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FREEWAYS TO FUEL: A BASELINE STUDY OF BIOFUEL FEEDSTOCK GROWTH ON NON TRADITIONAL AGRONOMIC LANDS IN UTAH

Prepared For:

Utah Department of Transportation
Research Division

Submitted By:

Utah State University
Department of Agriculture Science

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16. Abstract

The goal of the FreeWays to Fuel Project is to develop sustainable, agronomic, crop growth methods that will allow biofuel feedstock production to occur on marginal or non-traditional plots of lands.

Canola and Safflower plots were established in 2007 and 2008 along roadsides in four different regions of the Utah I-15 corridor. Harsh climatic conditions with above average temperatures and below average precipitation existed in both years. Plots were sprayed pre-plant with glyphosate herbicide to kill the existing vegetation and crops were planted using conventional Tye Pasture Pleaser no till drill. 2007 yields of safflower, spring and fall canola under control conditions were 706, 394, and 485 lbs/acre respectively. This represents less than 50 percent average yields for safflower and 25 percent yields for canola under normal climatic conditions. Roadside plots all yielded under 200 pounds/acre of seed for both crops. Two-thousand and eight seeds were placed two inches deep during planting to position them closer to moisture. No measureable yield was observed for any crops in control plots and less than 10 pounds/acre in roadside plots.

We found that it was not economical to grow oilseed crops for biodiesel production along Utah roadsides under the climatic conditions experienced during 2007 – 2008 while using a Ty no-till drill.

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1.0 INTRODUCTION

Nearly all highway, airport, and military areas in the United States currently cost money to maintain and they are often a safe harbor for noxious weeds and pests (Kuhns, WSDOT). Utah alone has over 5,000 miles of highway roadsides that require maintenance, not including airport or military areas. The public cost for highway roadside maintenance—which can reach over $300 per mile—to mow, control pests, and maintain these areas each year are high (UDOT 2007). These areas also pose the problem of growing noxious weeds. A potential solution for these issues could be to use them as an agronomic resource for growing biofuel crops.

With proper agronomic research, millions of acres of unused, non-traditional, agronomic lands could be put into biomass production for the production of biofuels.

- Roadways—Four million miles (if 25 percent of area is used = 10 million acres)
- Railroads—140,000 miles of rights-of-way (if 75 percent of area is used = one million acres)
- Airports—19,820 (if 100 acres/ airport = two million acres)
- Military—Department of Defense owns 30 million acres of arable land in the United States (if 30 percent of areas are used eight million acres)

Currently, most of these areas grow weeds or some non-biofuel plant to control dust and erosion. Their use as a biofuel crop growing area has not been explored or utilized. All of these areas require maintenance and currently none are producing biofuels of any kind. If these areas were put into biofuel crop production they could serve as resource areas disseminating healthy, clean burning fuels into local communities.

Project Objectives

Various feed stocks will be evaluated by scientific comparison of different agronomic cropping locations and a host of oilseed feedstock crops under the management of various university partners and guidance from Utah State University. Collection, transportation, and storage of these feedstocks will be conducted with conventional equipment. Researchers will

evaluate what planting methods/crop combinations will provide most benefit to sustainable plant establishment and yield. Recommendations and implementation strategies will also be include in a final report to all partners and disseminated at public forums and through scientific sources. The economic team of researchers will investigate the will investigate the economic viability of the project.

Preliminary calculations show with the assumption of 750 cwt yield per acre (2/3 regular dry land production Appendix D Israelsen) and a 100 foot wide growing space, this method could provide ≈ 350 gallons of biodiesel fuel per mile of highway. This does not include the increased production in areas such as the eastern half of the United States where there is enough rainfall to produce crops that yield about two times those of the dry land yield of the arid west, or areas where two crops could be grown in a 12 month season, such as California. Preliminary economic models show this can be done at a profit to a state which would normally spend about $300-$3000 per mile in mowing alone.

Biofuels have been talked about since before the invention of the diesel engine. Their cost of production has kept them from being explored seriously until recent fluctuations in the crude oil market. Biofuels are fuels that are made from biomass; most commonly corn and oil seed crops. Examples of biofuels are biodiesel and ethanol. Uses for biofuels include but are not limited to:

- Transportation—Cars, trucks, motorcycles/mopeds, boats, ships, submarines, trains, and planes
- Industrial and Ag—Heavy equipment, pumps, generators, and welders
- Home—Heaters and furnaces, ranges and ovens, lanterns, barbeques, patio heaters, lawnmowers, and chainsaws

The United States has almost four million miles of roadways (FHWA) that could potentially provide billions of gallons of biodiesel annually. This would result in an infusion of billions of dollars of relatively inexpensive—at current market prices—fuel into the economies of American communities, with particular emphasis on rural America.

This project explores a method of growing biofuel crops in areas along roadways, airports, public and private right of ways, military areas, unused construction areas, and

government and subsidy lands. To date, these locations have been underutilized for biofuel production and are often a breeding ground for pests. This project would provide information necessary for using these areas to grow biofuel crops, which can be converted into clean burning fuels that are sustainable, decrease emissions, and provide employment for local communities. The beneficial uses of biofuels, such as biodiesel, are well documented by entities like the National Biodiesel Board.

> "In 2000, biodiesel became the only alternative fuel in the country to have successfully completed the EPA-required Tier I and Tier II health effects testing under the Clean Air Act. These independent tests conclusively demonstrated biodiesel's significant reduction of virtually all regulated emissions, and showed biodiesel does not pose a threat to human health. Biodiesel contains no sulfur or aromatics, and use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. A U.S. Department of Energy study showed that the production and use of biodiesel, compared to petroleum diesel, resulted in a 78.5% reduction in carbon dioxide emissions....In addition to being a domestically produced, renewable alternative fuel for diesel engines, biodiesel has positive performance attributes such as increased octane, high fuel lubricity, and high oxygen content, which may make it a preferred blending stock with future ultra-clean diesel.
>
> Effective November 1998, Congress approved the use of biodiesel as an Energy Policy Act (EPAct) compliance strategy. The legislation allows EPAct-covered fleets (federal, state and public utility fleets) to meet their alternative fuel vehicle purchase requirements simply by buying 450 gallons of pure biodiesel and burning it in new or existing diesel vehicles in at least a 20% blend with diesel fuel. The Congressional Budget Office and the U.S. Department of Agriculture have confirmed that the biodiesel option is the least-cost alternative fuel option for meeting the Federal government's EPAct compliance requirements. Because it works with existing diesel engines, biodiesel offers an immediate and seamless way to transition existing diesel vehicles into a cleaner burning fleet"(personal communication with Don Scott, National Biodiesel Board).

If successful, this process would become a triple hit by producing sustainable fuels from idle areas that are costly to maintain and an economic drain for taxpayers, providing a mechanism to economically control weeds harbored by these areas, and supporting the local economy by creating jobs and relatively inexpensive fuels. By using this method, fuel can be grown in largely unused agronomic areas and processed in a more sustainable manner, decreasing the need for transportation of fuel feedstock from long distances, such as crude oil or current biofuel stocks (e.g. soybeans from the Midwest to California). It is the purpose of this study to investigate the use of planting, fertilizing, controlling weeds, and harvesting methods to rapidly adapt and economically grow biofuel in these areas.

The potential application of this research is to reduce the dependence of America on foreign, high polluting, petroleum fuels by using an untapped resource. State Departments of Transportation could invest in the agronomic equipment necessary to grow the crop (most of which they already possess for maintenance) and fully integrate the process of making biodiesel in-house. Alternatively they could coordinate/contract with local farmers to grow roadside oil seed crops and have the seeds transported to a regional facility where the biomass (a renewable energy source that is biological material), would be turned into biodiesel for their fleet and equipment. Another application would be to have local farmers contract with the state to lease the roadside ground and produce biodiesel for their farm operation. All of these applications increase local job demand and decrease dependence on foreign oil.

If this non-productive land was converted into biofuel producing land, it would benefit the public in the following ways: local fuel production, reduced air pollutants, decreased land maintenance costs, enhanced visual quality of the community, public transportation, and reduced carbon footprints and greenhouse gases.

With rapidly changing technological development on the refining side of the biofuels process already in place, the focus of this project is to grow and process biofuels in a more environmentally friendly, economically feasible, and sustainable manner. The goal of this study is get proof of concept that will result in the rapid adoption of this method. Proof of concept in this case means production of oilseed crops along roadways in an economically efficient and feasible manner. If successful, this will lead to implementation of this new technology on a state-wide basis for transit vehicles. This environmentally efficient fuel should be a first priority for use by local transit authorities to power vehicles because of its sustainability and increased engine performance. For this to take place, local farmers with existing equipment could immediately begin managing sections of highways for biofuel crops, much like is done in mid-western states for the harvest of grass for forage use. The yield of the crops would then be processed and the resultant fuels could be utilized in transit vehicles or state fleets.

The United States consumed over 100 billion gallons of gasoline and over 60 billion gallons of diesel in 2005 (USEIA). A majority of that energy comes from fossil fuels that are imported (60%) from other countries around the world. When these fuels are combusted, they not only release enormous amount of pollutants into the atmosphere causing disease and distress,

but they add to the net carbon content of the atmosphere. In the last decade, the majority of growth in greenhouse gas (GHG) emissions came from heavy duty trucks (USEPA). The United States has almost four million miles (FHWA) of roadways that potentially could provide a billion gallons of biodiesel/year. This would result in the infusion of billions of dollars of relatively inexpensive (at current market prices) fuel into the economies of American communities and decrease dependence on petroleum based fuels. The beneficial uses of biofuels such as biodiesel are well documented.

