given area. These coefficients provide daily adjustments to the ETref values generated each day throughout the growing season. In practice, the coefficient is used as a multiplier such that the actual daily ET for a given crop on a specific day of the season is the product of the ETref obtained for that date times the crop coefficient for that same date. The procedures described here are for use under conditions where soil moisture is not limiting. If moisture does become limiting, an additional adjustment factor, called the soil coefficient, can be applied in addition to the crop coefficient. A discussion of how to use the soil coefficient factor can be found in the fact sheet publication mentioned below.

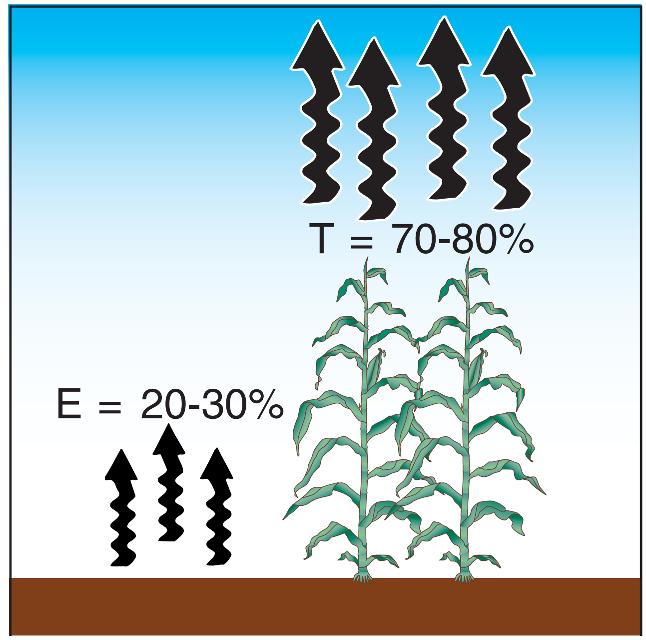

Figure 1. Transpiration accounts for the majority of ET.

Most states, including Colorado, have a network of weather stations that provide localized reference ET values. The network for Colorado is called the CoAgMet network, and is accessible through the web pages of the Colorado Climate Center (web address: www.coagmet.com). This network provides local reference ET values on a daily basis throughout the growing season for most of Colorado. Crop coefficients for specific crops can be obtained through local Cooperative Extension offices or from a CSU Cooperative Extension Fact Sheet titled, Irrigation Scheduling: The Water Balance Approach (Fact Sheet number 4.707), which can be accessed on line at through CSU's Cooperative Extension web pages: (http://www.ext.colostate.edu/PUBS/crops/04707.html).

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Seasonal Water Needs for Colorado Crops

Understanding net crop requirement is helpful in selecting crops under limited water.

CoAgMet weather station

Crop water use, consumptive use and evapotranspiration (ET), are terms that are used interchangeably to describe the water that is consumed by a crop.

Water requirements of crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the same weather conditions. Crops will transpire water at the maximum rate when the soil water is at field capacity. When soil moisture decreases crops have to exert higher forces (energy) to extract water from the soil. Usually, the transpiration rate doesn't decrease significantly until the soil moisture falls below 50% of field capacity.

Knowing seasonal crop water requirements is crucial for planning your crop planting mixture especially during drought years. For example, in the Greeley area, the seasonal water use of sugar beets is 30 in. while corn uses only 22 in. of water. That means, to fully irrigate sugar beets you need to apply 36% more water as compared to corn. These water requirements are net crop water use, the amount that the **crop will use** (not counting water losses such as deep percolation and runoff) in an average year, given soil moisture levels didn't fall below critical levels. Under ideal conditions this net water requirement is reduced by the effective rain, which for the Greeley area is 7 in. for the growing season. The rest of the crop water requirement must be supplied by irrigation. No irrigation system is 100% efficient, so to apply the net water requirement to the entire field the amount of water applied should be increased or multiplied by the efficiency (or inefficiency) of the irrigation system. Therefore, the difference in the gross irrigation water requirement between the two crops is also increased by the irrigation system efficiency. The net water requirements in the above example, after subtracting effective rain, are 23 in. for sugar beets and 15 in. for corn. If the irrigation system is 85% efficient, 27 in. (gross irrigation amount) must be applied to the sugar beets crop and 17.6 in. to the corn crop in order to store the net water requirement in the crops' root zone. Now the difference between the seasonal gross water requirements of sugar beets and corn is 53%. The difference in the gross irrigation requirement amounts increases as the irrigation system efficiency decreases.

Net Crop water Requirement

Net crop water requirement is estimated using models, which are based on weather variables. Seasonal crop water requirement can be estimated using these models by averaging weather conditions for many years, creating an average weather year. Tables 1 and 2 are a summary of net water requirements of different crops and effective precipitation for different locations in eastern Colorado and western Colorado respectively. To determine the net irrigation requirement subtract the effective rain (Av. Effective Precipitation from Tables 1 and 2) from the net crop water requirement. The gross irrigation water requirement is the net irrigation requirement divided by the irrigation system efficiency (fraction of one.) For example, corn for grain in Burlington requires 26 in. of water. Effective precipitation is 11.3 in. for the season, therefore the net irrigation requirement is 14.7 in. The gross irrigation requirement for a center pivot with 80% irrigation efficiency is 18.4 in. while for a furrow irrigation system with 55% irrigation efficiency the gross irrigation requirement is 26.8 in.

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Seasonal Water Needs for Colorado Crops (Continued)

Table 1. Estimated seasonal water requirement (Consumptive Use) in Eastern Colorado*

	Burlington	Greeley	Lamar	Longmont	Rocky Ford	Springfield	Sterling	Wray
	----------	----------	----------	----------	inches/season	----------	----------	----------
Alfalfa	35.6	31.6	39.1	30.9	37.7	37.4	35.2	35.2
Grass hay/pasture	31.1	26.6	34.2	26.2	32.9	32.6	28.0	30.9
Dry beans	19.2	18.4		15.8			18.7	18.7
Corn, grain	26.0		26.8	21.7	27.7	26.7		25.4
Corn, silage	22.8	21.7		19.7	24.3		20.3	
Corn, sweet		22.7			20.4			
Melons			15.8		15.1			
Potatoes		28.1						
Small vegetables		17.7	18.8		22.2			
Sorghum, grain	21.5	19.5	22.6			22.6		21.0
Spring grains			11.8	11.4	14.1	10.4	14.3	15.2
Sugarbeets	30.0	29.3	34.3	25.5	32.7	32.3	30.0	30.0
Wheat, winter	19.0	16.4	19.3	18.5		18.6	18.5	
Av. Precipitation	16.3	12.2	15.3	12.7	12.5	15.4	14.9	18.5
Av. Effective Precipitation	11.3	7.3	11.0	7.0	8.9	10.9	6.7	12.6

Table 2. Estimated seasonal water requirement (Consumptive Use) in Western Colorado*

	Cortez	Durango	Gunnison	Fruita	Meeker	Monte Vista	Norwood	Walden
	----------	----------	----------	----------	inches/season	----------	----------	----------
Alfalfa	29.4	27.5	18.0	36.2	23.5	23.6	23.6	12.9
Grass hay/pasture	24.7	23.2	17.1	31.4	21.4	19.8	20.4	13.6
Dry beans				19.9				
Corn, grain				25.1				
Corn, silage	18.0	16.1		22.7	17.3			
Orchards w/o cover crop								
Orchards w/ cover crop				25.7				
Potatoes						16.5		
Small vegetables				18.1		6.8		
Spring grains (barley, wheat)	14.8	16.7		19.6	15.5	12.7	11.4	
Sugarbeets				31.6				
Wheat, winter	20.1	18.8		18.9				
Av. Precipitation	12.9	18.6	11.0	8.3	17.1	7.2	15.7	9.6
Av. Effective Precipitation	5.1	8.3	3.8	4.0	6.2	3.9	6.1	3.0

*Colorado Irrigation Guide, 1988
Net irrigation requirement is the difference between crop consumptive use and effective precipitation

Considerations for Limited Irrigation

Producers can make some adjustments to compensate for reduced allocations or well capacity.

Limited irrigation results from restricted water supplies that cannot meet the full evapotranspiration demands of a crop. Reasons that producers may be limited on the amount of available water include limited capacity of the irrigation well or reduced surface water supplies.

When producers cannot apply water to meet crop ET, they must realize that with typical management practices, yields and returns will be reduced as compared to a fully irrigated crop. To properly manage the water for the greatest return, producers must have an understanding of how crops respond to water, how cropping mixes can be adjusted to better match water availability, and how changes in agronomic practices can influence water needs.

