From the Ground Up

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Crop Rotation That Reduce Fallow Frequency in Dryland Crop Rotations

Alan L. Helm, Neil Hansen

The sequence of dryland crops and fallow periods in a crop rotation influences every aspect of the system, including production, ecological, and management factors. Production factors influenced by crop rotation include crop yield and yield stability, which are controlled by the interaction of crop water use, precipitation, temperature patterns, and nutrient cycling.

Ecological factors influenced by crop rotation include weed dynamics, cycles of insect pests and diseases, and soil conservation. Crop rotation also influences management related issues such as labor demands, equipment needs, grain storage requirements, and marketing. The objective of this article is to demonstrate how crop rotation influences each of these factors.

Effect of Crop Rotation on Dryland Crop Production

Historically, the dominant dryland crop rotation in Colorado is winter wheat-summer fallow, resulting in one crop every two years. The intent of the fallow period is to capture and store precipitation for the subsequent crop. Fallowing allows for mineralization of soil organic matter that provides some available nitrogen for the subsequent crop. While the winter wheat-summer fallow crop rotation allows for good yield stability over time, there are some serious concerns associated with the winter wheat-summer fallow rotation. One concern is that only about 20-25% of the moisture during the fallow period in a W-F rotation remains in the soil for use by the subsequent crop. A second concern is soil degradation due to erosion and loss of organic matter. A third concern is the lack of diversity in crop markets.

Results of a long term no-till based study of dryland crop rotations at three locations in Eastern Colorado have shown a yield advantage for crop rotations that reduce the frequency of fallow (Figure 1). The study shows that yields averaged over a period of 23 years increase when a summer crop such as corn or millet are included in the rotation. The primary reason for the yield increase is that crop rotations that include a summer crop have better correlation of crop water use to the incidence of precipitation. For typical precipitation scenario in Eastern Colorado, only about 30% of the annual precipitation falls during a period with a growing crop for the winter wheat-summer fallow rotation. The percent of precipitation falling on a growing crop increases to around 40% for a 3-year rotation like wheat-corn-fallow and to nearly 50% for a 4 year crop rotation like wheat-corn-millet-fallow. Simply put, reducing the frequency of fallow with more intensive crop rotations results in the production of "more crop per drop" compared to the traditional wheat fallow system. Precipitation is used more efficiently because less water is lost to evaporation.

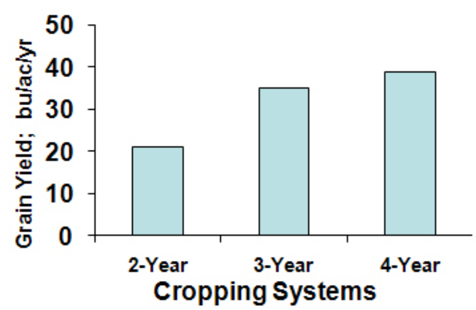

Figure 1. Annualized grain yield comparison of a winter wheat-summer fallow rotation (2-year) with a winter wheat-corn-fallow (3-year) and a winter wheat-corn-proso millet-fallow rotation (4-year).

Fallow periods in a dryland crop rotation are an effective means of improving yield stability. When compared to continuous crop rotations with no fallow such as winter wheat-corn-millet (WCM) and winter wheat-winter wheat-corn-millet (WWCM), rotations with a summer fallow were observed to have a lower frequency of crop failure (Figure 2). However the frequency of crop failure over time did not differ much for dryland crop rotations that included a fallow period with the frequency of fallow varying between 1 and 3 years (Figure 1). Thus, in the long term, reducing fallow frequency increases overeall farm productivity, but it may also increase the year to year risk of a crop failure for one or more of the crops in the rotations. The willingness to reduce fallow is therefore a decision that must be made by the producer based on the level of risk tolerance.

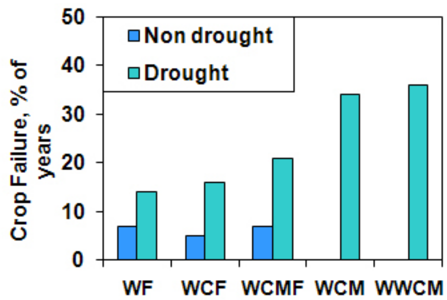

Figure 2. The frequency of the failure of one or more crops in different dryland crop rotations.

Ecological Effects of Dryland Crop Rotations

The ecological effects of crop rotations are interesting and important when managing a dryland crop rotation. Crops and crop sequences affect the cycles of weeds, pest, and diseases that compete in the system and crop rotation also affects soil quality.

A weed shift is a change, or series of changes in the species composition of a community of plants. The primary influence of crop rotation on weed and pest competition is the ability to interrupt growth cycles of pests and competitive weeds. For example, weeds that thrive in competition with a winter annual crop such as wheat generally do not compete well with a summer annual crop like corn or millet. Thus, rotating a winter annual and a summer annual dramatically reduces the negative effects of these pests or weeds. Further, with weed competition, the rotation of winter and summer annual crops generally results in the use of different herbicides with different modes of action and application timing. Again, this gives an advantage for effective weed management. Other factors that have an influence on competitive weeds include tillage and nutrient supply.