Oilseed crop production is not new to Utah or the Northwest. An estimated 2/3 dry land yield of both safflower and fall canola (Armah-Agyeman, Berglund, Bergman, Franzen) would return the amount of money spent on current maintenance activities along UDOT rights-of-ways given normal growing conditions and assumptions previously listed. The use of roadsides for hay crops is an ongoing method of decreasing maintenance costs along roadways in the Midwest (Kuhns, Martinson). In 2006 a California farmer harvested oats along I-505 for feed and straw (Figure 1.1). To date, no one except the FreeWays to Fuel team has investigated the use of these areas for biodiesel production.

Figure 1.1 Off-ramp area being harvested for oats along I-505 in California

Nearly all highway, airport, railway, and military areas in the United States have fallow agronomic areas that require maintenance, which costs the public or consumer significant monies. In addition to costly maintenance, these areas harbor noxious weeds and pests and often

become unattractive (weedy) parcels. For example, Utah has over 5000 miles of highway rights-of-way, which translates into over 1.5 million acres that need maintenance on an annual basis. The public costs to mow, control pests, and maintain these areas can reach over $300/mile/year which totals over 1.7 million dollars annually (2007 Utah Department of Transportation).

A potential solution for this problem is growing biofuel feedstock crops along the freeway rights-of-way under dry land conditions to convert into biofuels. Benefits of biofuel production with this method include:

- Displacement of petroleum usage with biofuels by the Utah Department of Transportation and other states that adopt this method.
- Food supply would not be affected by this method as acreage not currently used for food would be utilized.
- A decrease in weed pressures and subsequent use of pesticides along targeted areas such as roadsides.
- Significant decrease in exhaust emissions from equipment when biofuels grown on these areas are utilized in government and private fleets.
- Increased aesthetics along utilized areas.
- Increased sustainability of utilized areas.
- Decreased costs of maintenance—in some cases actually provides financial benefits
- Increase public awareness regarding biomass and biofuels by “freeway” exposure.
- Decrease fire danger of targeted areas because of biofuel crops.

This concept is somewhat elucidated by Buchanan et al. and Cherney et al. by stating that use of this land needs to be improved, and may be useful for livestock feed. FreeWay to Fuels (F2F) is a proposed method of using fallow areas along freeway rights-of-ways, railroads, airports and other non-traditional agronomic land to produce sustainable biomass for conversion into biofuels. Fuel to be researched from this process includes, but is not limited to, biodiesel from the oils of canola and safflower crops.

Preliminary work conducted in 2007 show conditions along UDOT highway rights-of-way meet the minimum growth standards for canola and safflower and should provide necessary growth conditions for a feasible yield. Initial soil analysis for plot regions of highway shoulders

show that physical and chemical soil conditions are favorable for growth of oilseed crops with the exception of high compaction conditions.

It is the purpose of this project to develop methods of crop establishment that will allow sustainable, economical, biofuel feedstock production to occur in these non-traditional agronomic areas.

FreeWays to Fuel

FreeWays to Fuel (F2F) seeks to enhance national energy security through development, distribution, and implementation of biobased energy technologies. This is provided through the growth of biofuel feedstocks on non-traditional agronomic lands such as freeway shoulders, railway rights-of-way, military lands, and airport facilities. The high visibility of this project will help to promote the education of the public to biofuels and biomass products.

F2F seeks to promote diversification and environmental sustainability of agricultural production in the United States through biobased energy and product technologies. Specifically, F2F seeks to utilize land currently overlooked as agronomically valuable but requires maintenance, with the utilization of petroleum based fuels and equipment. F2F hypothesizes that at least 40 million acres of roadside area across the country could be considered for this project, leading to billions of dollars of savings for taxpayers and rural and economic development, while decreasing dependence on petroleum fuel. Roadsides are the first step in utilizing non-traditional agronomic lands. There are many more opportunities such as railways, power company rights-of-ways, military, and other municipality lands that should be considered for biofuel production.

F2F seeks to promote economic diversification in rural areas of the United States through biobased energy and product technologies. Current methods of plant oil esterifictation lend to easy, segmented, small scale production. In one scenario, DOT's, railways, and military institutions would provide contracts with local farmers or other interested parties to plant, harvest, and ship biofuel feedstocks. In the preferred scenario, the construction of small regionalized processing plants close to where biofuel feedstocks are grown and harvested would also help increase rural development along with supporting new jobs. As new technology platforms such as thermal and cellulosic biomass to biofuel/bioproduct come online, this method could be readily adapted to them.

F2F seeks to enhance the efficiency of bioenergy and biomass research and development programs through improved coordination and collaboration between the Department of Agriculture, the Department of Energy, and Land Grant colleges and universities. This coordination is enhanced because F2F already has interest from DOT's and Land Grant Universities in addition to those found in Utah. Once developed, this method will be readily adaptable to other agencies and regions of the country and world.

Proposed feedstocks for this project are varieties of safflower and canola which are commonly grown in the western United States region. They are well adapted to dry-land growth and are suspected to yield well in unique, and often overlooked, landscapes/climates, such as highway shoulders and rights-of-way. Collection, transportation, and storage of these feedstocks will be conducted with conventional equipment which gives hope to rapid transition of this technology to the public sector and implementation within 3 to 4 years. This proposed project focuses on methods to establish existing feedstocks that could be instrumental in assisting the education of urban and rural areas in biofuel production/sustainability and the economic benefits of growing a biomass feedstock industry that can be utilized for reduced dependence on imported petroleum fuels and enhanced rural economic development in the United States.

This project was designed to develop sustainable, agronomic crop growth methods that will allow feasible oilseed feedstock production to occur in marginal or non-traditional agronomic areas (e.g. roadways, railroads, airports, military installations) within 3 to 4 years.

If successful, the FreeWays to Fuel concept could pave the way for biofuel crops to be grown in largely unused agronomic areas and processed in a more sustainable manner, decreasing need for transportation of fuel feedstock from long distances such as crude oil or current biofuel stocks (i.e. soybeans from the Midwest to California). As new thermal or cellulosic platforms become available, this number should increase and be more available. As long as there are rights-of-ways there will be a need for maintenance. Converting the rights-of-ways to the production of biofuel crops seems, environmentally sound, and fiscally possible.

Interest in F2F is already being shown from other states (Michigan, Tennessee, North Carolina, and Washington). Members of academic, research, extension, and production sectors have been researching the application of F2F in their local areas. The National Biodiesel Board

cited this as a project in their 2008 - 2009 meetings. Members of automotive, biofuel, biomass and agricultural organizations have also expressed interest in the process. This process would draw on a large pool of participants and integrate many different facets of renewable energy education, research, extension, and production.

Potentially, millions of acres along FHWA rights-of-way could be put into production, nearly doubling the amount of biodiesel feedstock currently available. This would occur without any affect on traditional agricultural acreages or processes. This acreage would significantly impact the amount of biodiesel feedstock available. The application of this research would reduce the dependence of the United States on foreign, high pollution, petroleum fuels by using an untapped resource at home.

State departments of transportation (DOT's) could utilize conventional agronomic equipment necessary to grow the crop—most of which they own to conduct normal maintenance—and fully integrate the process of making biodiesel in-house. Alternatively, they could coordinate/contract with local farmers to grow roadside oilseed crops and have the seeds transported to regional facilities, or have the farmers convert the oil where the biomass would be turned into biodiesel for fleet and equipment. Another application would be for local farmers to contract with the state to lease roadside ground and make biodiesel for their farm operation. In summary, benefits of this project with proper agronomic methods to the public include: local biofuel production, reduced air pollutants, decreased maintenance costs, subsequent tax relief, decreased weed species, enhanced visual quality of the rights-of-way, increased use of biofuel public land stewards, possibility of sale of biofuels on the local market, and reduced carbon footprint and greenhouse gases.

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2.0 ECONOMICS

Introduction

FreeWays to Fuel model demonstrates that maintained non-traditional agronomic land can become an economic benefit to stewards rather than a loss. Collection, transportation, and storage of these feed stocks will utilize conventional equipment which provides for a rapid transition of this technology to the public sector and successful implementation within 3 to 4 years. If applied nationally, this strategy would, in theory, produce economically viable feedstock sustainably displacing approximately one billion gallons of conventional diesel fuel per year, and the resultant carbon emission.

Economic models based on glyphosate resistant winter canola production show feasible production of ≈350 gallons of biodiesel per mile, given approximately 2/3 dry land yield in a growing area totaling 100 feet in width along roadways. This yield appears to be sustainable with as little as 14 inches of precipitation per year. Economic models show this can save the Utah Department of Transportation (UDOT) the $300 per mile which they would normally spend in mowing alone (assume petrol diesel costs above $3.00/gal and yields of 6 cwt/acre. The vast difference in cost between private agricultural models and the FreeWays to Fuel model include land, insurance, and customized application of pesticides. To date, most of these roadside areas now grow weeds, or some non-oil producing plant, to control dust and erosion. This project could explore cellulosic ethanol production from remaining residues where oilseed crop growing areas have not been explored or utilized in any part of the world. UDOT consumes approximately one million gallons of petro diesel per year for use in equipment like those shown in Figure 2.1. This method of biodiesel production would produce enough biodiesel annually to run UDOT's fleet given the assumptions listed above. This paradigm would be a new frontier for the growth of biomass utilized for biofuels. Growth of oilseed crops along freeways and coupled with the production of ethanol from the remaining biomass residues present a new frontier in renewable energy production. This procedure would add to transportation resources and disseminate healthy, clean burning fuels into local communities along with the creation of jobs in rural areas.