Yield vs ET and Irrigation

Crop yields increase linearly with the water that is used by the crop (Figure 2). Crops such as corn, respond with more yield for every inch of water that the crop consumes as compared to winter wheat or sunflower. However, high water use crops such as corn also require more water for plant development and maintenance before grain yield is produced. Corn requires approximately 10 inches of ET as compared to 4.5 and 7.5 inches of ET for wheat and sunflower before any yield is produced. These crops also require less ET for maximum production compared to corn.

Irrigation results in increased ET and thus grain yields by supplementing rainfall in periods when ET is greater than precipitation. However, not all of the irrigation water applied will result in ET because of losses resulting from irrigation system inefficiencies. As yield is maximized, more losses occur since the soil is close to field capacity and more prone to losses such as deep percolation and runoff (Figure 3). As shown in figure 3, a reduction in water applied from point A to point B can save water with little or no yield reduction.

Limited Water Management – Reduced Allocations

When producers are faced with reduced surface water supplies, they have three management options that can be utilized: 1) reduce irrigated acreage 2) reduce the amount of irrigation applied to the entire field or 3) include different crops that

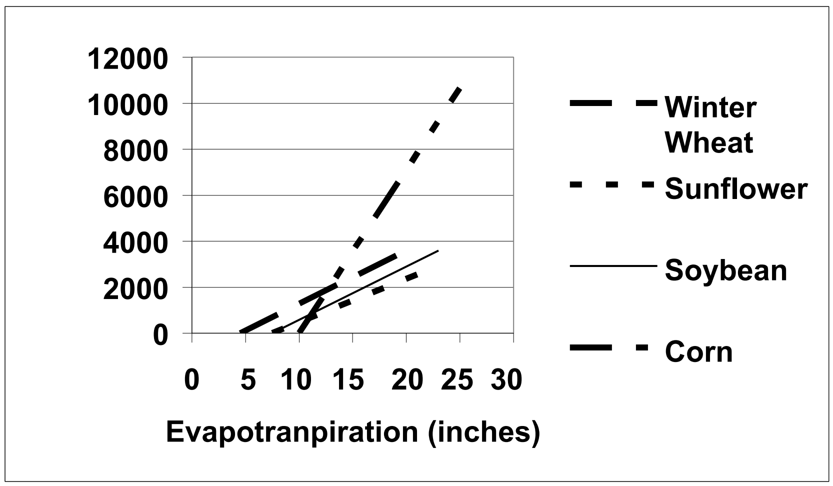

Figure 2. Yield vs ET relationship for several irrigated crops.

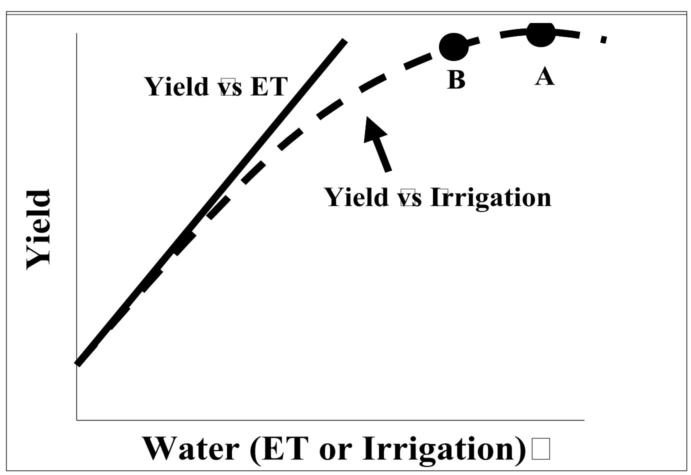

Figure 3. Generalized yield vs ET and yield vs irrigation production functions.

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Considerations for Limited Irrigation (Continued)

require less irrigation. Option one idles potentially productive ground while option two reduces yields for the entire irrigated acres unless precipitation is above normal. The third option involves using crops that require less water for maximum production and then using any "saved water" to fully irrigate reduced acreage of traditionally irrigated crops.

The following is an example of these three options under reduced allocations using ET from Longmont. A grower could produce all irrigated corn or irrigate some corn and a lower water use crop such as dry beans. Corn grown around Longmont (see Table 1 in previous article) requires 17.3 inches of net irrigation (assuming 85% efficiency) and dry bean requires 10.4 inches. If the allocation from the ditch limits a producer to 14 inches of water the producer could raise 80% of their acres to irrigated corn and the remainder in dry-land production or idle. He could also raise 100% of his acres to corn and apply only 80% of the irrigation required for maximum production. The final option would be that he could raise 50% of his acres to dry bean and 50% of his acres to corn and maintain maximum production on all of his acres.

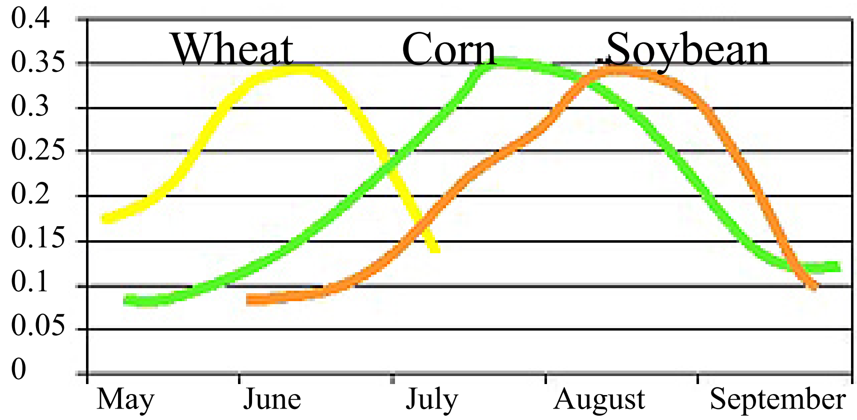

Figure 4. Example of daily ET during the growing season.

Limited Water Management – Low Capacity Systems

When managing for maximum production, irrigation systems must have minimum capacities to meet crop water requirements during peak water use periods (see fact sheet 4.704) referenced on page 15. If irrigation system capacities are below what is normally required, reduced yields are expected with normal precipitation. Management strategies to compensate for low capacity include pre-irrigation and beginning irrigation events at higher soil moisture contents. These strategies may maintain yields in above normal precipitation years but, are less effective in below normal precipitation years. One management strategy to alleviate this problem is splitting fields under one irrigation systems into 2 or more crops that have different peak water needs.

Fields split into different crops help to spread the irrigation season over a greater time period, but on fewer acres irrigated at any one time, as compared to a single crop. Crops such as corn, soybean and wheat have different timings for peak water use (Figure 4). With low capacity wells, planting multiple crops on smaller acreages allows for water to be applied at amounts and times when the crop needs the water. The advantage of irrigating fewer acres at any one point in time is that peak ET demand of that crop can be better met with the lower capacity. A more definited description of this concept is available in the Neb Guide, "Irrigating for Maximum Economic Return with Limited Water" referenced on page 15.

Another option is to plant the entire pivot or field to a single crop. Irrigation management with low capacity systems requires that a producer maintain soil moisture at or near field capacity early in the growing season when the system capacity exceeds ET. When the ET for the crop is greater than the capacity of the system, plants will use stored soil moisture to maintain ET. This strategy intends to maintain soil moisture for the crop when they reach the reproductive growth stage, which is also the peak water demand which the system cannot keep up. However, if precipitation is less than anticipated, soil moisture, during peak water demand, may fall below critical levels and yields will probably be reduced.

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Limited and Full Irrigation Comparison for Corn and Grain Sorghum

Southeast Colorado research shows limited irrigation more profitable as pumping costs increase.

The importance of limited irrigation (supplemental irrigation) has traditionally been associated with very low capacity irrigation wells. The current high fuel prices and associated pumping costs places new emphasis on limited irrigation as a replacement for full irrigation. We define limited irrigation on corn and grain sorghum as applying one in-season furrow irrigation of less than 9 A-in./A or a similar amount of water applied with a sprinkler. Applying less than 9 A-in./A as an in-season irrigation assumes that the soil water profile is full from sufficient winter moisture, or, if winter moisture is lacking, the soil water profile is filled by pre-irrigation.

Limited irrigation becomes a more profitable choice as fuel costs increase. Our research (http://www.colostate.edu/depts/prc/rc_pl_rp_pubs.html) suggests that the decision point for conversion from full irrigation to limited irrigation with our current costs, and the loan rate ($1.89/Bu) as the expected grain price, is $3.25/A-in. pumping cost for corn and $3.50/A-in. pumping cost for grain sorghum (Fig. 5). With a commodity price of $2.29/Bu for corn and grain sorghum, the decision point for conversion from full to limited irrigation increases to $5/A-in. pumping cost for both corn and grain sorghum.