Continuous tillage in the crop rotation selects for weed species that are capable of regenerating from roots or shoots. Whereas reduced and notill systems result in an increase in competition from annual species that reproduce from seeds and competition from shallow rooted perennials. An example of how some producers have adjusted to these types of weed shifts is the occasional use of sweeps or shallow tillage in predominantly no-till systems to disrupt weed competition. This has been especially effective for perennial grasses such as red three awn, some perennial brome species, and buffalo grass, all weeds that are difficult to control economically with herbicides.

Nutrient supply can affect the composition and density of weed species. Cropping systems with a high input requirement for nitrogen fertilizers often result in greater competition from weeds that respond well to available nitrogen. Examples of such weeds are kochia, Russian thistle, sandbur, and foxtail. Continuous use of the same herbicide or herbicides with similar modes of action may select for weeds that exhibit higher levels of tolerance or resistance to these herbicides. Roundup, Glean, and Fusilade are examples of herbicides that weed species have developed resistance or elevated tolerance.

Another ecological benefit to crop rotations relates to the ability to conserve the soil and maintain the ability to produce good crops into the future. One key parameter used to measure soil quality is soil organic matter content. A major problem with continuous winter wheat-summer fallow cropping is a loss over time of soil organic matter. Along with the loss of organic matter comes a reduction in both soil fertility and the soil structure which is key to the soils ability to hold water. The long term study conducted at three sites in Eastern Colorado has shown that the more diverse crop rotations with less frequent fallow increased soil organic matter content (Figure 3). The reason for this increase is that the cropping systems with fewer fallow periods have more annual production of residue that is returned to the soil and that forms soil organic matter. The higher soil organic matter levels improve soil structure, water holding capacity and nutrient supply.

Another important benefit to dryland crop rotations that reduce the frequency of fallow periods is the reduction in soil erosion by wind and water. Soil erosion results in long term degradation of the soils productivity and is irreversible. One Colorado study showed that water erosion was reduced by as much as 1 ton of soil per acre per year when converting from a W-F system to a W-C-F or W-M-F systems.

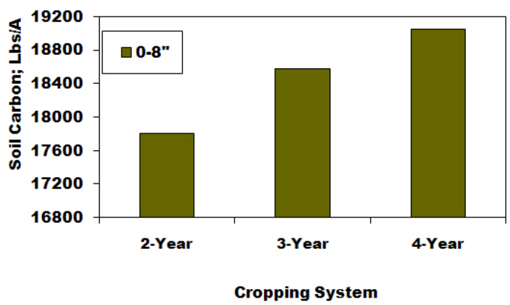

Figure 3. A comparison of soil carbon after 12 years of a winter wheat-summer fallow rotation (2-year), a winter wheat-corn-fallow (3-year), and a winter wheat-corn-proso millet-fallow rotation (4-year).

Management Considerations

When considering a change from wheat fallow to more intensive cropping systems with less fallow, there are some key management consideration that must be made. In a wheat fallow system, the annual work load is concentrated around the planting and harvest periods for wheat. For a more intensive rotation, the work load is distributed more evenly through the growing season. Therefore, plans to match the labor needs with available labor supply must be considered. Similarly, the need for adjusting equipment components and grain handling and storage issues must be considered. One significant advantage to diversifying the crop rotation is the natural outcome of having a more diversified market rather than depending on a single commodity. Over the long term, this diversification reduces financial risk.

CSU Extension Welcomes New Associate Director

Colorado State University (CSU) Extension recently welcomed Jan Carroll, Ph.D., as its new associate director. In her new role, Carroll will provide leadership, strategic planning, project management, and summary evaluation and assessment processes for statewide programs. To identify and prioritize local needs, foster interdisciplinary team efforts, and increase grant funding she will work closely with college leadership and Extension specialists on campus and Extension field leadership and agents throughout Colorado.

“There are many issues in Colorado that are of critical interest to Colorado and CSU Extension,” said Carroll. “Many of them are appropriate for our involvement. I believe we can mobilize resources to realize our vision, to lead the University in helping the people of Colorado put knowledge to work.”

Carroll began her career with CSU Extension in 1994 as a family resource specialist. Since 1996 she has led K-12, military 4-H, and workforce preparation efforts as a 4-H Youth Development Specialist. She has also administered Colorado’s Children, Youth & Families at Risk (CYFAR) projects for over 10 years, securing nearly $2 million in external funding for Extension programming for Colorado families and youth.

Carroll earned her Ph.D. in vocational education with an emphasis in human resource development and her master’s degree in consumer science, both from CSU. She currently serves as an honorary trustee of the Women’s Foundation of Colorado, a sustaining member of the Junior League of Fort Collins, and the CSU representative on the Colorado Prevention Leadership Council.

*Article reprinted with permission from the Colorado Water Institute.

Have you noticed your atrazine application is not protecting your crop anymore?