Figure 2.1 Equipment that could be used for F2F grown biodesel

Calculation Metrics for Model

The economic feasibility of this model is outlined in Table 2.1 below. Calculations associated with the costs of producing B100 are detailed in the table. Footnotes following the table explain the calculations necessary for the economic model.

Utah F2F Model - Private Contractor, Aerator and Biosolids/Nitrate Fertility							
*baseline values compared to Eastern Washington Estimates by Kathleen Painter and Dennis Roe: http://cff.wsu.edu/Publications/budgets/dryland%20winter%20canola%20budget_14inch.xls							
Cost/Acre							
processing costs/acre	$31.68	**Operating Costs**	units	cost/unit	total		
gallons of B100/acre*	26.4	Aerator/Spreader/Seeder	1	$2.00	$2.00		
meal for cattle feed	$38.88	Canola Seed	8	$2.00	$16.00	*adjusted to untreated prices	
Total Cost B100/acre	**$71.83**	Nitrogen ((NH4)2SO4	5	$0.55	$2.75		
Worth of B100/acre	**$79.20**	biosolids (Class A)	5	$3.00	$15.00		
profit/acre	**$7.37**	P2O5	0	$0.30	$0.00		
cost B100/gal	**$2.72**	Sulfur	0	$0.19	$0.00		
		Herbicide - glyphosate	2	$5.00	$10.00	*adjusted to generic prices	
Cost/Mile		Insecticides	0.1	$7.00	$0.70	*adjusted to generic prices	
market diesel value	**$3.00**	Fuel - Diesel/Gasoline	2	$3.00	$6.00		
width of growing area(ft)	**75.0**	Machinery Repair	1	$5.98	$5.98	*this may be modified down	
acres of grow area/mile	**9.1**	Labor (machine)	2.5	$12.00	$30.00		
yield per mile cwt	**54.5**	Labor (non-machine) hrs	0.25	$12.00	$3.00		
gallons of oil/mile	**240.0**	Interest on Capital @ 5.50%	0	$2.50	$0.00		
cost B100 production/mile	**$653.00**	**Total Operating Costs/Acre**			**$91.43**		
value of B100/mile	**$720.00**						
profit/mile to grower	**$67.00**						
Savings to DOT/Mile	**$300.00**	**Fixed Costs**					
		General Overhead		$2.00	$2.00		
		Lease Payment/Depreciation		$6.00	$6.00	*alternative cropping methods	
Assumptons:		Machinery Interest		$0.00	$0.00	*all equipment leased	
yield cwt/acre**	6.0	Traffic Control Costs		$4.00	$5.00		
cost of maint/mile	$300.00	Land Rent		$0.00	$0.00	*state owned	
cost of maint/acre	$33.00	Management Fee		$1.00	$1.00		
pressing per gal	$0.40	Fallow Cost		$0.00	$0.00	*state owned - no rent due	
processing costs (gallon)	$0.80	Property Taxes		$0.00	$0.00	*state owned	
fuel tax credit	$1.00	Insurance		$0.00	$0.00	*state owned	
weight of oil per gal	7.6	**Total Cash Ownership Costs/Acre**			**$14.00**		
seed oil content (%)	40.0%						
extraction efficiency (%)	88.0%	**Total Cost/Acre**			**$105.43**		
value of meal/ton	$200.00						
*95% conversion							
**lower than average yeilds		assumptions:					
		commercial production costs >200.00/acre					
		14" of precipitation					

Table 2.1 Utah F2F Economic Model–Private Contractor, Aerator and Biosolids/Nitrate Fertility

Formulas for calculations used in Table 2.1

- processing costs/acre = gallons of B100/acre × (pressing per gal + processing costs per gallon)
- gallons of B100/acre = yield cwt/acre × 100 lbs × weight of oil per gal × seed oil content (percent) × extraction efficiency (percent)

- meal for cattle feed = (value of meal/ton ÷ yield cwt/acre) ÷ 20 × (1.00 − seed oil content (percent) × extraction efficiency (percent))
- Total Cost B100/acre = Total Cost/Acre + processing costs per gallon – (fuel tax credit × gallons of B100/acre)
- Value of B100/acre = gallons of B100/acre × market diesel fuel value
- profit/acre = Value of B100/acre - Total Cost B100/acre
- cost B100/gal = Total Cost B100 per acre ÷ gallons of B100 per acre
- market diesel value = current market value of diesel
- width of growing area(ft) = width of growing area available along roadside – inclusive of shoulder and median areas
- acres of growing area/mile = width of growing area(ft) ×5280 ft ÷ 43560 ft
- yield per mile cwt = acres of cropped area/mile × yield cwt/acre
- gallons of oil/mile = gallons of B100/acre × acres of grow area/mile
- cost B100 production/mile = Total Cost B100/acre × acres of grow area/mile
- value of B100/mile = market diesel value × gallons of oil/mile
- Savings per mile = profit/acre× acres of grow area/mile + maintenance fees
- yield cwt/acre = lbs of seed ×100/acre
- cost of maintenance/mile = value given from DOT
- cost of maintenance/acre = cost of maintenance/mile ÷ acres of grow area/mile
- pressing/gal = seed oil crushing costs
- processing costs/gallon = materials and labor to convert seed oil into biodiesel
- fuel tax credit = the volumetric excise tax credit for Agri-Biodiesel is $1.00 per gallon
- weight of oil per gal ≈ 7.6 lbs/gallon
- seed oil content (percent) = amount of total oil by mass in seed
- extraction efficiency (percent) = amount of oil actually extracted from the seed
- value of meal/ton = market value (canola meal is one of the most widely used protein sources in animal feeds http://www.canola-council.org/canola_meal.aspx)
- Total Operating Costs/Acre = all inputs including planting, fuel, fertilizer, pesticides, machinery, labor

- Total Cash Ownership Costs/Acre = machinery costs, management fees, land costs
- Total Costs/Acre = total Operating Costs/Acre + Total Cash Ownership Costs/Acre

(-) in the above calculations = minus sign

Assuming $3.00/gallon biodiesel production costs 40 percent average oil content, 85 percent extraction efficiency, $200.00 per ton of meal for livestock feed, operation production costs of $100.00/acre and 95 percent conversion output as described in figure 2.0. At 700 cwt of oilseed yield and $2.00/gal petroleum diesel, UDOT would have to pay $146.18/mile in addition to the $300.00 of maintenance budget money/mile to produce biodiesel. With this method, UDOT would realize a $300.00 savings/mile as they near either the 900 pounds of oilseed/acre range with petroleum fuels at $2.50/gal, or 700 pounds of oilseed/acre range with petroleum prices approaching $3.25/gal. On the extremely high end of the matrix, petroleum fuel at 4.00/gal and yields of 2100 pounds of oilseed/acre would yield an almost 10X savings with respect to current maintenance budgets. Table 2.2 illustrates a break even matrix with two variables, petroleum fuel costs and oilseed yield per acre. The table includes a range of $2.00/gal and 700 lbs/acre to $4.00/gal and 2100 lbs/acre of oilseed production per acre scenarios.

Savings/Mile Matrix								
	production lbs/acre							
	700	900	1100	1300	1500	1700	1900	2100
fuel costs								
$2.00	-$446.18	-$224.36	-$2.55	$219.27	$441.09	$662.91	$884.73	$1,106.55
$2.25	-$356.03	-$108.45	$139.12	$386.70	$634.27	$881.85	$1,129.42	$1,377.00
$2.50	-$265.88	$7.45	$280.79	$554.12	$827.45	$1,100.79	$1,374.12	$1,647.45
$2.75	-$175.73	$123.36	$422.45	$721.55	$1,020.64	$1,319.73	$1,618.82	$1,917.91
$3.00	-$85.58	$239.27	$564.12	$888.97	$1,213.82	$1,538.67	$1,863.52	$2,188.36
$3.25	$4.58	$355.18	$705.79	$1,056.39	$1,407.00	$1,757.61	$2,108.21	$2,458.82
$3.50	$94.73	$471.09	$847.45	$1,223.82	$1,600.18	$1,976.55	$2,352.91	$2,729.27
$3.75	$184.88	$587.00	$989.12	$1,391.24	$1,793.36	$2,195.48	$2,597.61	$2,999.73
$4.00	$275.03	$702.91	$1,130.79	$1,558.67	$1,986.55	$2,414.42	$2,842.30	$3,270.18
assumptions: state operated, no excise tax credit and conventional fertility								

Table 2.2 Break Even Matrix for FreeWays to Fuel

In this scenario states would utilize equipment already in inventory to maintain roadsides for oilseed crop production. Additional equipment may have to be purchased for harvest and refining oilseed into biodiesel. These are included into the equation under machinery expenses, pressing/gal, and processing costs in Table 2.0. The economic model in Table 2.0 would utilize conventional fertility inputs vs. low cost biosolids fertility inputs in Table 2.1. Cost savings over conventional production by private growers include land costs, property taxes, machinery interests, and insurance. Table 2.4 illustrates the idea of states fully integrating the production of oilseed crops, refining of the biomass into biodiesel start to finish.