An economic comparison between corn and grain sorghum under full and limited irrigation is dependent on commodity price. The current loan rate for corn and grain sorghum is equal ($1.89/Bu). Using the same commodity price for corn and grain sorghum provides grain sorghum with higher net income than corn under both limited and full irrigation. However, when corn and grain sorghum commodity prices are above the loan rate, corn frequently has a $0.30/Bu price advantage compared to grain sorghum in the local market. Corn priced $0.30/Bu higher than grain sorghum provides higher net income than grain sorghum under both full and limited irrigation.

Decreases in commodity prices give limited irrigation the income advantage over full irrigation. If the current loan rate becomes the price growers receive for their corn and grain sorghum crops next season and irrigation costs remain high, limited irrigation will continue to be more profitable than full irrigation for smaller capacity wells.

The current high cost of fuel makes pumping cost the most responsive variable driving conversion from full to limited irrigation. Nonetheless, inputs such as fertilizer and seed, which differ between full and limited irrigation regimes, favor limited irrigation when these input costs increase.

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Net Income and Pumping Cost for Limited and Full Irrigation Corn and Grain Sorghum

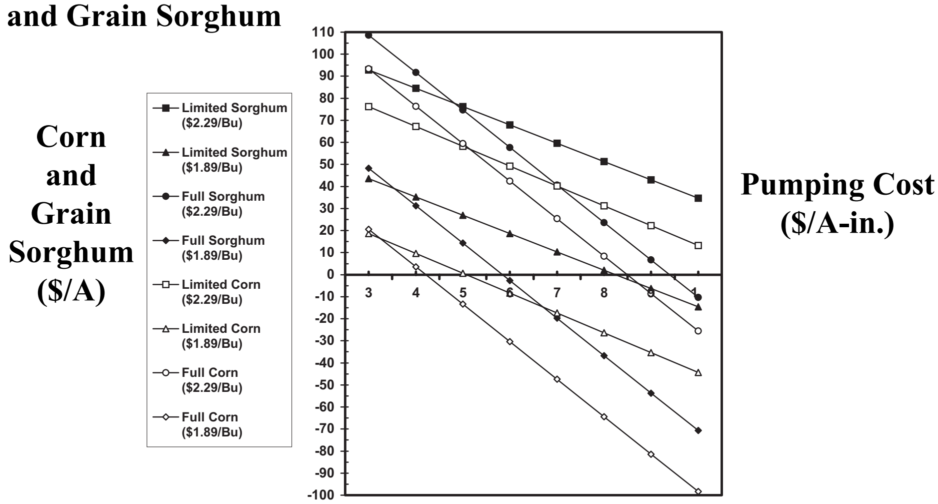

Fig. 5. Full and limited sprinkler irrigation comparison of net income for corn and grain sorghum. Assumptions: yield: 151 Bu/A for full irrigation grain sorghum, 123 Bu/A for limited irrigation grain sorghum, 182 Bu/A for full irrigation corn, and 144 Bu/A for limited irrigation corn; grain price: $1.89/Bu and $2.29/Bu; irrigation: 17 A-in./A for full irrigation corn and grain sorghum, 8.3 A-in./A for limited irrigation grain sorghum, and 9 A-in./A for limited irrigation corn; production costs: pumping cost varies from $3 to $10/A-in., all other costs remain constant.

Surface Irrigation Tips for Limited Water

Adjustments for surface irrigation are crucial to operate with less water.

Advances in irrigation technology have resulted in improved sprinkler and drip irrigation systems, but surface irrigation still accounts for about half of the irrigated acreage in Colorado. While these systems are still used for a variety of good reasons and meet the needs of many growers, surface irrigation is inherently inefficient (25 to 60% application efficiency) and non-uniform. When water is plentiful, low efficiency is usually overlooked and becomes more of a water quality problem (leaching and runoff) than a water quantity problem. However, in water short years, inefficiency and poor uniformity results in water lost to crop productivity and all management practices (Table 3) to improve efficiency should be considered.

The main cause of inefficiency in surface irrigation results from the extra irrigation water that is necessary to get water to the end of the row. This problem becomes more acute on long runs (>1,000 ft.) and/or coarse-textured soils. As Figure 6 shows, this leads to poor uniformity with excess water applied at the upper end of the field and not enough on the lower end. Additionally, the extra set time required to adequately soak the bottom of the field results in runoff losses. This poor uniformity can be improved by a variety of management practices:

- Shorten row length
- Increase stream size and cutback
- Use optimum set time
- Pack furrows
- Use surge valves or manually surge rows

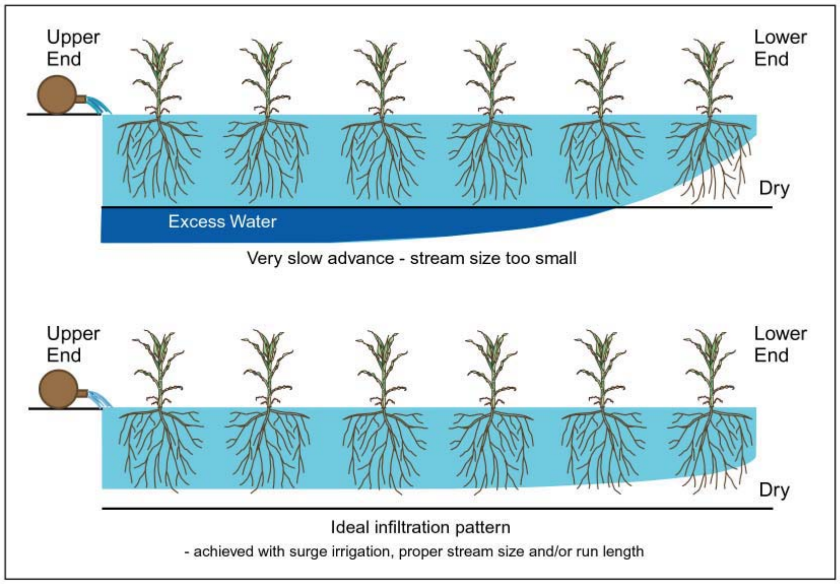

Figure 6. Long runs combined with coarse-textured soils and/or low stream size require extra water to adequately wet the bottom of fields.

One adjustment that should be considered under tight water supplies is shorter runs. This is especially relevant in situations where growers are planning to reduce their irrigated acres. In these situations, a potential strategy would be to leave fallow or plant a dryland crop on the lower one-third of long runs, especially on fields that have a sandy loam texture or sandier. This strategy allows growers to use shorter set times and would keep water from being wasted trying to push to the field bottom, particularly on the first irrigation.

Increasing stream size helps increase advance rate, but has its limits with erosion and blowing out furrows. Additionally, increasing stream size without cutback will result in more runoff if growers allow for a full wetting of the furrow. Polyacrylamide (PAM) can help maintain furrows when using high flows, but will not help water advance. In fact, PAM usually increases infiltration on many soils, and may increase advance time if flows rates are not increased by two-fold. However, when lateral wetting to the bed center is desired, for example when the crop has to be irrigated up, PAM has been shown to improve lateral infiltration. In these situations PAM may save water because set times might be shorter to accomplish lateral soak. PAM is also appropriate for fields where inefficiency is caused by poor infiltration due to short and/or highly sloped fields with fine-textured soils. On these fields 10 ppm of PAM in the irrigation water may help soak up the field without having to run the water for extended periods of time.

Furrow firming (packing) is also a practice that can increase advance rate in many situations. In a study at

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Surface Irrigation Tips for Limited Water (Continued)

Scottsbluff, Nebraska, (Yonts, 2000) advance time was reduced by 18 percent for either surge irrigation in a soft furrow or continuous irrigation in a firmed furrow when compared to continuous irrigation in a soft furrow. When the two treatments were combined, advance time was reduced by 27 percent compared to continuous irrigation in a soft furrow. These results indicate either furrow firming or surge irrigation equally reduces furrow advance time, but a greater reduction can be achieved when the two methods are used together. However, furrow firming will be of limited value if soil moisture contents are extremely low.

Most surface irrigation systems are inherently inefficient and limit irrigation options during dry years. However, growers can make some management adjustments to improve their systems and maximize water available for crop production.

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References: C. Dean Yonts. 2000. Firming Irrigation Furrows to Improve Irrigation Performance. Neb. Guide G1340

Table 3. Potential adjustments for surface irrigation systems.

Practice	Benefit(s)	Management notes
Row length	Proper row length improves uniformity.	Leveled fields should be approximately 660’ on coarse and 1300’ on fine textured soils.
Stream size	Should be adjusted for slope and texture, and rate doubled when using PAM.	Easy management to adjust with both siphon tube and gated pipe.
Length of set	Allows irrigator ability to control volume of application.	Should be adjusted for stream size and run length. 12-hour standard is convenient, but not appropriate for many situations.
Furrow packing	Can increase advance rate 15 – 20 % on some soils.	More effective when using a designed furrow forming/packing tool than when driven with tractor.
Alternate row irrigation	Reduces gross irrigation by 46%, net by 29%. Allows for rainfall storage in dry row.	Not appropriate for steep slopes or soils with infiltration problems.
Surge irrigation	Can greatly improve uniformity and can improve efficiency by 10 - 30%	Once learned, reduces labor requirement.
Crop residue	Increases infiltration. Reduces erosion.	Furrow irrigation can be accomplished under conservation tillage with appropriate management changes.*
Polyacrylamide (PAM)	Reduces erosion by up to 90%. Increases lateral wetting and infiltration.	Must increase stream size to maintain advance times. PAM concentration should be 10 parts per million (ppm) in advancing water for optimum results.