Dale Shaner, Raj Khosla, Phil Westra, Alan Helm and Bruce Bosley

Atrazine is an important herbicide that is used to manage weeds in corn, sorghum and chemical fallow in Colorado. Atrazine is also a component of many of the new mixtures that are being used in corn and it is critical for providing residual weed control in Roundup Ready corn. Have you noticed that atrazine isn't lasting as long as it used to? Are you able to plant sensitive follow crops like dry beans and sunflowers sooner after atrazine than you used to? You may have already noticed that phenomenon or you may be wondering why it is taking more applications of atrazine these days to accomplish weed control? You may be thinking of one reason to be the reduced rates/acre of atrazine application. But is that really the reason? Let's find out.

A couple of years back we (team of authors) were contacted by a number of growers in Colorado, who brought this to our attention, i.e., that atrazine is not doing as good a job as it used to before. We thought of several reasons that could be responsible for this lack of efficacy of atrazine application (i) leaching of atrazine below the root zone, (ii) weed resistance to atrazine application and (iii) degradation of atrazine in crop fields. Since then, we have done several studies across Colorado fields and looked at leaching of atrazine to 10 foot depth and also if there is weed resistance to atrazine. Our study does not support either reason. However, we have found a new phenomenon in Colorado fields that you should be aware of. If you have used atrazine for 3 or more years in a row, the herbicide may be degrading more rapidly than it has in the past. We used to depend on atrazine to provide season long control but now it may not be controlling weeds for more than 4 to 5 weeks. The reason is that the soil microorganisms have adapted to degrade atrazine quickly. They are using the atrazine as a source of nitrogen. We have done an extensive survey of fields in eastern Colorado (See Figure 1), collecting soils from more than 70 fields with different histories of atrazine use. Where atrazine has been used extensively, including irrigated and dryland corn and wheat-chemical fallow fields, the herbicide is being rapidly degraded. Approximately 30% of the fields we surveyed showed enhanced atrazine degradation. In these fields atrazine is only lasting about 3 to 5 weeks where it used to last 8-12 weeks or longer.

What can happen in a field that has enhanced atrazine degradation? Figure 2 shows a field we tested in 2006 that was planted in corn where atrazine had been used continuously for 5 years. The farmer applied 1 lb/acre of atrazine on April 30th. As you can see in Figure 2, the atrazine began to dissipate rapidly. The farmer applied another pound of atrazine on May 27th. This time atrazine degraded rapidly and by July 2 there was no detectable atrazine left in the field. The field was under conventional corn and by the time the farmer realized that the atrazine was no longer controlling his weeds, the weeds were too big for him to do much about. Needless to say, he had a very weedy field.

We have developed a rapid assay to test soils for enhanced degradation. We can tell within a few days if the soil can rapidly degrade atrazine. Typical results are shown in Table 1. In fields that have enhanced degradation, the half life (the time it takes for half of the herbicide to be degraded) is less than 2.5 days under laboratory conditions. In soils without enhanced degradation, the half life will be 9 or more days.

So, how would you know if atrazine is degrading too quickly in your field and what can you do about it? If you have used atrazine every year for the last 3 or more years, the herbicide is probably degrading quickly and you should be on the look out for weeds escaping where you normally wouldn't expect them. In dryland fields, atrazine will degrade more quickly in the more productive parts of the field and that is where the weeds will break first. To combat this potential problem, you should not use atrazine as your only herbicide and you should rotate with other herbicides to keep the soil microbes from adapting to breakdown the herbicide. In field where atrazine is only used every 3 years, we do not see the very rapid degradation. In many dryland situations with a 3 year crop rotation, you should be all right, at least for now.

Would you like to know if soils in your crop fields are showing signs of enhanced herbicide degradation?

If you would like to know if your soils have enhanced degradation, you can send in a ziplock bag with approximately 1 pound of soil collected from the top 4 inches of the field to the address Dr. Dale Shaner, USDA-ARS, 2150 Centre Avenue, Bldg. D, Suite 320, Fort Collins, CO 80526, and we'll run our rapid assay analysis and let you know the results.

Dr. Dale Shaner is plant physiology-Weed Scientist at the USDA-ARS Unit Fort Collins.
Dr. Raj Khosla is Precision Agriculture Extension Specialist, with Colorado State University.
Dr. Phil Westra is an Extension Weed Specialist, with Colorado State University.
Mr. Alan Helm and Bruce Bosley are Regional Extension Agents with Colorado State University.