Table 2.3 illustrates the same concept as Table 2.1, with the exception of the use of inorganic nitrogen as crop fertilizer, rather than biosolid fertility inputs. Table 2.1 and Table 2.3 illustrate the idea of states forming public/private relationships with local growers to produce oilseed crops and refining of the biomass into biodiesel. In this scenario states would likely contract with area growers to grow the crops, harvest the crops, and refine the crops into useable biofuels. All models would utilize the federal excise tax credit for virgin oil biodiesel production.

Utah F2F Model - Private Contractor, Aerator and Nitrate Fertility									
*baseline values compared to Eastern Washington Estimates by Kathleen Painter and Dennis Roe:									
http://cff.wsu.edu/Publications/budgets/dryland%20winter%20canola%20budget_14inch.xls									
Cost/Acre									
processing costs/acre	$31.68		**Operating Costs**	units	cost/unit	total			
gallons of B100/acre*	26.4		Aerator/Spreader/Seeder	1	$2.00	$2.00			
meal for cattle feed	$38.88		Canola Seed	8	$2.00	$16.00		*adjusted to untreated prices	
Total Cost B100/acre	**$81.58**		Nitrogen ((NH4)2SO4	50	$0.55	$27.50			
Worth of B100/acre	**$79.20**		biosolids (Class A)	0	$3.00	$0.00			
profit/acre	**-$2.38**		P2O5	0	$0.30	$0.00			
cost B100/gal	**$3.09**		Sulfur	0	$0.19	$0.00			
			Herbicide - glyphosate	2	$5.00	$10.00		*adjusted to generic prices	
Cost/Mile			Insecticides	0.1	$7.00	$0.70		*adjusted to generic prices	
market diesel value	**$3.00**		Fuel - Diesel/Gasoline	2	$3.00	$6.00			
width of growing area(ft)	**75.0**		Machinery Repair	1	$5.98	$5.98		*this may be modified down	
acres of grow area/mile	**9.1**		Labor (machine)	2.5	$12.00	$30.00			
yield per mile cwt	**54.5**		Labor (non-machine) hrs	0.25	$12.00	$3.00			
gallons of oil/mile	**240.0**		Interest on Capital @ 5.50%	0	$2.50	$0.00			
cost B100 production/mile	**$741.64**		**Total Operating Costs/Acre**			**$101.18**			
value of B100/mile	**$720.00**								
profit/mile to grower	**-$21.64**								
Savings to DOT/Mile	**$300.00**		**Fixed Costs**						
			General Overhead		$2.00	$2.00			
			Lease Payment/Depreciation		$6.00	$6.00		*alternative cropping methods	
Assumptons:			Machinery Interest		$0.00	$0.00		*all equipment leased	
yield cwt/acre**	6.0		Traffic Control Costs		$4.00	$5.00			
cost of maint/mile	$300.00		Land Rent		$0.00	$0.00		*state owned	
cost of maint/acre	$33.00		Management Fee		$1.00	$1.00			
pressing per gal	$0.40		Fallow Cost		$0.00	$0.00		*state owned - no rent due	
processing costs (gallon)	$0.80		Property Taxes		$0.00	$0.00		*state owned	
fuel tax credit	$1.00		Insurance		$0.00	$0.00		*state owned	
weight of oil per gal	7.6		**Total Cash Ownership Costs/Acre**			**$14.00**			
seed oil content (%)	40.0%								
extraction efficiency (%)	88.0%		**Total Cost/Acre**			**$115.18**			
value of meal/ton	$200.00								
*95% conversion									
**lower than average yeilds			assumptions:						
			commercial production costs >200.00/acre						
			14" of precipitation						

Table 2.3 Utah F2F Economic Model - Private Contractor, Aerator and Nitrate Fertility

Utah F2F Model - DOT Operated, Aerator and Biosolids/Nitrate Fertility

*baseline values compared to Eastern Washington Estimates by Kathleen Painter and Dennis Roe:
http://cff.wsu.edu/Publications/budgets/dryland%20winter%20canola%20budget_14inch.xls

Cost/Acre							
processing costs/acre	$31.68		**Operating Costs**	units	cost/unit	total	
gallons of B100/acre*	26.4		Aerator/Spreader/Seeder	1	$2.00	$2.00	
meal for cattle feed	$38.88		Canola Seed	8	$2.00	$16.00	*adjusted to untreated prices
Total Cost B100/acre	**$88.33**		Nitrogen ((NH4)2SO4	5	$0.55	$2.75	
Worth of B100/acre	**$79.20**		biosolids (Class A)	5	$3.00	$15.00	
profit/acre	**-$9.13**		P2O5	0	$0.30	$0.00	
cost B100/gal	**$3.35**		Sulfur	0	$0.19	$0.00	
			Herbicide - glyphosate	2	$5.00	$10.00	*adjusted to generic prices
Cost/Mile			Insecticides	0.1	$7.00	$0.70	*adjusted to generic prices
market diesel value	**$3.00**		Fuel - Diesel/Gasoline	2	$3.00	$6.00	
width of growing area(ft)	**75.0**		Machinery Repair	1	$5.98	$5.98	*this may be modified down
acres of grow area/mile	**9.1**		Labor (machine)	2.5	$18.00	$45.00	
yield per mile cwt	**54.5**		Labor (non-machine) hrs	0.25	$18.00	$4.50	
gallons of oil/mile	**240.0**		Interest on Capital @ 5.50%	0	$2.50	$0.00	
cost B100 production/mile	**$803.00**		**Total Operating Costs/Acre**			**$107.93**	
value of B100/mile	**$720.00**						
profit/mile to grower	**-$83.00**						
Savings to DOT/Mile	**$300.00**		**Fixed Costs**				
			General Overhead		$2.00	$2.00	
			Lease Payment/Depreciation		$6.00	$6.00	*alternative cropping methods
Assumptons:			Machinery Interest		$0.00	$0.00	*all equipment leased
yield cwt/acre**	6.0		Traffic Control Costs		$4.00	$5.00	
cost of maint/mile	$300.00		Land Rent		$0.00	$0.00	*state owned
cost of maint/acre	$33.00		Management Fee		$1.00	$1.00	
pressing per gal	$0.40		Fallow Cost		$0.00	$0.00	*state owned - no rent due
processing costs (gallon)	$0.80		Property Taxes		$0.00	$0.00	*state owned
fuel tax credit	$1.00		Insurance		$0.00	$0.00	*state owned
weight of oil per gal	7.6		**Total Cash Ownership Costs/Acre**			**$14.00**	
seed oil content (%)	40.0%						
extraction efficiency (%)	88.0%		**Total Cost/Acre**			**$121.93**	
value of meal/ton	$200.00						
*95% conversion							
**lower than average yeilds			assumptions:				
			commercial production costs >200.00/acre				
			14" of precipitation				

Table 2.4 Utah F2F Model—DOT Operated, Aerator and Biosolids/Nitrate Fertility

Utah F2F Model - DOT Operated, Aerator and Nitrate Fertility							
http://cff.wsu.edu/Publications/budgets/dryland%20winter%20canola%20budget_14inch.xls							
Cost/Acre							
processing costs/acre	$31.68		**Operating Costs**	units	cost/unit	total	
gallons of B100/acre*	26.4		Aerator/Spreader/Seeder	1	$2.00	$2.00	
meal for cattle feed	$38.88		Canola Seed	8	$2.00	$16.00	*adjusted to untreated prices
Total Cost B100/acre	**$98.08**		Nitrogen ((NH4)2SO4	50	$0.55	$27.50	
Worth of B100/acre	**$79.20**		biosolids (Class A)	0	$3.00	$0.00	
profit/acre	**-$18.88**		P2O5	0	$0.30	$0.00	
cost B100/gal	**$3.72**		Sulfur	0	$0.19	$0.00	
			Herbicide - glyphosate	2	$5.00	$10.00	*adjusted to generic prices
Cost/Mile			Insecticides	0.1	$7.00	$0.70	*adjusted to generic prices
market diesel value	**$3.00**		Fuel - Diesel/Gasoline	2	$3.00	$6.00	
width of growing area(ft)	**75.0**		Machinery Repair	1	$5.98	$5.98	*this may be modified down
acres of grow area/mile	**9.1**		Labor (machine)	2.5	$18.00	$45.00	
yield per mile cwt	**54.5**		Labor (non-machine) hrs	0.25	$18.00	$4.50	
gallons of oil/mile	**240.0**		Interest on Capital @ 5.50%	0	$2.50	$0.00	
cost B100 production/mile	**$891.64**		**Total Operating Costs/Acre**			**$117.68**	
value of B100/mile	**$720.00**						
profit/mile to grower	**-$171.64**						
Savings to DOT/Mile	**$300.00**		**Fixed Costs**				
			General Overhead		$2.00	$2.00	
			Lease Payment/Depreciation		$6.00	$6.00	*alternative cropping methods
Assumptons:			Machinery Interest		$0.00	$0.00	*all equipment leased
yield cwt/acre**	6.0		Traffic Control Costs		$4.00	$5.00	
cost of maint/mile	$300.00		Land Rent		$0.00	$0.00	*state owned
cost of maint/acre	$33.00		Management Fee		$1.00	$1.00	
pressing per gal	$0.40		Fallow Cost		$0.00	$0.00	*state owned - no rent due
processing costs (gallon)	$0.80		Property Taxes		$0.00	$0.00	*state owned
fuel tax credit	$1.00		Insurance		$0.00	$0.00	*state owned
weight of oil per gal	7.6		**Total Cash Ownership Costs/Acre**			**$14.00**	
seed oil content (%)	40.0%						
extraction efficiency (%)	88.0%		**Total Cost/Acre**			**$131.68**	
value of meal/ton	$200.00						
*95% conversion							
**lower than average yeilds			assumptions:				
			commercial production costs >200.00/acre				
			14" of precipitation				

Table 2.5 Utah F2F Model—DOT Operated, Aerator and Nitrate Fertility

Results and Discussion

Several different scenarios to growing, harvesting and processing biodiesel feedstock have been examined. They include fully integrated state operated solutions, and a public-private integrations with both organic and inorganic fertility variables.