*See Guidelines for Using Conservation Tillage Under Furrow irrigation TR02-6 at http://www.colostate.edu/Depts/AES/

Crop Residue Effects on Evaporation from Soils

Wheat residue saved nearly four inches of water compared to bare soil under sprinkler irrigation

Center pivot irrigation systems typically wet the soil surface 15-20 times during the irrigation season. Each wetting cycle produces evaporation directly back into the atmosphere that is controlled by the amount of energy reaching the soil surface. Even with developed crop canopies, energy limited evaporation can be a substantial portion of evapotranspiration (ET). Klocke et al. (1985) measured E and T independently in fully irrigated corn grown in sandy soils and found that E was 30 percent of ET during the irrigation season.

Crop residues remaining on the surface have a role in reducing evaporation from soils. Todd et al. (1991) demonstrated that the equivalent of 6000 lb/ac of wheat stubble laying flat could reduce bare soil evaporation in half under a fully irrigated corn crop. This crop received only nine irrigation events during the growing season. Klocke (2003) reviewed this study and projected the full season evaporation (120 days) in Table 4 below:

Table 4. Growing season evaporation from soil surface.

	---No Crop Canopy---		---Beneath Crop Canopy---	
	Bare Soil	Straw Covered	Bare Soil	Straw Covered
Year	inches/season			
	Full Irrigation			
1986	15.1	8.5	7.6	3.8
1987	14.6	9.4	8.5	5.7
	Dryland			
1986	7.6	7.6	4.7	5.2
1987	8	7.1	6.1	5.7

The experiment was subject to 23 and 29 rainfall events during the two growing seasons, respectively. During 1986 only 6 of the events were between 0.5 and 0.75 inch and the rest were less in accumulation. These small events led to the preponderance of soil limited evaporation in the dryland treatment. The canopy had similar effect as the straw reducing evaporation in the cropped situation. The straw was not very effective in the fallow situation either because of the transient nature of energy limited evaporation effects when rainfall amounts are small and scattered. However, the benefits of straw cover for runoff control and capture of soil moisture, snow capture of soil moisture, and evaporation suppression when the large events occur will become evident.

The reduction in evaporation in the fully irrigated management of 6.8 inches due to the crop canopy and an additional 3.8 inches was due to the straw mulch. This savings of nearly 4 inches of water in evaporation due to the crop residue is only part of the story. This savings was measured during 120 days of the growing season. The other benefits for crop residue are present then and during the rest of the year including runoff control and soil moisture capture and snow capture. These other benefits could easily add 2 inches or more of soil moisture to irrigation programs, as has been documented by dryland systems with residue management.

Other types of residues need to be considered to suppress evaporation including corn stalks and standing wheat stubble. Whether or not they will be as good as flat wheat stubble for suppressing evaporation will be the subject of future research.

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Agronomic Practices to Stretch Limited Water Supplies

Crop production considerations for producers facing limited water include plant populations, residue management, water timing, and soil fertility.

Plant Populations

Plant populations for dryland production have traditionally been less than for irrigated production. Populations are reduced to better match precipitation and stored soil water to crop ET. However, populations on irrigated corn must be reduced to less than 18,000 plants/acre to reduce ET significantly. Lamm and Trooien (2001) found that corn grain yields generally increased as plant populations increased from 22,000 plants/acre to 34,000 plants/acre for varying irrigation capacities. Little yield penalty was observed at higher plant populations compared to lower populations when no irrigation was applied. Therefore, if corn is grown for irrigated production, even limited, then producers should stay with their normal populations. If the intent is to grow dryland corn with no irrigation, then a dryland population (12,000 to 18,000 plant/acre) is the best option.

Residue Management

The goal when working with limited water is to capture every possible source of water in the production system. These sources include rainfall, snowfall and irrigation water. Residue management can have a significant impact upon increasing the availability of water. Runoff from precipitation and irrigation is also reduced when surface residue is present. Residue acts as small dams that slow water movement and allow more time for the water to infiltrate into the soil. Residue also reduces the impact of rainfall and irrigation upon surface sealing which increases infiltration rates. As droplets impact the soil surface, they destroy the surface structure which will seal the soil surface and reduce infiltration rates. Residue protects the soil surface from the impact of these droplets. Many benefits of increased residue on evaporation losses and stored soil moisture are covered in more detail in articles by Klocke and Nielsen in this issue of Agronomy News.

Crop Rotations and Water Timing

Crop rotations that have lower water use crops (see article by Schneekloth) can reduce irrigation needs. Schneekloth et al. (1991) found that when limited to 6 inches of irrigation, corn following wheat yielded 13 bu/acre (8 percent) more than continuous corn. The increased grain yield following wheat was due to increased stored soil moisture during the non-growing season that was available for ET during the growing season. Crop rotations also spread the irrigation season over a greater time period as compared to a single crop. When planting multiple crops such as corn and winter wheat, the irrigation season is extended from May to early October as compared to continuous corn, which is predominantly irrigated from June to early September.

Some systems can never meet crop ET, even with normal precipitation. O'Brien et al. (2001) found that when irrigation system capacity was increased from 0.1 inches/day to 0.2 inches/day yields increased by 28%. To achieve this change in capacity per irrigated acre, a producer would have to reduce irrigated acres by 50%. Profitability of increasing the irrigation capacity by reducing

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Agronomic Practices to Stretch Limited (Continued)

irrigated acres increased net returns per irrigated acre by nearly 4 times. Though only half of the acres were irrigated, profits were more than twice that of irrigating the entire acreage.

Timing of water is critical to crop response. A great amount of research has been done on this subject in irrigated regions. The general finding is that the greatest response to water is during the reproductive growth stages for most crops. A table of critical growth stages for some Colorado crops is provided in the fact sheet "Crop Water Use and Growth Stages, no. 4.715" available online at http://www.ext.colostate.edu/pubs/crops/04715.html. In most cases, grain crops can incur some stress during the vegetative growth stages without significant yield loss, but will decline rapidly with stress during reproductive growth.

Soil Fertility

Although the focus of this newsletter is on limited water, it is important to remember that yield potential can be limited by a variety of other factors as well (insects, disease, heat units, soil fertility, etc.). During dry years the goal of crop production is to maximize water use efficiency (WUE) defined as yield divided by water used. Fields that are deficient in one or more nutrients are less able to tolerate water stress and will have a lower WUE than fields with sufficient soil fertility. The key is to match fertility requirements to yield potential determined by water supply. As in water sufficient years, the most reliable method to determine soil fertility needs is through soil sampling and analysis. In-season tests may have the most potential for return on fertilizer dollars this year because our knowledge of water supply will improve as the season advances. In-season testing is described in the February-March 2001 issue, Vol. 21 of Agronomy News. Articles in this newsletter also address coping with high nitrogen fertilizer prices, which is also becoming an issue for the 2003 growing season.

Balanced soil fertility should also be a consideration during dry years. Research has shown an improvement in WUE when phosphorus (P) fertilizer is applied to deficient soils. Phosphorus may increase WUE for a variety of reasons. One is that P is not mobile in soil and with limited water, an adequate supply within plant roots may explain part of the benefit. Another is the possible root stimulation under P fertilization. Regardless of the reasons, growers should evaluate whether their fertility program has adequate P, K, and other nutrients besides N. A balanced fertilizer package basing N, P, K on soil test results and adjusting N for a potential yield decline under drought conditions will produce the best return under limited water supplies.

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Colorado Wheat Field Days 2003

Stratton	June 3
Walsh	June 9
Lamar	June 9
Sheridan Lake	June 10
Cheyenne Wells	June 10
Burlington	June 10
Genoa	June 11
Julesburg	June 11
Ovid (Irr)	June 11
Orchard	June 12
Briggsdale	June 12
Bennett	June 17
Akron	June 18

For more details see http://www.colostate.edu/Depts/SoilCrop/extension/CropVar/wheat03/fieldday2003.pdf

Managing Dry Beans in Dry Years

Dry beans requires less water for optimum production (16 to 20 in. of consumptive use) than most other field crops grown in Southwestern Colorado.