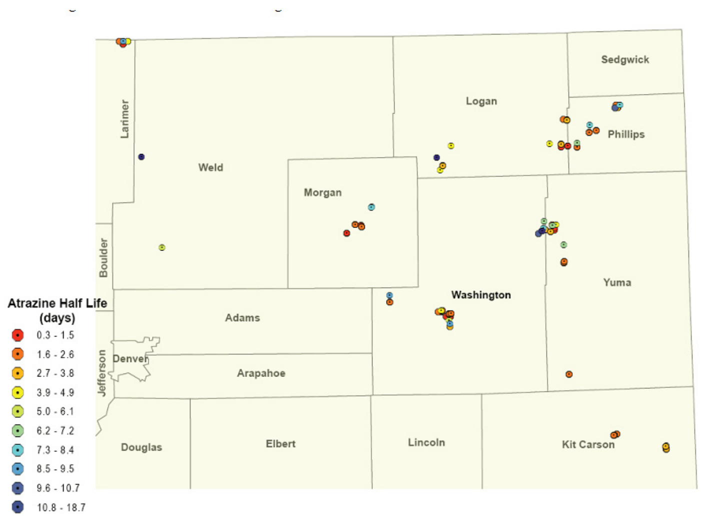

Figure 1: Distribution of atrazine degradation rates in Colorado

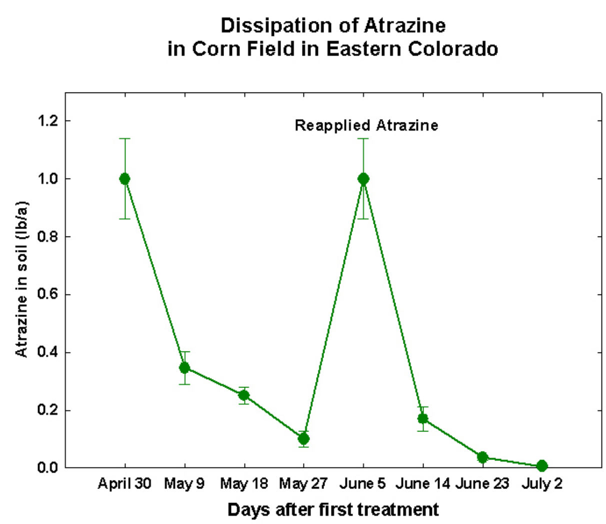

Figure 2: The dissipation of atrazine in a corn field in eastern Colorado that has enhanced atrazine degradation.

Atrazine Degradation Rapid Assay

Farm	Field	Half-life of atrazine (d)
1	Continuous Corn	0.7
	Wheat	11.6
2	Continuous Corn	2.2
	Wheat	10.3
	Grass Waterway	9.0

Table 1: Typical results from rapid assay on atrazine degradation

Alfalfa Nutrient Management

Bruce Bosley

Providing nutrients is essential for producing profitable alfalfa yields. Throughout its growth alfalfa continuously depletes soil nutrients. Each ton of alfalfa hay contains approximately 50 pounds of nitrogen (N), 10 pounds of phosphorus (P), 60 pounds of potassium (K), and 4 pounds of sulfur (S). These and other micronutrients are removed from fields with each cutting. Plant deficiencies of other nutrients, while rare, can occur in Colorado fields. Managing proper levels of plant nutrients begins with assessing nutrient levels available in soil and through plant tissue testing. Test soils for nutrient availability prior to planting and each year afterward. In the west, phosphorus is needed more often and in much greater amounts than any other nutrient element. In addition, sulfur, potassium, zinc (Zn), boron (B), and molybdenum (Mo) are sometimes required. Lab soil testing results provide accurate information for determining nutrient availability and potential for plant deficiencies. Properly sampled, plant tissue testing is used to assess nutrients taken up by the plants and is useful in determining in-season plant nutrition status. Soil and tissue testing are both useful for determining nutrient needs on established alfalfa.

Tables 1 to 5 give Colorado State University's Soil and Plant Testing recommendation levels for alfalfa. Closely follow the lab's procedures for taking and handling soil or plant tissue samples. The depth of the surface soil samples varies by labs as does the timing and way they suggest taking plant samples for tissue testing. Each lab has calibrated their testing procedures for providing accurate results to their customers. Taking and handling samples differently may introduce errors in the lab tests and reduce the consistency in their recommendation.

Take many soil or plant sub-samples to be combined into a composite sample. It is important to randomly collect soil or plant samples across several areas of the field or field partition. In taking samples from a field or portion of a field, ten samples are the minimum number needed and fifteen to twenty are recommended for gathering a representative composite sample for lab testing; Figure 1. Make sure to take samples well within the field, including areas around the center. Avoid sampling close to field edges where field traffic is greatest and where equipment slowing may result in greater fertilizer applications.

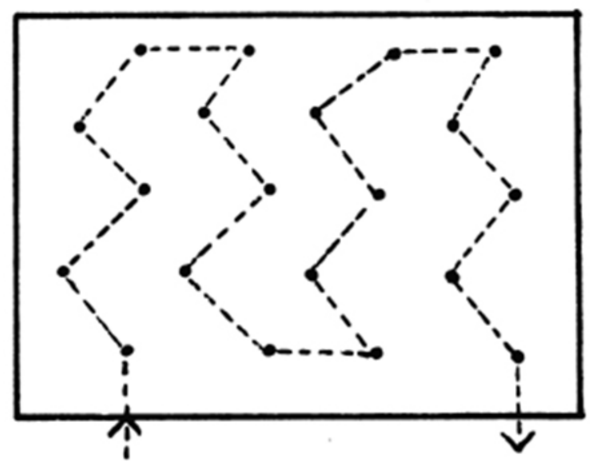

Figure 1: Random Sampling Example

Colorado State University recommends splitting large fields for sampling. CSU also recommends taking additional samples from field areas with different plant growth or appearance or a history of varying crop yield. Sample a minimum every forty acres for irrigated fields and a minimum of every eighty acres for dryland fields. Colorado State's Soil and Crop Science Extension Newsletter, "From the Ground Up", provided one issue specifically on managing field variability. It contains an article on managing field fertility variability. Copies can be obtained at local Extension offices or on the Web at: http://www.extsoilcrop.colostate.edu/Newsletters/2003/Variability/variability.pdf.