Table 2.6 shows the results of each relative to savings/profit per mile utilizing F2F maintenance cost reduction methods. State operated systems do not access the 1.00/gallon excise tax credit option offered to private growers. Biosolid fertility inputs on both state operated and public/private relationships dramatically increased savings/profit per mile.

Comparison of DOT vs. Private Contractor Savings/Profit from F2F Method			
	Savings/Profit per Mile		
	DOT	Private	Combined
Private Contractor, Aerator and Biosolids/Nitrate Fertility	$300.00	$67.00	$367.00
Private Contractor, Aerator and Nitrate Fertility	$300.00	-$21.64	$278.36
DOT as Contractor, Aerator and Biosolids/Nitrate Fertility	-$83.00	$0.00	-$83.00
DOT as Contractor, Aerator and Nitrate Fertility	-$171.64	$0.00	-$171.64
assumptions: petrol diesel at $3.00, 75 ft wide growing area, $1.00/gal tax credit, 6 cwt/acre			

Table 2.6 Savings/Profit Comparison of State Operated vs. Private Operated F2F Maintenance

Figure 2.2 shows the majority of savings compared to conventional growth of oilseed crops utilizing F2F methods. Major savings include land costs, taxes, interest and insurance.

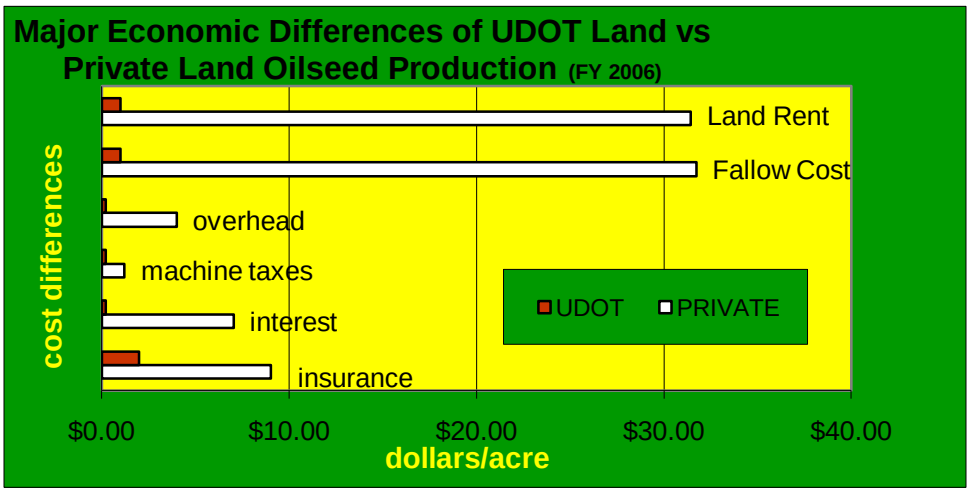

Figure 2.2 F2F Economic differences between conventional and F2F costs

Conclusion

With the information elucidated above, the private contractor utilizing inexpensive public biosolids for fertility brings the most total savings/profit for the parties involved in both the state operated and public/private scenario. Using inexpensive municipal biosolids for fertility inputs decreases the cost of F2F produced biodiesel $0.39 and $0.45 by state operated and public/private operations respectively.

UDOT can potentially save 1.7 million dollars per year in maintenance fees ($300/mile) by public/private relationships that produce 6.0 cwt given the information in Table 2.0 and growers can profit $67 per mile given the same assumptions.

3.0 AGRONOMIC CONDITIONS ALONG UTAH ROADSIDES

Introduction

Current US public policies combined with global demand for low-carbon fuels have created a strong market for more sustainable advanced biofuels, particularly biodiesel. However, according to Don Scott, Sustainability Director for the National Biodiesel Board, "70 percent of the [US] biodiesel plants…are sitting idle because of the lack of affordable feedstock" (Personal communication, February 2009).

The goal of the FreeWays to Fuel Project is to develop sustainable, agronomic crop growth methods that will allow biofuel feedstock production to occur on marginal or non-traditional plots of land (e.g., roadways, railroads, airports, military installations). Recent economic feasibility models by Utah State University indicate that said agronomic lands in the United States would, in theory, produce one billion gallons of economically viable new feedstock annually. Specifically, USU models show that if 60 percent (700 pounds/acre) of dry land oilseed can be produced, maintenance costs of these non-traditional agronomic lands can be recovered as well as production of approximately 30 gallons/acre of renewable biodiesel. Any yields above this would add to the partners revenue streams.

With proper agronomic research, millions of acres of unused non-traditional agronomic lands could be put into biomass production for the production of biofuels. This feedstock yield would increase US biodiesel production between 100-200 percent and save federal and state agencies substantial financial resources. Preliminary impact considerations that have been taken into account for production on non-traditional land include: safety, structural integrity, economics, wildlife impacts, ecology/environmental impacts, water quality, soil quality, water use, generation/reduction of hazardous/toxic substances, air emissions, wastewater discharges, reductions in use of pesticides, fertilizer, and others.

It was the purpose of this study to investigate the planting, growing, and harvesting methods to rapidly adopt, economically grow, and convert oil seed crops on non-traditional cropland into renewable, clean burning biofuels. The current barrier to biofuel feedstock production under this scenario is lack of knowledge regarding crop establishment techniques.

These areas are generally not managed as typical agronomic areas would be. Roadsides, for example, are a disturbed environment and designed to serve a singular purpose. Because of this situation, compaction in arid soils along roadsides has been discovered as one of the prohibiting factors in growing biofuel feedstocks along roadsides in Utah. A new paradigm regarding the construction and use of these areas needs to be considered in light of their abundance and potential. The conditions along roadsides must be examined through an agronomic perspective in order to evaluate their use for biofuel feedstock production.

Materials and Methods

ROADSIDE CLIMATIC CONDITIONS

Climatic conditions in test areas were measured utilizing weather data from the Western Regional Climate Center (i.e. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut2726).

ROADSIDE SOIL CONDITIONS

SOIL NUTRIENT

Soil depth, along with samples for nutrient, pH, EC, and OM were taken with a standard soil probe made from chrome molybdenum type 4130 steel with a hardened tip and nickel plated for rust resistance. The probe was inserted into the soil approximately six inches in depth and the resultant sample placed into a poly bucket for mixing with soils from other replications. Four individual samples were taken from one replication to make a composite sample for testing. One composite sample was collected per replication per location.

SOIL ANALYSIS METHODOLOGY

The following soil analysis methods were used:

- Soil pH and EC - 1:2 soil:water extract Method
- OM – Total Kjeldahl Nitrogen (TKN) Method
- N - KCl Extraction/Cd-Reduction Method
- P, K - Sodium Bicarbonate Method
- Zn, Cu, Fe Mg - DTPA Extraction Method
- S - Calcium Phosphate - Turbidimetric Method

References for each method listed above may be found at http://cropandsoil.oregonstate.edu/wera103/soil_methods.

Bulk Density

Soil samples for bulk density were taken with a two-inch, inner diameter, by six inch length, steel AMS Soil Core Sampler with Slide Hammer. The AMS Slide Hammer has a mass of about 10 pounds and attached directly to the sampler Top Cap. The core Sampler was inserted into the ground to six inch depths and resultant soil collected. Soil was weighed in its moist state and then put into a drying oven at 105º F for 24 hours. Dry soil was weighed and the bulk density was calculated via the following equation:

Bulk density = dry weight (grams) ÷ volume (cm^3)

Where dry weight is oven dried weight of soil sample and volume is 8.45 fl oz (250 cm^3) for 2” × 6” core sampler cylinder.

Cone Penetrometer

Cone penetrometer readings were taken in each plot with the Field Scout® Soil Compaction Meter. The penetrometer, equipped with an ASAE standard cone, was inserted into the ground. The resistance of the cone as it is pushed in the ground was measured and recorded in the memory of the compaction meter. The depth of the cone below soil surface was also measured and recorded in the memory. Compaction data were recorded and displayed at one inch intervals, in PSI. Cone penetrometer estimate data was substantiated by bulk density measurements.

Results and Discussion

Roadside Climatic Conditions

The spring and summer of 2007 presented one of the hotter and drier periods in Utah history. Coupled with later April and May plantings, this led to a harsh growing environment for roadside conditions. Figures 3.1-3.5 illustrate the lack of precipitation during the 2007-2008 growing season for each of the sites.