Dry beans (mostly pintos) are an important crop in SW Colorado and are primarily grown under dryland conditions. Dry bean production was substantially down from 2000 to 2002 due to drought. Growers asked numerous questions about whether to grow dry beans in 2002 and how to manage the crop to lessen drought effects. In hindsight, the answer would have been not to plant any dry beans (in most cases) in SW Colorado in 2002, unless there was the potential for supplemental irrigation. However, since weather is hard to predict, bean growers need to have alternate plans for dry years like 2002.

Dry bean planting in SW Colorado usually coincides with the driest period of the year, thus adequate soil moisture at planting is critical to ensure good germination and stand establishment. Depending on the variety used, dry beans should be planted as soon as possible after the likelihood of a killing frost has passed. In SW Colorado, this usually occurs after May 25th, Planting early, for instance, during the first or second week of June will ensure that the crop is mature before fall frost hits.

Bean planting may be delayed when there is not enough moisture in the seedbed to germinate the bean seeds. Planting dry beans in dry soil in SW Colorado is risky given the low probability of precipitation in June. Furthermore, soils in the region tend to form a crust after a rain, hindering bean emergence. As a rule of thumb, there needs to be enough available moisture in the top one to two feet of soil to ensure good germination and adequate plant growth from planting through early to mid-July when the monsoon season usually starts in SW Colorado. Beans should be planted into moist soil but no more than four inches deep by using the proper equipment, such as shoe-type planters with press wheels to ensure good soil-seed contact and minimize soil evaporation.

One should maximize soil water infiltration, storage, and conservation during the non-crop season (example, from wheat harvest to bean planting) through proper soil and weed management. No-till and minimum tillage practices are one way to conserve moisture but they are uncommon in SW Colorado. Regardless of the tillage system used, it is essential to keep the soil weed free throughout the “fallow” period. This means controlling volunteer wheat (or another crop) and winter annuals with tillage and/or herbicide in the fall and keeping it weed free thereafter. The cost of chemical weed control may be too high for most dry bean growers in SW Colorado, given the low level of production (400 to 500 lb/acre on average). Further weed control can be achieved through cultivation during the vegetative growth period.

Adjusting bean planting pattern and density provides another means of optimizing water and/or weed management. In SW Colorado, most dryland farmers plant beans in 30 to 36-in rows at 18,000 to 24,000 seeds/acre. Manipulating planting density within this range may not impact bean yield much, but one should plant lighter in dry years to optimize water use.

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Managing Dry Beans in Dry Years (Continued)

When water is scarce, avoid planting beans in fields with high residual nitrogen such as is usually the case after alfalfa. Too much nitrogen will promote excessive vegetative growth early in the season, thus depleting soil water quickly. Dry beans obtain most of their water from the upper 2 feet of soil but will extract water from deeper soil layers (2 to 4 ft.) during periods of high evaporative demand.

If water is available for supplemental irrigation, it should be applied early in the season and during flowering to early pod fill. Starting the season with a full soil moisture profile by pre-irrigating is a good hedge against drought in SW Colorado given the precipitation pattern. Dry beans are very sensitive to water stress during flowering to early pod fill, thus one or more irrigations during this period will boost seed yield. Applying water late in the season or too much water is not recommended since it would delay maturity and promote diseases such as white mold.

Dry beans are a crop that is well adapted to the soil and climatic conditions of SW Colorado. It is also one that requires less water for optimum production (16 to 20 in. of consumptive use) than most other field crops grown in SW Colorado. With proper management, it can be grown in most years and provide a decent income, in combination with other farm enterprises.

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Web Sites

Crop Water Use (ET) Information online
http://www.coagmet.com
http://www.ncwcd.org/ims/ims_Weather_form.asp

Crop Water Use and Growth Stages Fact Sheet
http://www.ext.colostate.edu/pubs/crops/04715.html

Estimating Soil Moisture Fact Sheet
http://www.ext.colostate.edu/pubs/crops/04700.html

Best Management Practices for Irrigation Management
http://www.ext.colostate.edu/pubs/crops/xcm173.pdf

Irrigation Management Agronomy News – Vol. 19, Issue 6.
http://www.colostate.edu/Depts/SoilCrop/extension/Newsletters/1999/GUJUNE99.PDF

Irrigating for Maximum Economic Return with Limited Water
http://www.ianr.unl.edu/pubs/water/g1422.html

Colorado State University Drought Home Page
http://www.drought.colostate.edu/

Dry Bean Production Under Limited Irrigation

Flowering and pod fill are critical growth stages for water stress.

Production practices that maximize economic return for the dry bean crop recommend irrigation when the available soil moisture reaches approximately 50%. In our region, this equates to approximately 16 to 20 inches of water during the growing season. During peak water use periods, dry beans require approximately 0.30 inches of water per day, similar to corn, sugar beets and alfalfa. However, because dry beans are a short season crop they result in a shorter water demand period (Yonts, 1996). The question many bean producers are asking is how to reduce season water requirements. Further, can the bean crop withstand lower soil moisture conditions during a portion of the growing season, and what cultural practices can be implemented to reduce the effects of limited soil moisture. From a management perspective, the question becomes, can irrigation be limited without jeopardizing yield potential and net return? The answer to this question is related to many factors in the production system including, crop rooting depth, timing of soil moisture stress, soil texture, density and depth, quality of the irrigation water, the variety of bean, severity of root diseases, and rate of evapotranspiration during the growing season.

The rooting depth of a crop greatly influences the ability to extract soil moisture. The maximum rooting depth for dry beans is 24 to 30 inches (Yonts, 1996). On most soils, bean roots in the upper 18 inches of the soil profile extracted 85% of the total crop needs. Therefore, beans have a shallow rooting system compared to other crops such as corn, wheat, sunflower or small grains and require more frequent watering, especially during the reproductive stage of growth (pod set and fill) when the air temperature is high.

The reproductive stage is the most critical time during the life cycle of the bean crop to limit or prevent soil moisture deficits. Research at Colorado State University studied the effects irrigation level and timing have on pinto bean production (Bandaranayake, 1990). In that study, the crop was watered at 30, 50 and 70 % available soil moisture during the vegetative and reproductive stages of growth to simulate high, medium and low soil moisture stress levels, respectively. A non-irrigated check treatment was included that had a yield of 1726 lbs/acre. This yield was higher than expected because timely and excessive rain occurred during the growing season. Mean yield for treatments that had high and low stress during the reproductive stage of growth with no stress during the vegetative stage was 2443 and 3335 lbs/acre, respectively. Mean yield for treatments that had high and low stress levels during the vegetative stage of growth with no stress during the reproductive period were not statistically different (3535 vs 3220 lbs/acre). These results clearly demonstrated that stress during the reproductive stage was more critical than during the vegetative stage. Caution should be taken when making conclusions from this data because the research was only conducted in one site-year. However, the trend was very clear, limited available soil moisture during the vegetative stage had little effect on seed yield, but during reproductive growth it reduced seed yield by almost 900 lbs/acre.

A method to estimate yield losses due to limited soil moisture, termed the FAO method, was reported by Allen, Yonts and Wright (2000). That method estimates yield based on limiting evapotranspiration due to soil moisture stress during the growing season. They reported that when seasonal ET was limited by 30 % during the vegetative period, yield was predicted to decline 6 %. However the same reduction in ET during flowering would reduce yield 33 %. The authors reaffirmed that flowering and pod fill periods were the most sensitive periods for the bean crop.

Irrigation water should be limited during late season. Irrigation should be terminated when 20% of the lower leaves and pods have turned yellow due to physiological maturity (Yonts, 1996). Irrigating late in the season can delay maturity and increase disease potential by saturating the root zone when the plant only requires minimal water.

Monitor soil moisture every week during June, then twice a week or more during July and early August. Always try to apply sufficient water to refill the root zone plus a small margin to account for root growth that

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Dry Bean Production Under Limited Irrigation (Continued)

will occur before the next irrigation. Irrigation water applied beyond the root zone is wasted. During the reproductive stage, try to irrigate when the air temperature is less than 70 to 80^0 to prevent temperature shock to the plant that can cause floral abortion.

Soil structure and tilth play important roles to determine the depth of root penetration, efficiency of soil moisture extraction, and amount of water the soil can hold. The presence of layers that restrict root growth, such as hard pans, will reduce the rooting depth, consequently the ability of the plant to extract soil moisture. Soil compaction can significantly reduce bean yields by limiting root growth, preventing water from infiltrating through the soil profile, and increasing the incidence of root rot disease. If a compacted layer occurs, the field should be deep chiseled and/or planted to a crop that is less sensitive to compaction, such as corn, sunflower or wheat. Deep chiseling should only be done when the soil is relatively dry, because the chisel points do not break up or fracture the compacted layer in wet soil.

Poor soils, such as those that have salinity problems or low organic matter, do not hold soil moisture or respond to fertilization. Because beans are extremely sensitive to soil salinity (Blaylock, 1996), production of beans on fields that have a history of salinity problems should be avoided, especially if irrigation water is reduced. Since most crops are more tolerant than beans, fields that have a history of salt problems should be planted to an alternative crop such as barley, sugarbeets or sorghum.