Based on the lab's test recommendations, it is important to apply and incorporate two or three year's supply of soil immobile nutrients, such as P, K, and Zn, prior to planting. When P or other soil immobile nutrients are called for on established alfalfa, they can be applied by top-dress or chemigated fertilizer applications. Alfalfa roots can pick up the immobile nutrients near the soil surface readily enough to justify these in-crop applications.

Soil and plant testing laboratories use different soil phosphorus extraction methods. Two different phosphorus extraction methods (AB-DTPA & NaHCO3) are included in Colorado State University's Soil and Plant Testing lab's recommendations: Tables 1 & 2. As a result, each lab uses different test thresholds for representing P availability and conversely fertility needed. For this reason, it is best to send samples to the same lab and use their fertility recommendations for obtaining consistent results and maintaining comparable records.

Table 1: Suggested P rates for irrigated alfalfa				
parts per million (ppm) P in soil			Fertilizer rate, P_2O_5/A	
AB-DTPA	$NaHCO_3$	Relative level	New seedings	Established stands*
0 - 3	0 - 6	very low	200	100
4 - 7	7 – 14	low	150	75
8 - 11	15 – 22	medium high	50	0
> 11	> 22	high	0	0
* Suggested P rates for established stands should be based on new soil test results.				

Table 2: Suggested P rates for dryland alfalfa				
parts per million (ppm) P in soil			Fertilizer rate, P_2O_5/A	
AB-DTPA	$NaHCO_3$	Relative level	New seedings	Established stands*
0 - 3	0 - 6	low	60	45
4 - 7	7 – 14	medium	45	30
> 7	15 – 22	high	0	0
* Suggested P rates for established stands should be based on new soil test results.				

High pH fields usually contain high levels of excess lime which can react with phosphorus reducing it's availability to plants over time. This chemical reaction is slow in alkaline soils (above 7.6) or in acidic soils (below 5.5) and is fairly stable in soils with pH levels near neutral (7.0). Even in alkaline soils phosphorus applications are generally available in the first season after application. For this reason, phosphorus should be evaluated each year until the seasonal P nutrient availability pattern of a field has been established. Alfalfa, being a legume, has a symbiotic relationship with nitrogen fixing soil bacteria. When active and present, these bacteria fix atmospheric nitrogen and supply all the nitrogen needs of alfalfa plants. Healthy alfalfa will develop pink nodules on the plant roots to facilitate good populations of these bacteria. Always inoculate alfalfa seeds with an alfalfa bacterial culture in fields with no history of alfalfa production. A small application of N (20 to 40 lb/acre) at planting may be beneficial as well. Adding too much N can suppress the bacterial symbiosis and can reduce alfalfa growth and enhance weed establishment and competition.

Table 3: Suggested N rates for new seedlings of irrigated alfalfa		
	Companion Crop:	
Ppm NO3-N in soil	With	Without
0-3	60	20
4-6	30	10
>6	0	0
New seedings of dryland alfalfa generally do not benefit from preplant N. Note: Nitrogen fertilizers should not be applied to established stands of alfalfa. N fixation activity can be decreased.		

Potassium and sulfur deficiencies most commonly occur in sandy soils with low organic matter. Irrigation water from groundwater wells, as well as irrigation ditches on rivers downstream from cities, may have enough sulfur and boron to supply alfalfa fertility needs. Sulfur deficiencies may also occur in rain-fed or very pure mountain stream irrigated fields.

Table 4: Suggested K rates for irrigated alfalfa		
ppm K in soil AB-DTPA or NH_4OA_C	Relative level	Fertilizer Rate K_2O/A Alfalfa
0 – 60	low	200
60 - 120	medium	100
> 120	high	0
Rates are for 3 years of production		

Table 5: Suggested K rates for dryland alfalfa			
ppm K in soil		Fertilizer Rate lb K_2O/A	
AB-DTPA or NH_4OA_C	Relative level	New seedings*	Established stands **
0 – 60	low	45	30
> 60	high	0	0
* Suggested rates are for 3 years of production ** Suggested rates are for 1 year of production Potassium applications are not suggested for grass-legume mixtures under dryland conditions			

It is helpful to be able to recognize phosphorus deficiency symptoms because P deficiency is common throughout Colorado. Phosphorus deficiency in alfalfa shows up as thin, weak stands with stunted and grey-green foliage. Deficient areas will appear drought stressed even when the field is wet. Stems may appear red to purple in color in warm weather. Purpling in stems also can occur when alfalfa grows in cold soils or long periods of cold weather. Leaves are frequently folded, and not fully expanded. Compare these plant symptoms with vigorous plants taken from field areas with good growth characteristics. See Figures 2 – 5. Further information on alfalfa nutrition management and can be found at County Extension Offices located throughout Colorado. Office locations and research-based information on this and many other subjects are available on the Colorado State University Extension Website: www.ext.colostate.edu.