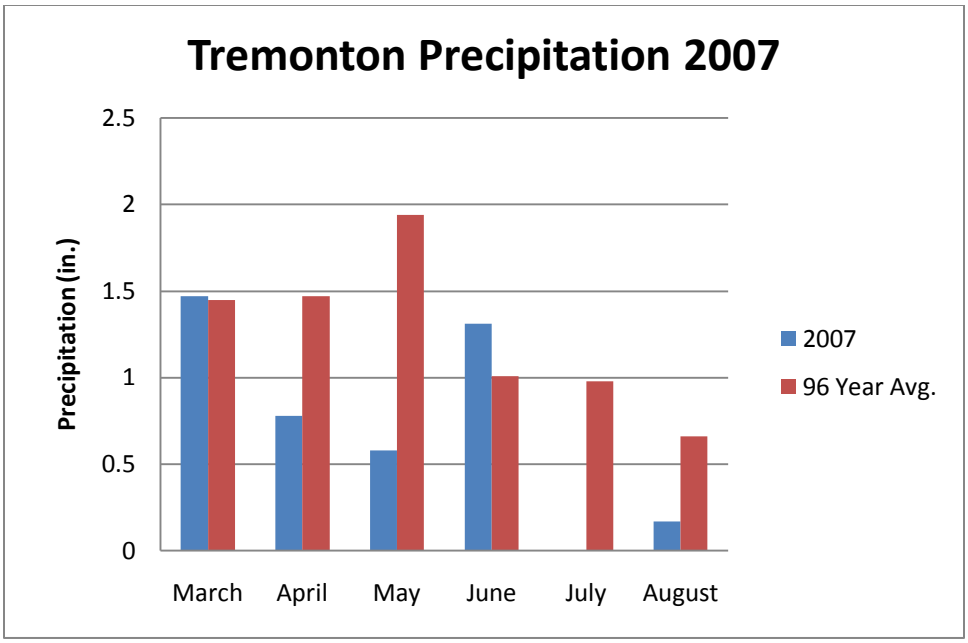

Figure 3.1 Roadside plot area precipitation data 2007

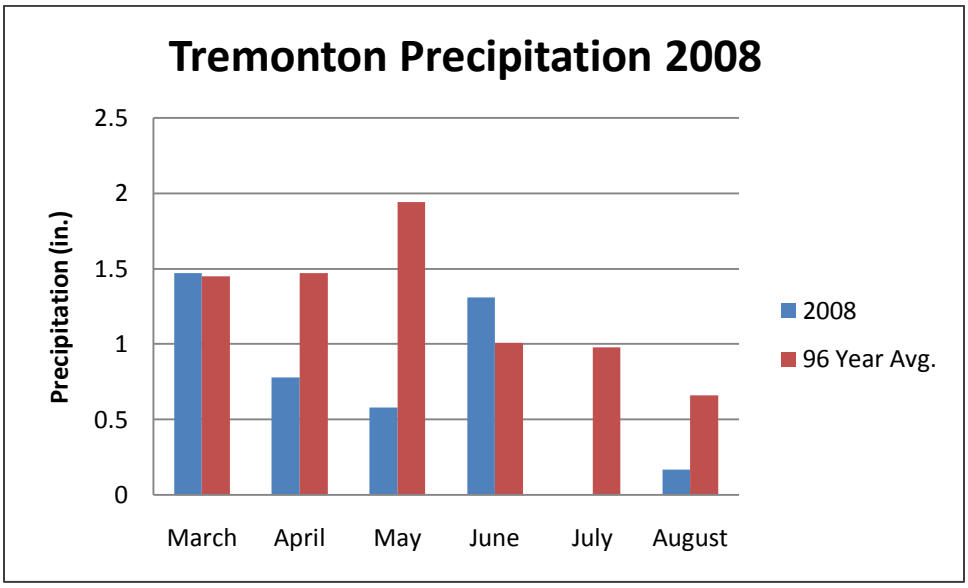

Figure 3.2 Roadside plot area precipitation data 2008

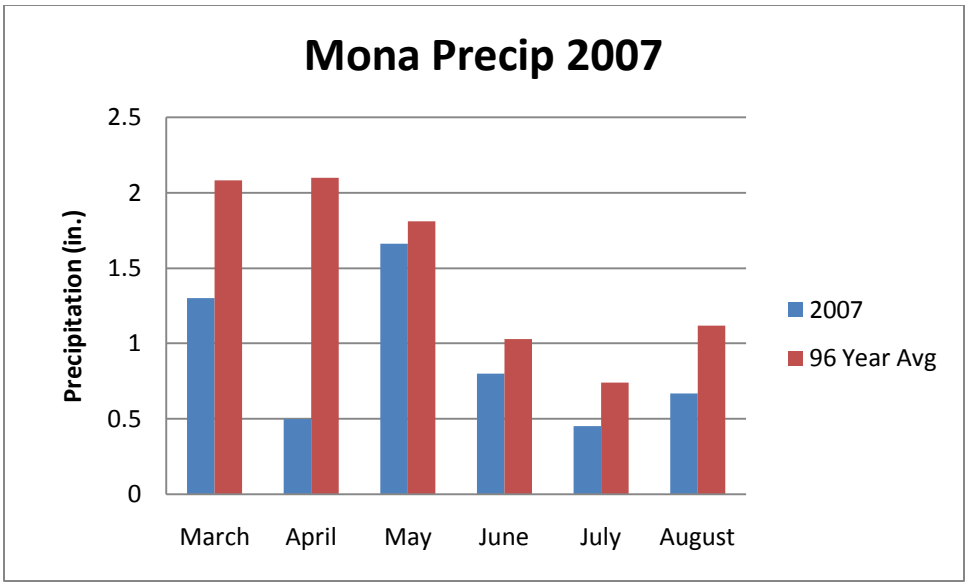

Figure 3.3 Roadside plot area precipitation data 2007

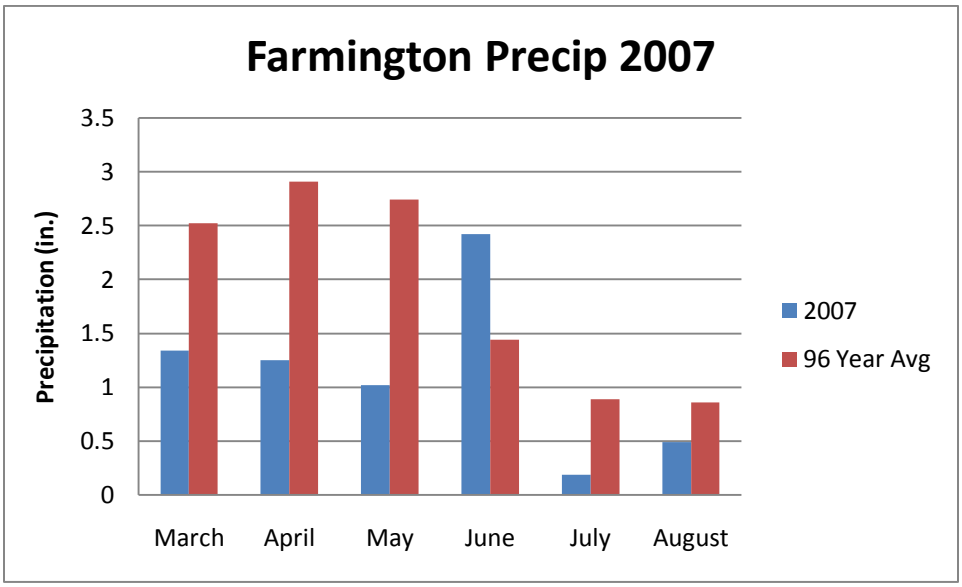

Figure 3.4 Roadside plot area precipitation data 2007

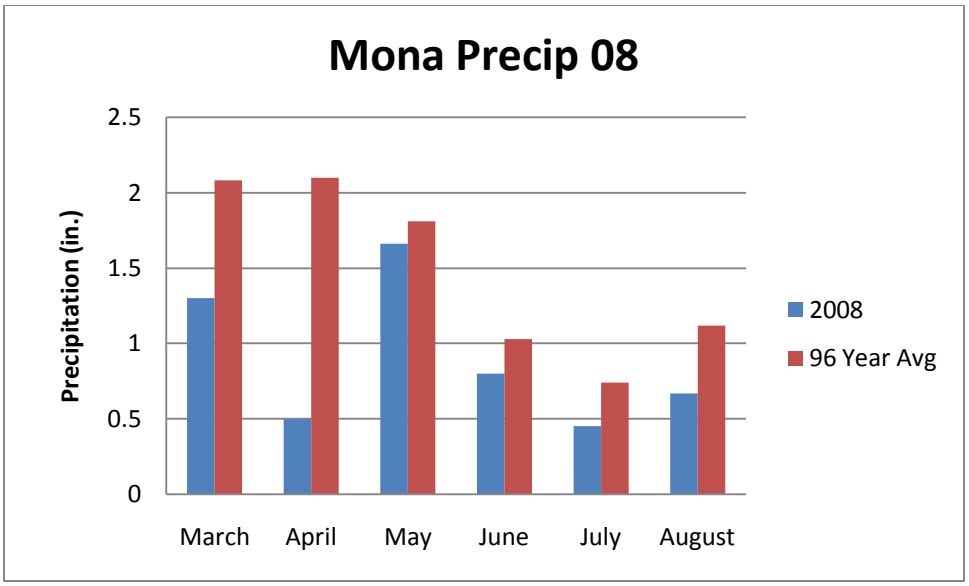

Figure 3.5 Roadside plot area precipitation data 2008

Lack of moisture made for difficult growing conditions during the summers of 2007-2008. This is reflected by the low yields observed under normal agronomic conditions. Soil fertility was similar, if not actually improved, in control plots when compared to the roadside plots. Consequently, soil fertility was ruled out as a cause for reduced yield. With compaction and soil fertility eliminated as possibilities for the loss of yield, climatic conditions appeared to be the casual agent for the low yields.