Varieties differ in their response to drought stress. Research at Colorado State University has shown that varieties in the pink market class, such as Rosa and Viva, are among the most tolerant of drought stress. In general, varieties in the pinto market class that have a vigorous vine growth habit and full season maturity are more tolerant to drought stress than upright short season varieties. The ability to withstand low soil moisture is related to a variety's ability to produce vegetative growth to shade the soil surface and have an extended period of pod set and fill to maximize the opportunity to produce seed. Alternatively, varieties with early season maturity can reduce total seasonal water needs, and a variety such as Othello may be a good choice if irrigation water will be available during the critical flower and pod fill stages.

Dryland varieties, developed by the breeding program at Colorado State University for the nonirrigated regions of the San Juan Basin in SW Colorado and NW New Mexico, are not adapted to the High Plains. The most recent releases, Fisher and Cahone, were developed for dryland systems in this region, however, they are not recommended for the High Plains because neither has resistance to pathogens in the High Plains, such as rust and common bacterial blight, and they are very long season (>105 days) when grown outside of their region of adaptation.

Management with limited irrigation is more critical than with full irrigation. Scout bean fields twice weekly. Carefully observe both upper and lower leaf surfaces for disease or insect pests, dig plants to inspect rooting patterns, soil moisture, nodulation and the general health of the root system. Be especially aware of patterns in the field that could indicate early disease infection, poor water distribution, or other problems that can be addressed in a management program, including the timely application of pesticides. Production systems under limited irrigation are much more sensitive to attack by biotic pests, especially foliar and root pathogens. Early detection can make the difference between financial profit and loss.

In summary, management of the bean crop is more difficult under limited irrigation. Conserve irrigation water for the critical growth periods of flowering and pod fill. Monitor every aspect of the crop to limit or reduce damage by pathogens, especially root pathogens. For further information, contact the author by phone at 970-491-6501 or via e-mail at mbrick@lamar.colostate.edu.

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3. Yonts, C.D. 1996. Irrigation Requirements. pp. 24-26. *In:* Schwartz, H.F., M.A. Brick, D.S. Nuland, and G.D. Franc (eds). Dry Bean Production and Pest Management, Regional Bulletin No. 562A. Colo. State Univ. Ext. and Agr. Exp. Sta., Ft. Collins, CO. 106 pp.

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Drought Effects Upon Plant Disease Potential

Disease potential and severity will vary depending upon the pathogen and the crop.

Plants and plant pathogens respond differently to environmental conditions and variations that occur throughout their life cycles. Temperature and moisture extremes create stress on plants, and in some cases predispose plants to greater loss from specific types of plant pathogens. On the other hand, temperature and moisture extremes can negatively impact specific types of plant pathogens, and reduce their ability to survive and cause plant diseases in stressed plants (Plant Pathology, 4th ed., G. N. Agrios, Academic Press).

Moisture Effects on Plant Pathogens
Moisture is indispensable for the germination of fungal spores and penetration of host tissues, and for the activation of bacterial and nematode pathogens before they can infect a plant. Moisture (especially in the form of rain or irrigation water) is critical for the distribution and spread of pathogens from plant to plant, and field to field. Access to abundant moisture increases the succulence of host plants and thus their susceptibility to certain pathogens, which in turn affects the extent and severity of diseases.

The occurrence of many diseases in a particular region is often closely correlated with the amount and distribution of rainfall or other sources of moisture (irrigation water, dew period, relative humidity) during the plant and pathogen cycles. Indeed, rainfall and other moisture sources such as irrigation water may determine not only the severity of the disease, but also whether the disease will even occur in a given season.

Some foliar-infecting pathogens, such as those causing late blight of potato or downy mildew of onion must have high relative humidity or free moisture in the environment throughout their development. Other foliar-infecting pathogens, such as that causing powdery mildew, are actually favored by lower moisture (especially relative humidity less than 70 percent) and are inhibited by high moisture conditions.

	Deficient	Average	Excess
Rhizoctonia Root Rot	↓	↑	↑
Fusarium Root Rot	↑	→	↑
Fasarium Wilt	↑	→	↑

Figure 7. Root disease management under varying water conditions.

Some soil-borne pathogens such as Pythium damping-off of seedlings are favored by high moisture, and the severity of the disease is proportional to the amount of soil moisture. The increased moisture favors movement of spores in soil water films, and plant roots may be more stressed for oxygen due to waterlogged and cooler soils. Other soil-borne pathogens such as Rhizoctonia or Sclerotinia cause the most damage on wet, but not flooded or dry soils. Other soil-borne pathogens such as Fusarium grow fairly well in dry soil environments on plants that are stressed by insufficient water and/or high temperature.

	Deficient	Average	Excess
White Mold	↓	↑	↑
Rust	↓	↑	↑
Common Bacterial Blight	↓	↑	↑

Figure 9. Root disease management under varying water conditions.

Temperature Effects on Plant Pathogens
Most plants grow best within a temperature range of 60º – 86º F (15º – 30º C), as do most plant pathogens. Pathogens are less active and cause less disease during prolonged periods of extreme temperatures; that is less than 60º F or greater than 86º F. Plants are generally injured faster and to a greater extent when temperatures become higher than the maximum for growth than when they are lower than the minimum. High temperature often causes its effects on the plant in conjunction with the effects of other environmental factors, particularly excessive light, drought, lack of oxygen, or high winds accompanied by low relative humidity. High temperature can be responsible for sunscald injuries on the exposed side of plant tissues. High soil temperature at the soil line sometimes kills young seedlings, or causes cankers at the crown on stems of older plants.

Drought Effects on Plant Diseases
Insufficient moisture and high temperature are drought conditions that negatively affect plant survival,

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Drought Effects Upon Plant Disease Potential (Continued)

growth and reproduction. Abiotic responses in stressed plants can include stunting, light color (pale green to light yellow), few and small leaves, few and small pods or fruits, wilting and death. Plants weakened by drought are also more susceptible to some plant pathogens and insect pests.

	< 80°	Average	> 90°
Rhizoctonia Root Rot	↑	↑	↓
Fusarium Root Rot	→	↑	↑
Fasarium Wilt	→	↑	↑

Figure 8. Root disease management under varying temperatures

Soil-borne pathogens such as Fusarium (Fusarium root rot and Fusarium wilt of dry bean) and Macrophomina (ashy stem blight of dry bean, charcoal rot of corn) are usually favored by drought conditions that stress plant roots and predispose them to colonization and infection. Foliar pathogens such as powdery mildew (of sugar beet, pumpkin) are also favored by extended periods of low moisture and relative humidity. Drought conditions discourage the survival and activity of other soil-borne pathogens and most foliar-infecting pathogens that require high moisture conditions for survival, infection and disease development.

So, continued drought conditions in Colorado and the surrounding region will discourage the survival and outbreaks of most foliar-infecting pathogens such as rust or bacterial blight. However, soil-borne pathogens such as Fusarium and Macrophomina will be favored by these types of conditions that stress the plant. So, disease management should target any cultural practice that reduces stress to the roots such as planting during recommended periods when soil temperatures and moisture are adequate for emergence, and early-season tillage to remove soil compaction and permit more vigorous root development. And, always follow an integrated pest management approach that targets all pests (abiotic or biotic) that can threaten plants and their productivity. The following dry bean IPM strategy can be adapted to other crops and plant species grown in our region.

	< 80°	Average	> 90°
White Mold	↑	↑	↓
Rust	↑	↑	↓
Common Bacterial Blight	↑	↑	↑

Figure 10. Root disease management under varying temperatures

SUMMARY OF Dry Bean Disease IPM STATEGY for 2003:

1. Rotate out of dry beans for at least 2 years to reduce survival of soil-borne and foliar-infecting pathogens and other pests.
2. Eliminate bean debris and sources of volunteer beans during the fall of 2002 and spring of 2003.
3. Plant high quality, certified, treated seed of disease resistant varieties, if available and suitable for your market needs, when soil moisture is adequate and soil temperatures are greater than 60º F at the seeding depth.
4. Follow recommended production practices to avoid stress from extremes of moisture, temperature, and soil compaction.
5. Manage water and fertilizer inputs to provide adequate, but not elevated components to avoid excess canopy development.
6. Carefully scout fields to detect foliar infection as early as possible, get confirmation of disease diagnosis from appropriate experts in your area.
7. Monitor reports on weather patterns, disease forecasts, and confirmed pest sightings in your region via the CSU VegNet at http://www.colostate.edu/Orgs/VegNet/
8. When and if infection is confirmed in or near your field, implement a timely program of fungicides and bactericides with protectant and systemic modes of action. Rotate appropriate fungicide chemistry, apply labeled rates, use an adjuvant, and stay within recommended spray intervals.
9. Adjust combine at harvest to maximize seed quality, and reduce seed loss that can produce volunteer plants next spring.
10. Thoroughly incorporate diseased crop residue to reduce carryover and potential disease pressure the following season. Rely upon cultivation and herbicide in next year's rotation crop to reduce volunteer bean emergence and possible infection by foliar-infecting pathogens which can then be spread to next year's host crop.