Figure 2

Healthy Alfalfa plants | P deficient plants

Figure 3

Healthy alfalfa stems | P deficient note purpling on stems

Figure 4

Normal leaves | P deficient – note leaf folding

Figure 5

P deficient alfalfa field – Field in 2nd year after planting
Note evidence of old corn rows (P – in corn starter band)
Alfalfa also appears droughty (grey-green) in low spots

Oilseed Crops for Biofuels in Colorado -Review of Research and Development Progress-

Alan L. Helm and Jerry Johnson

The production of biofuels from oilseed crops is not a new concept, but the increased interest in the development of fuel sources other than foreign oil has brought biofuels into the forefront of crop research. Applied oilseed research at CSU is not new either. CSU

Department of Soil and Crops Sciences has conducted collaborative winter canola variety trials with Kansas State University on research stations throughout Colorado for more than 15 years. Applied research and extension efforts for oilseed for biofuel began in 2002 on Indian brown mustard, Camelina, and spring canola with support from Blue Sun Biodiesel Company. Over time, there has been collaboration with federal and state agencies, other universities and private companies. Collaboration has included USDA ARS, NRCS, FSA, RMA, and DOE at the federal level; Colorado Department of Agriculture, Colorado Office of Economic Development and International Trade, and the Colorado Governor's Energy Office on the state level; universities, in addition to many researchers within CSU, include University of Nebraska, Kansas State University, University of Wyoming, Montana State University, New Mexico State University, and Oklahoma State University; and private company collaborators include Pioneer Hybrids, Monsanto, Blue Sun Biodiesel, and San Juan Biodiesel. The International Center for Appropriate and Sustainable Technology (iCAST) has been the primary non-profit organization that has collaborated with us on multiple projects. At present, the authors are collaborating or are primary investigators on more than 15 different oilseed for biofuel projects.

In the paragraphs below we discuss the state of knowledge, promising aspects, and constraints of five oilseed crops that are in advanced stages of adaptation or adoption. Oilseed crops that are either currently being grown or are being developed for Colorado producers include; sunflower, safflower, soybean, canola, and Camelina. In addition to specific considerations for crop producers wanting to grow oilseed crops for biofuel, this article serves to inform research and extension colleagues and our partners to opportunities and constraints facing oilseed research and development.

Sunflower is a crop that has a long history in Colorado and large acreages have been grown in Colorado since the early-1990s aided by vigorous development and extension efforts by Golden Plains agronomist, Ron Meyer. Sunflower is adapted to both dryland and irrigated production. Crop variety trials conducted since early-1990s show dryland oil sunflower yields from 1000-2000 lb/ac and irrigated yields in excess of 3000 lb/ac with oil content in seed as high as 47% (www.csucrops.com).

High yields have been obtained under limited irrigation in northeast Colorado where available water for irrigation is a serious production constraint for all crops. There is a well established market for the crop and an established federal crop insurance program. There is a premium for the oil paid to sunflower producers for high oil content. There is a good understanding of pest problems and management for Colorado conditions and sunflowers are relatively storm-resistant, and better able to recover from hail damage than many crops. Sunflowers fit well into conventional and no-till cropping systems which have contributed to wide adoption by Colorado producers adopting improved rotations (including a summer crop like sunflower, corn, or proso millet) while moving away from the traditional wheat-fallow rotation. Many high-yielding and high oil content sunflower hybrid varieties are available for producers who benefit from large sunflower improvement investment by many major crop seed companies and crop variety testing under Colorado conditions. Sunflowers are well suited for direct harvest with planting, tillage, and harvest equipment already owned or available for rent by Colorado producers. Even prior to the recent release of herbicide resistant sunflower hybrids, conventional chemical weed control packages existed that, albeit not perfect, was suitable for Colorado production. High protein sunflower meal is valuable to sunflower processing companies. In addition to the National Sunflower Association the support research and promotes sunflower products, the Colorado Sunflower Administrative Committee, our state 'check-off' organization created and funded by Colorado producers, supports applied research and promotion of Colorado produced sunflower products. Sunflower oil is the second most produced oilseed for biofuel in Europe.