2007	Mean Temp	Norm Temp	SE	T-Obs	P-value	L95	U95	Same Result	Tobs	P-value	Straight Avg.
March	46.38	39.7	4.25329	1.5701	0.126872	37.87	54.88	No	5.4351	**0.00001**	47.77
April	53.82	48.7	2.50217	2.0478	**0.049422**	48.82	58.83	Close	3.8670	**0.00057**	53.03
May		57.3									
June		66.7									
July	82.23	75.5	0.8351558	8.0593	**0.000000**	80.56	83.90	Missing Data	8.0593	0.00000	82.23
2008											
March	41.57	39.7	2.04287	0.9157	0.367143	37.48	45.66	No	2.6712	**0.01209**	42.10
April	47.63	48.7	1.23581	0.8697	0.391630	45.15	50.10	Yes	0.7141	0.48089	47.75
May	57.06	57.3	3.35978	0.0715	0.943508	50.34	63.78	Yes	0.4378	0.66466	57.89
June	70.28	66.7	6.27285	0.5702	0.572934	57.73	82.82	Unreliable	1.1243	0.27009	68.73
July	78.66	75.5	0.87636	3.6112	**0.001098**	76.91	80.42	Yes	5.2615	**0.00001**	78.55
				Mona							
2007	**Mean Temp**	**Norm Temp**	**SE**	**T-Obs**	**P-value**	**L95**	**U95**	**Same Result**	**Tobs**	**P-value**	**Straigh Avg.**
March	43.12	39.95	4.85547	0.6533	0.518531	33.41	52.83	No	2.2092	**0.03494**	44.31
April	52.16	48	3.92261	1.0613	0.297302	44.32	60.01	Yes	1.7357	0.09323	50.68
May	61.16	57.3	2.96895	1.3004	0.203349	55.22	67.10	No	2.0988	**0.04436**	61.03
June		66.3						Unreliable	3.2925	**0.00262**	71.9
July	81.83	75.2	1.10078	6.0215	**0.000001**	79.63	84.03	Yes	11.1871	**0.00000**	81.85
2008											
March	38.67	39.95	2.4694	0.5189	0.607649	33.73	43.61	Yes	0.6951	0.49234	39.05
April	44.48	48	3.05084	1.1528	0.258111	38.38	50.58	Marginal	2.0660	**0.04786**	44.53
May	55.04	57.3	2.84013	0.7967	0.431878	49.36	60.72	Yes	1.2940	0.20553	55.18
June	68.72	66.3	7.29378	0.3313	0.742748	54.13	83.30	Yes	0.0961	0.92410	66.13
July	77.49	75.2	0.64351	3.5571	**0.001268**	76.20	78.78	Yes	4.5459	**0.00008**	77.49
				Bountiful							
2007	**Mean Temp**	**Norm Temp**	**SE**	**T-Obs**	**P-value**	**L95**	**U95**	**Same Result**	**Tobs**	**P-value**	**Straigh Avg.**
March	43.12	42.35	4.85547	0.1590	0.874715	33.41	52.83	Yes	0.9921	0.32906	44.31
April	52.16	49.8	3.92261	0.6024	0.551404	44.32	60.01	Yes	0.5714	0.57214	50.68
May	61.16	58.95	2.96895	0.7447	0.462249	55.22	67.10	Yes	1.1709	0.25084	61.03
June	71.87	68.1	2.48832	1.5149	0.140261	66.89	76.85	Non-Normal			
July	81.83	76.65	1.10078	4.7043	**0.000054**	79.63	84.03	Yes	8.7496	**0.00000**	81.86
2008											
March	38.67	42.35	2.4694	1.4908	0.146460	33.73	43.61	Marginal	2.5454	**0.01629**	39.05
April	44.50	49.8	2.21892	2.3883	**0.023420**	40.06	48.94	Yes	3.1388	**0.00388**	44.53
May	55.04	58.95	2.84013	1.3777	0.178496	49.36	60.72	No	2.2999	0.02859	55.18
June	67.00	68.1	4.56694	0.2417	0.810669	57.86	76.13	Yes	1.1341	0.26605	66.13
July	77.48	76.65	0.59712	1.3973	0.172586	76.29	78.68	Yes	1.6598	0.10738	77.48

Table 3.1 Roadside Plot Area Temperatures ANOV 2007/2008

The most reliable results related to temperature data are listed in Table 3.1. Significant p-values are highlighted in red. These values are significant at the p=.05 level. Values that are significant in this table are significantly higher than the 96-year average for each of the areas specified. In months evaluated, there is little difference in temperature except for the month of July. During July, temperatures recorded at weather stations near research areas during 2007 and 2008 (with the exception of the 2008 data for Bountiful) showed significantly higher temperatures when compared to the 96-year average.

Two tests for significance were conducted. The first test was an analysis where time was not considered as a factor. During the second analysis, data were treated as time series data (accounting for the factor of time). The distribution of these data for each month was normal, but

there were some cyclical (or seasonal) trends that could slightly affect the mean and variance (which were used to obtain p-values).

Months that were not stationary (constant over time), were adjusted for the mean with a moving average. There is little difference between means after the adjustment (compare the two columns “Mean Temp” and “Straight Avg.” in Table 3.1) where “Mean Temp” is the adjusted mean. There was a greater effect on the Standard Error, which in turn made some of the p-values less significant. From the “Same results” column, it is obvious that the adjustment did not have a dramatic change on the results when using the straight average.

L95 and U95 columns can be used for the lower and upper bounds of a 95 percent confidence interval for the Mean Temperature for the given month, year, and area in Table 3.1.

ROADSIDE SOIL CONDITIONS

Figure 3.6 represents a cross section of a typical road construction. Of particular interest is the shoulder portion of the diagram that illustrates the increasing depths of topsoil the further away from pavement. As distance increases from edge of pavement, so does depth of topsoil.

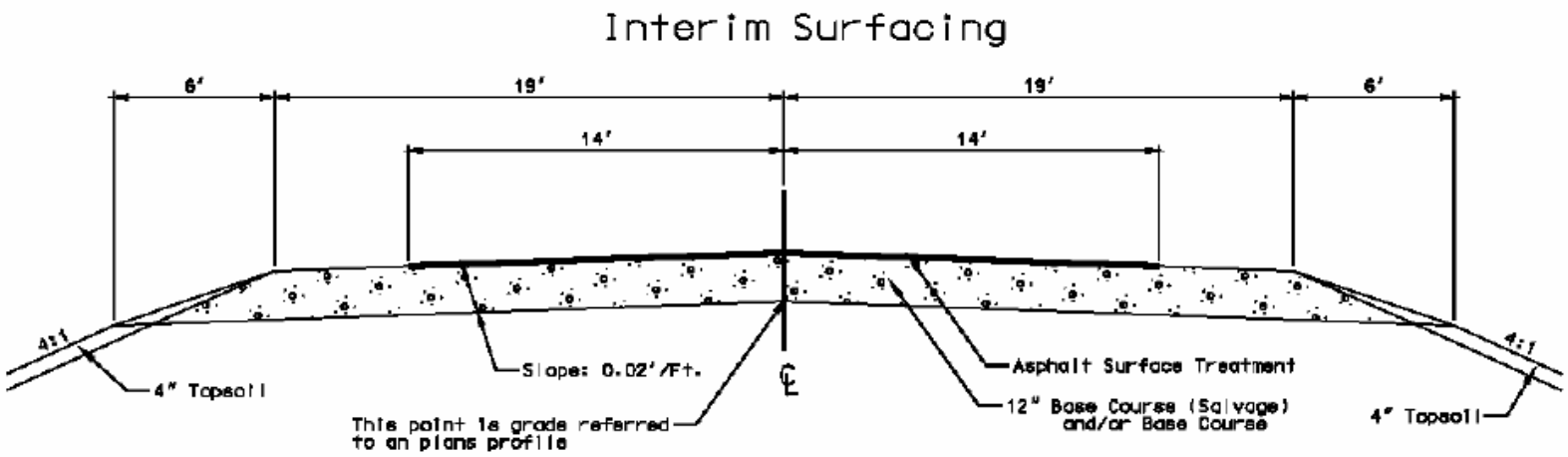

Figure 3.6 Cross section of typical road constructions

Roadside soil conditions were agronomically acceptable with the exception of compaction. Textures ranged from loam to sandy loam, but were similar along the Utah I-15 corridor. This could be explained by UDOT landscaping specification issues for topsoil when roadsides are constructed.