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Stubble Management Effects on Available Soil Water in Dryland Cropping Systems

As we head into what might potentially be another year of drought, dryland growers should consider how much residue they leave in their summer fallow operations.

The extreme and widespread drought of 2002 has caused all of us to reconsider the importance of water. Yet dryland crop production on the semi-arid plains of eastern Colorado faces water shortages of some degree every year. Consequently, it is important for farmers to use production methods that keep every drop (or flake) of precipitation that falls from the sky. Good stubble (crop residue) management will aid in that goal.

Good stubble management through reduced tillage production systems maintains crop residues remaining on the soil surface after harvest, and increases non-crop-period precipitation storage efficiency and soil water content at planting through decreased evaporation. This reduction in evaporation also continues during the early portion of the crop growing season when crop canopy closure is incomplete.

Evaporation from the soil surface is a three-stage process (Fig. 11). During the first stage, when the soil surface is wet, evaporation proceeds at a linear, high rate controlled by atmospheric conditions (dry, warm air and windy conditions increasing evaporation rate). Evaporation from a bare soil during this stage occurs at the same rate as evaporation from a water surface. The second stage is curvilinear as the soil surface becomes dry and the evaporation rate slows down. Third stage evaporation occurs when the soil surface is dry and water vapor diffuses slowly through the soil to the soil surface. As the amount of residue left on the soil surface increases, the rate of first stage drying decreases allowing more time for water to infiltrate and move deeper into the soil profile. Additionally, crop residues on the soil surface also reduce raindrop impact, thereby maintaining high soil surface infiltration rates.

Studies conducted in Sidney, MT, Akron, CO, and North Platte, NE have shown the increase in precipitation storage efficiency that occurs with increasing amount of crop residue left on the soil surface (Fig. 12). Those studies showed that precipitation storage efficiency was about 16% during the period between wheat harvest and wheat planting in the fall of the next year when there were no residues left on the soil surface. Precipitation storage efficiency over that same time period increased to 34% when 9000 lb/a of wheat residues were left on the soil surface after harvest.

No-till production systems also eliminate the "soil stirring" that occurs with conventional tillage weed control. With fewer tillage events and less soil stirring, there is less opportunity for stimulated evaporation from moist soil being brought to the soil surface. Data collected at Akron, CO following wheat harvest in 2001 (Fig. 13) demonstrate the much lower soil water storage that occurred when the soil was tilled four times (W-F, CT) between wheat harvest and the spring of the following year compared with no-till management (W-F, NT; W-C-F, NT).

Wheat yields respond dramatically to available soil water at planting, so the efficient storage of precipitation is extremely important to wheat yield. At Akron, we have found that for most years (April-June), wheat yields increase by about 5.4 bu/a for every inch of water stored in the soil (Fig. 14). In the years with extremely

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Stubble Management Effects on Available Soil Water in Dryland Cropping Systems (Continued)

dry conditions during April, May, and June (10-13% of the time), wheat yields increase by 1.7 bu/a for every inch of water stored in the soil. The kind of predictive relationship shown in Fig. 4 for wheat does not exist for corn, as dryland corn yield is much more determined by precipitation falling in July and August than by stored soil water. However, within a given year, corn yield does increase with increasing amount of stored soil water. The rate of increase in yield with available soil water changes from year to year depending on timing of precipitation.

No matter what the crop is, producers should be encouraged to efficiently store precipitation with good stubble management methods. The better the stubble management, the higher the precipitation storage efficiencies and crop yields will be.

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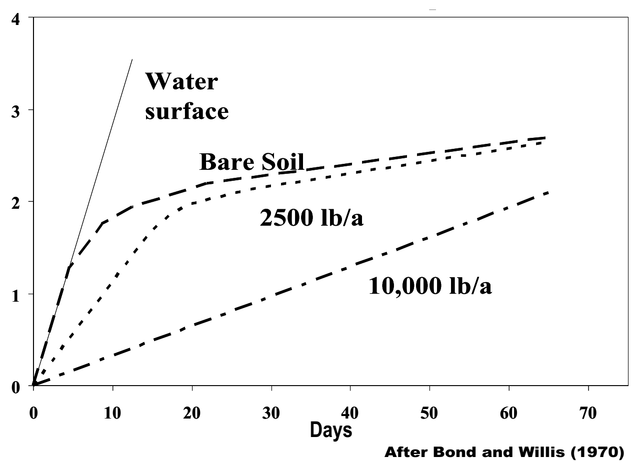

Figure 11. Wheat straw effect on evaporation

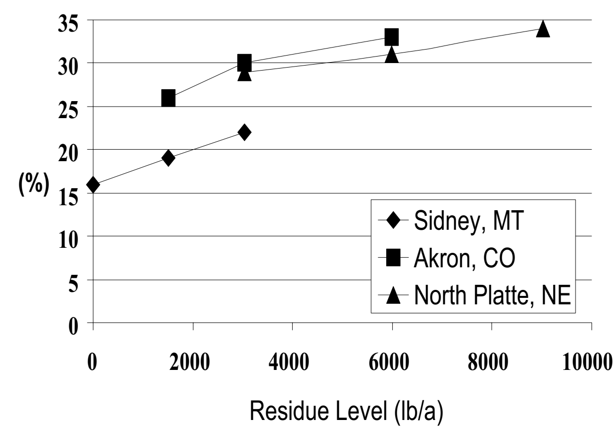

Figure 12. Precipitation storage efficiency

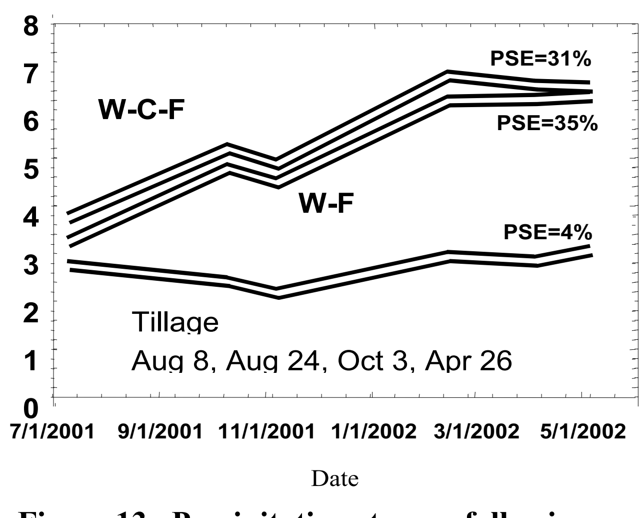

Figure 13. Precipitation storage following wheat harvest

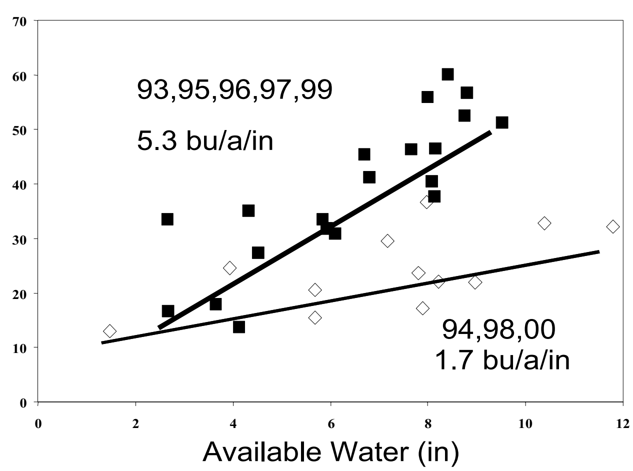

Figure 14. Wheat yield vs. starting soil water

Cover Crops

Consider cover crops for land that is being fallowed due to drought.

When fall and winter precipitation have not replenished soil profile moisture for another growing season and below average moisture looms, growers are limited in what can protect fields from erosive winds. Additionally, many growers have leased or sold their water for 2003, but may have bare soil or minimal residue cover, and some vegetative cover is necessary. The question for many growers is what kind of crop will provide adequate cover at reasonable input costs.