There are some constraints to sunflower production that should be mentioned. When rotating to other crops after sunflower there have been some instances of yield reduction in the subsequent crop due to extensive water and nutrient extraction by a good sunflower crop. Sunflowers have a history of poor emergence under dry planting conditions which can lead to poor stand establishment. Weed management in sunflower can be troublesome when dealing with late emerging weeds and exacerbated in dryland conditions by dry and hot soils. Sunflower residue after harvest is not significant and does not stand up to high winds. Rodent, voles, ground squirrels, and birds can unearth newly planted sunflower seed causing poor stand establishment in parts of fields. Bird damage can be severe before harvest, especially in areas where sunflowers are widely grown and become targets of local blackbird populations. When processing sunflower for biofuel, wax content from the oils needs to removed to avoid damage to the engine. Although sunflower has good potential as a biofuel crop in Colorado, vegetable oil market prices have historically exceeded the value of the oil for biofuel. At present, the only Colorado company crushing sunflowers for oil is in Lamar and the whole oil is exported out of Colorado for refining and retail sales. The majority of the Colorado sunflower crop produced in northeast Colorado must be transported to Goodland, KS for crushing. San Juan Bioenergy LLC, in Dove Creek, CO has built up considerable sunflower production in SW Colorado among local producers and are beginning crush and bioenergy production in December 2008.

<u>Soybean</u> is another well-established oilseed crop currently grown on limited acreage in Eastern Colorado. It too has an established market and crop insurance programs. Soybeans are a relatively good fit for irrigated cropping systems but are not suited for dryland production. Soybean variety trial maximum yields in eastern Colorado have been 99 bu/ac in 2006 and 2007. We feel soybean is an underexploited crop in Colorado due to low input costs and lower water requirements than corn. Many major seed companies are investing millions of dollars in soybean research, some of which benefits Colorado producers. Pest management and agronomics are well understood in Colorado conditions where emergence and stand establishment are not problematic. Soybeans fit well into an irrigated winter wheat rotation with wheat benefitting from symbiotically-fixed nitrogen from soybeans. Soybean processing into biofuel is straight-forward and simply requires pressing the oil from the seed. Soybeans are the major oil source for current biodiesel production in the U.S. Soybean meal has high protein content and is the preferred and most consumed livestock protein feed additive, something of considerable interest to Colorado confined feeding operations. No specialized equipment is needed for soybean planting, cultivation, and harvest.

Constraints to soybean production in Colorado also exist. All soybean production, like most of our sunflower crop, must be transported out of state, usually to Goodland KS, for crushing and processing. It is felt that the lack of a Colorado soybean crushing capacity in northeast Colorado is a major constraint to more widespread cultivation of soybeans in our state. Other constraints include above average sensitivity to high pH, salty and sodic soil conditions. Soybean crop residue is insignificant. There are also issues with soil pH, and water quality, as well as little residue remaining after harvest. Soybeans have low oil content (~18%) by comparison to other oilseed crops. Planting, irrigation and harvest may overlap other summer crops creating a time constraint for some farmers. There is no state 'check-off' program in Colorado to support state crop improvement research. All soybean production in the US, including Colorado, is potentially threatened by soybean rust.

Safflower is a potential oilseed crop for Colorado production that is more suited for dryland production. There is a limited market established for safflower in the state, meaning that producers interested in growing safflower should identify a market before planting the crop. There is no crop insurance available for safflower in Colorado and there is no 'check-off' or grower organization that would support research and marketing of safflower. Being a relatively short season crop it fits well into crop rotations, it is also an aggressive scavenger for water and residual fertility. Safflower has relatively high oil content and is easily processed; it requires no special equipment for planting and is directly harvested. Emergence and stand establishment typically are not a problem in production.

Safflower production and use constraints outnumber the constraints for more widely produced crops like sunflower and soybean. There is no strong varietal improvement program in the High Plains and seed for planting can be hard to find. Weed management in safflower can be problematic due to the lack of herbicides labeled for broadleaf weed control. Hauling the harvested crop is an issue since the market is limited. The research knowledge base for safflower production in Colorado is scarce since no producer organization promotes this crop. Safflower's response to irrigation is not established but is being researched. Safflower can be a fire hazard during harvest and leaves little residue. Safflower is another potential biofuel crop but competes directly with human consumption the same as sunflower. Average safflower oil content is relatively high ~45%, with some varieties approaching 50% oil content.

Canola is another potential irrigated biofuel crop in Colorado that could find a niche in limited irrigation rotations. There are both winter and spring canola varieties that can be planted in Colorado. Winter canola needs to be planted before the end of August to obtain plants that are developed enough to be able to withstand low winter temperatures without a reduction in population. Late planted winter canola, especially north of I-70, has not been able to withstand winter freeze. Weed control is generally not a problem because winter canola starts regrowth in early spring and competes well with weeds.

Varieties from public and private sources have been screened in five different Colorado agro-climatic conditions through a collaborative research program with Kansas State University. Planting and harvest equipment are readily available although canola is commonly swathed prior to threshing to allow uniform maturity of pods from the top to the bottom of the canopy and to avoid excessive shattering. Fall planted varieties have a grazing opportunity for livestock and can still yield well. Spring canola might be an attractive alternative crop under limited irrigation due existence of high yielding roundup-ready cultivars from private seed companies. Peak water use for canola is from mid-May to mid-June, well before peak water demands of summer crops (corn, alfalfa, and sunflower). Canola leaves relatively sturdy residue after harvest. Oil content in Canola is relatively high and the seed is easily processed. The meal byproduct is high in protein and is a valuable livestock feed like soybean. Canola produces a high quality fuel and has good potential for biofuel and meal production for use on the farm.

Canola stand

There are several downsides to canola production. Flea beetles that attack young canola seedlings must be controlled with chemical treatments. There is not a well established market and there is no grower organization to promote production and research. Canola is not a good candidate for direct harvest and should be swathed and then picked up much the same as millet. Canola is sensitive to many of the herbicides that we use in other crops and in fallow periods such as atrazine, Ally, and others. Since there is not a well established market for canola in Colorado, hauling of the harvested product can be an issue. Canola is small-seeded and needs to be shallow planted to obtain good stands. Deep seeding, or soil crusting, or planting into dry soil conditions can significantly reduce stands. Canola is sensitive to high temperatures during flowering and yields can be reduced. Winter canola, with earlier maturity than spring canola, has a higher potential for escaping high temperatures at flowering. Low crop prices and lack of an established market infrastructure for canola are significant obstacles to more widespread production in Colorado. With limited grower experience and the lack of insurance programs, production of canola has been limited. Canola seed oil content ranges from 40 to 45%.

Camelina is a promising new oilseed crop that has become the subject of widespread research in the last few years because Camelina is not attacked by flea beetles, is more resistant to drought than other spring oilseed crops, and can be directly harvested. It can be grown in dryland and limited irrigation cropping systems. Water requirements for irrigated Camelina are being investigated but like canola its peak water demand is early in the season when full summer crop water demands are low. Camelina is an early maturing crop, planted in early April and harvested in mid-July. Although some production issues must be solved, Camelina could become an excellent crop for our wheat-based no-till cropping systems that dominate eastern Colorado. If there is sufficient spring precipitation, Camelina can be planted in the spring following fall harvest of corn or sunflowers or proso millet and can be harvested in time to allow for accumulation of late July to mid-September precipitation before planting wheat. Instead of harvesting two crops in three years, the current improved cropping system, by producing Camelina in the spring it would be possible to harvest three crops in three years. Camelina is a low input crop. The seed is extremely small (~350,000 seeds/lb), seeding rates are low (~5 lb/ac), and seed costs are low. Fertilizer requirements are low and response to nitrogen fertilizer application has been low.


Camelina Flowers

Several private seed companies and universities have Camelina improvement projects that are providing more adapted Camelina cultivars for Colorado. Winter Camelina is more winter hardy than winter canola and can be planted later in the fall and still survive low winter temperatures. Camelina does not require any special planting equipment and can be directly harvested which means that equipment is readily available for production. Insect pressure on Camelina is almost non-existent. Camelina oil is high in Omega 3 fatty acids and oil studies are currently underway to determine if real health benefits result from consumption of Camelina oil. Camelina meal has been fed under experimental condition to livestock in Montana and Wyoming and it appears that it is wholly satisfactory.

Currently, there are significant production and marketing constraints to Camelina. Understandably, the agronomics of Camelina production are less well known than for other crops. Due to small seed size, Camelina must be planted shallow and pressed into the soil to have good seed to soil contact. Camelina can be planted in early spring; some claim that it can be seeded anytime during the winter or spring. Emergence is slow under cool spring soil temperatures, especially in variable soil moisture conditions. Unlike canola, Camelina is not attacked by flea beetles but stand establishment and weed control, although difficult currently, are being investigated actively in the Great Plains and the Pacific Northwest. There is currently very little acreage of Camelina being planted in Colorado thus no grower 'check-off' program to support research and production. Federal and state agencies are providing research funds that have helped us address some basic water and fertilizer requirement issues and to conduct variety trials. For several years Camelina producers were able to sell seed to Blue Sun Biodiesel but seed prices were low and hauling to crushing facilities was an additional cost. Marketing needs to be fully investigated by producers before planting. Camelina is a small seeded crop that may require adjustments to equipment to prevent loss during harvest and hauling. The meal currently is not legal for sale as livestock feed although high Omega 3 content in the oil and meal indicates that it might be more beneficial than other oils for human and livestock health. Camelina oil content ranges from 32 to 35%.

ARDEC - CSU Farm

Events

Colorado Ag Classic and CSGA/Colorado Seed Industry Annual Meetings
December 10-11th, 2008
The Ranch, Loveland, CO

Rocky Mountain Compost School
April 14-17th, 2009
Fort Collins, CO
www.rockymountaincompostschool.info

Links and Resources

Institute for Livstock and the Environment: www.livestockandenvironment.info

Ammonia Best Management Practices: www.ammoniabmp.info

Rocky Mountain Compost School: www.rockymountaincompostschoo.info

Colorado State University's Crops Testing Program: www.csucrops.com

Manure Management Program at CSU: www.manuremanagement.info

CSU Extension Water Quality Program: www.csuwater.info

CSU Extension Precision Agriculture: www.precisionag.colostate.edu