A few items to consider are: soil condition, moisture availability, forage requirements, weed control/ suppression, and future crop after cover crop. Soil conditions to consider include whether the field(s) in question have been tilled and are ready for a commodity crop, whether there is soil moisture to the three-foot depth, if any signs of soil compaction are present, and if the field(s) are highly erodible (HEL). Moisture remaining in the soil in late winter or early spring will assist the grower making the decision on quantity of seed to plant and how much of the remaining soil moisture will the cover crop need to adequately protect the soil. If the field has soil compaction at a shallow depth (<7 inches) the cover crop may be very sparse and not provide the needed protection. Fields with soils of HEL designation should have higher priority for cover crops and to remain in compliance with USDA. A wise move for all growers will be to probe the soils to the three-foot depth to determine the soil moisture status prior to putting in a cover crop this spring.

There are several types of cover crops that could be considered when planning for very limited or no irrigation water. First, small grains such as oats, wheat, triticale, and some millets at ¼ to ½ normal seeding rates will offer protection from erosion, especially wind, with little input costs. However, growers should not expect harvestable grain in this situation because it is our suggestion that at head eruption to just prior to flowering stage that the crop be swathed or mowed. The mowing/swathing device should be set to cut at the joint height or higher to eliminate seed production that could become weed problems from subsequent crops. A second group of crops includes legumes such as certain vetch species, medic, and red clover. These are valid choices when drilled at spacing narrower than 12 inches with a ¼ seeding rate of oats. Another possibility could be to drill long season soybeans (non-RoundUp Ready) in narrow spacing at 1/3 normal seeding rates. When they start to show flowers, use a broadleaf herbicide to stunt or kill and they will provide protection to the soil. For fields where pests such as nematodes are a problem, oil seed radishes are a great possibility for cover crop when drilled at close spacing. Turnips or even kale may offer other alternatives to the vegetable growers as cover crops at reduced seeding rates.

If the skies yield badly needed moisture, the above mentioned cover crops will have to be managed using contact herbicides or tillage to prevent them from going to seed, robbing soil moisture and becoming a weed pest for future crops.

By Michael Petersen
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Help for High Nitrogen Fertilizer Prices!

The February/March 2001 issue of Agronomy News has articles that address the current situation with Nitrogen fertilizer costs. Find it at http://www.colostate.edu/Depts/SoilCrop/extension/Newsletters/news.html.

Forages Fit Uncertain Water Supplies

Forages are a flexible and well-adapted choice among irrigated field crops when irrigation supplies are uncertain.

The continuing drought is causing many irrigators to struggle over crop planting decisions. Their struggle stems from the uncertainty over the total amount of water supplied and whether that water will be available throughout the season or only during the spring and early summer run of water. Many traditional field crops need the certainty of available water throughout the growing season and especially during each crop's critical growth period. Applying irrigation water to forage fields may be the best choice this year because of their inherent responsiveness to water and adaptability under mid and late summer water shortages.

Forage crops can be harvested at any growth stage and thus escape drought induced crop failures through early harvest. Secondly, established perennial forages will remain viable during drought periods only to re-initiate growth upon resumption of soil available moisture from either rainfall or irrigation. And finally, annual forages may be seeded as a relatively inexpensive opportunity crop or to utilize limited irrigations.

Forage crops have a linear water response relationship without an initial irrigation requirement (Figure 15). On the other hand, grain and oilseed crops require a minimum quantity of water for plant establishment prior to filling the crop's yield potential (Figure 16). Forages have the advantage in having a harvestable unit produced for each additional inch of water supplied.

When the supply of irrigation water is insufficient to supply the full seasonal water requirements of alfalfa or other cool season forage it is recommended to irrigate fully in the spring. For alfalfa, the first cutting should be emphasized with the possibly to take later cuttings should irrigation water supplies continue to be available. It is not advisable to try to "spread out" an insufficient water supply and deficit-irrigate for the entire season. Forage production is significantly reduced when plants are forced into and out of dormancy with regularity. The amount of irrigation water required per ton of alfalfa is less for the first cutting than for the second or third (Table 5). Temperatures are cooler in the spring and the chance of rainfall is greater. First-cutting yields usually surpass later cuttings.

Similarly, moderate temperatures create favorable growth conditions in September, especially in Colorado's high plains region and western slope river valleys. In these areas, the average first killing freeze, below 24º F are normally expected in late October or in many years well into November. In these areas, when water is available, a mid to late August irrigation can be beneficially applied and utilized for a fall harvest.

Research and field experience throughout the west have demonstrated that irrigation water can be withdrawn or reduced following the first cutting without significantly reducing stand density or yields the following year. Soil moisture deficit forces alfalfa into drought-induced dormancy. The stand usually fully recovers when it receives adequate water the next production season.

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Forages Fit Uncertain Water Supplies (Continued)

Small grains can be seeded in the early spring and winter wheat can all be harvested as a forage crop. These cool season grasses can be used to utilize winter stored soil moisture and efficiently use precipitation and early season irrigations to produce good tonnages and high quality forages. Wheat, barley, and triticale, haying should be completed before these grasses enter the boot stage of development. Oats can be swathed for haying up until the mid-dough stage of development, but care should be taken that the oat glumes do not begin to dry and initiate tanning. Care over livestock health issues, grass tetany and cow asthma should be taken when grazing these spring grains.

Warm season forages can be seeded in the late spring in many low elevation areas of Colorado as an opportunity crop. Forage sorghum, sorghum x sudan hybrids, and forage millets are often seeded in both dryland and irrigated fields. They have an advantage in that, once established, they can persist through weeks of heat and drought until significant rainfall occurs or irrigation is applied. Similarly to alfalfa, their growth and harvest potential is dependent upon crop evapotranspiration which is directly affected by precipitation and irrigation supplied soil water. Warm season forages can be very productive and quality can be good if harvested (repeatedly) during vegetative stages of growth. However, as a rule, warm season grasses tend to have higher lignin contents than cool season grasses and should be marketed accordingly.

As with all non traditional forages, make sure that the forages can be utilized on farm or that a buyer is reasonably secured before planting these forages. In addition, pay attention that the quality desired by the buyer is realized through proper swathing and haying timing. The producer and the buyer can negotiate the forage price over the balance of harvest quality and production.

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Table 5. Alfalfa water use efficiency (WUE)

Harvest	Irrigation	Irrigation + Precipitation	Hay Yield	Irr. WUE
	------ inches ------		tons/acre	in./ton
First	6.1	10.4	2.5	2.4
Second	7.0	9.3	2.2	3.2
Third	6.8	8.4	1.7	4.0
Fourth	3.7	5.0	1.7	2.2

*Projected from NE Colorado Research; Water use calculations from weather records – Yields from Wiggins Alfalfa Trial (1998 to 2001)

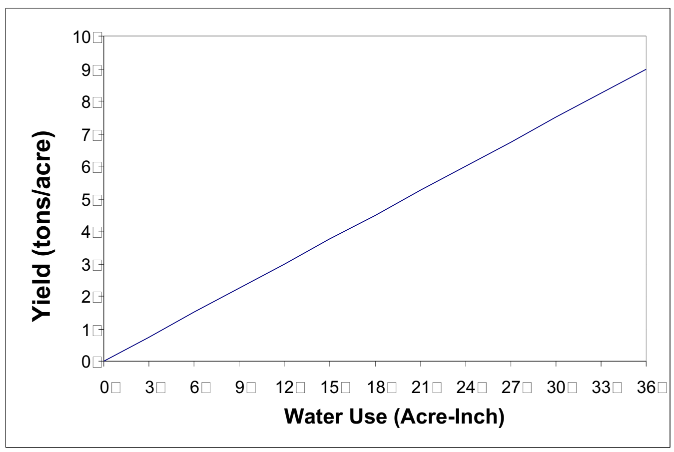

Figure 15. Forage yield vs. water use

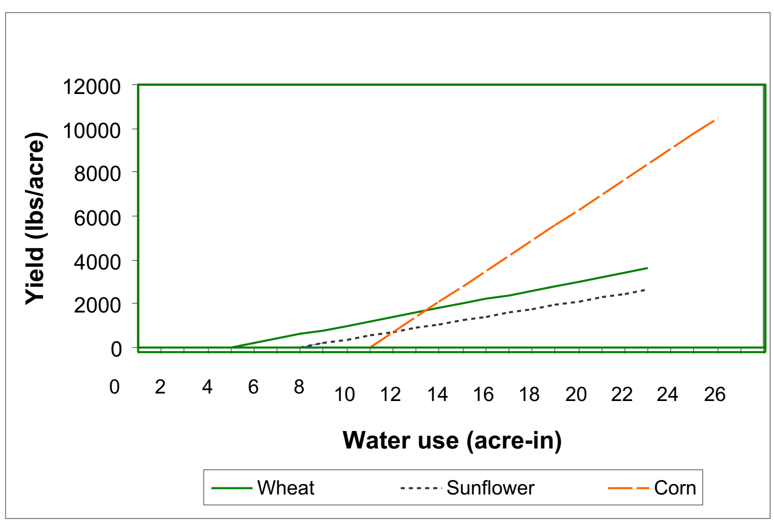

Figure 16. Grain yield vs. water use