Soil nutrient content for the different plot locations along the I-15 corridor was variable (Figure 3.7). Figure 3.8 shows that the salt content, organic matter (OM) and pH were within normal ranges of western calcareous soils. These results were unexpected due to the high level of salts used on roads for ice melting operations during the winter. Investigators expected the salt and pH levels to be high, but this was not observed in any of the locations. However, soil compaction levels measured on the roadsides were higher than expected.

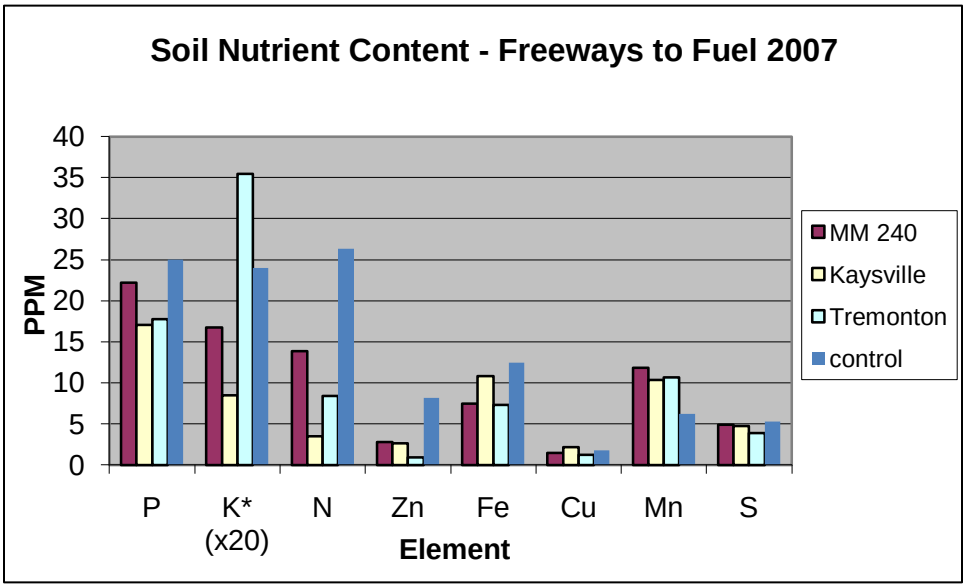

Figure 3.7 Specific nutrient content of roadside soils

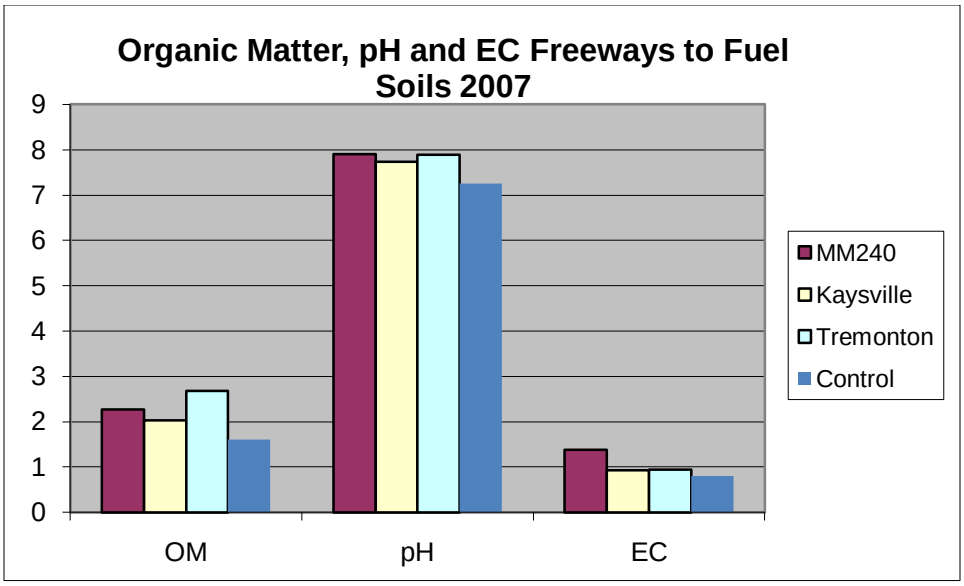

Figure 3.8 Organic matter, pH, and electrical conductivity of roadside soils

Figure 3.9 shows that roadside conditions were similar between the nutrient analysis of roadside and farm control conditions. Control conditions were taken from a plot site located at the USU Kaysville Research Farm. The control plot site was tilled in 2007 with a duck foot ripper, and the seed bed was prepared with a roller harrow prior to samples being taken or plots being established.

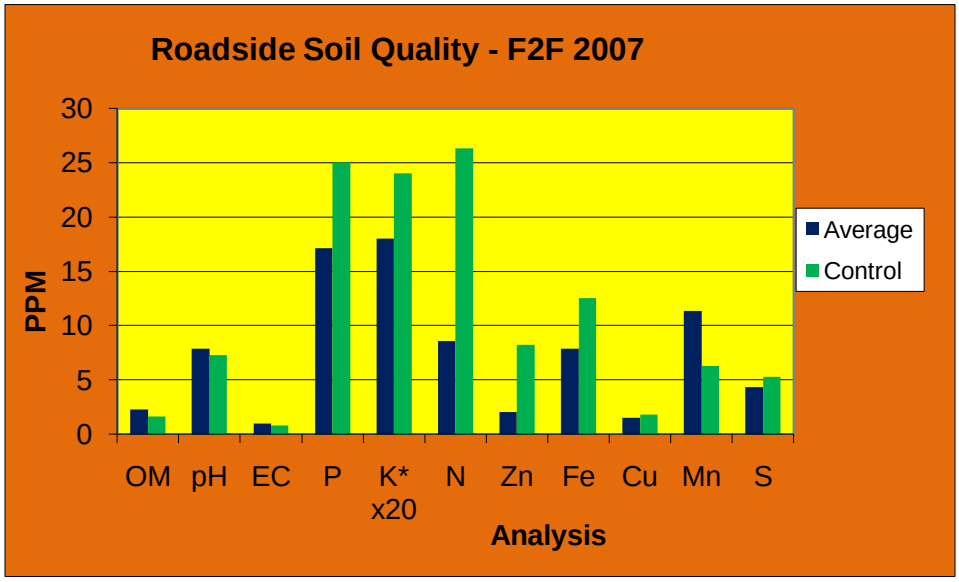

Figure 3.9 Average soil conditions along roadsides vs. control

Compaction numbers were the most surprising element in the soils analysis of roadside plots. Utah has freeze thaw cycles, and investigators anticipated that this would affect the compaction status of the roadside soils over the lifetime of the road. Bulk density and cone penetrometer compaction readings were taken throughout roadside plots. Both measurements showed that soil compaction levels were well above normal growing conditions. Wolkowiski and Lowery have reported on the effects of levels of bulk densities above 0.75 oz/in3 (1.3 g/cm3) on yields. They report that compaction affects nutrient availability and uptake, proper air and water dynamics, plant emergence and growth, in the soil. These limitations have deleterious effects on crop development and yields (Wolkowski & Lowery, 2008). Figure 3.5 shows that average soil bulk density (ρ) under roadside conditions averaged ≥ 0.98 oz/in^3 (1.7 g/cm^3). These results would adversely affect agronomic growth of oilseed crops by limiting air, water, and microbial activity to plants.

Roadside compaction was further investigated utilizing a cone penetrometer as reported in Figures 3.10 and 3.11. The cone penetrometer data confirms the difference in compaction along roadsides relative to acceptable levels.

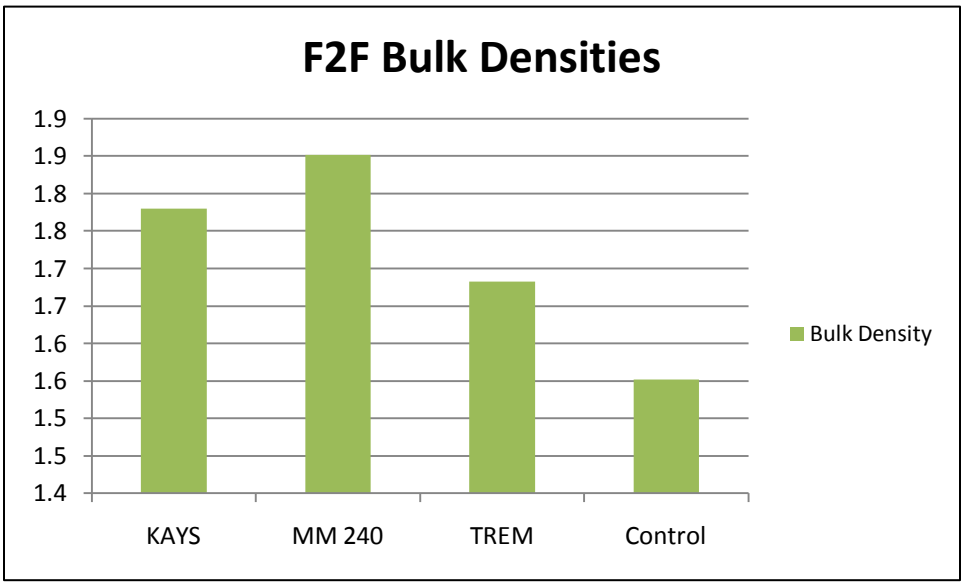

Figure 3.10 Bulk density measurements of roadside soil conditions vs. control (farm conditions)

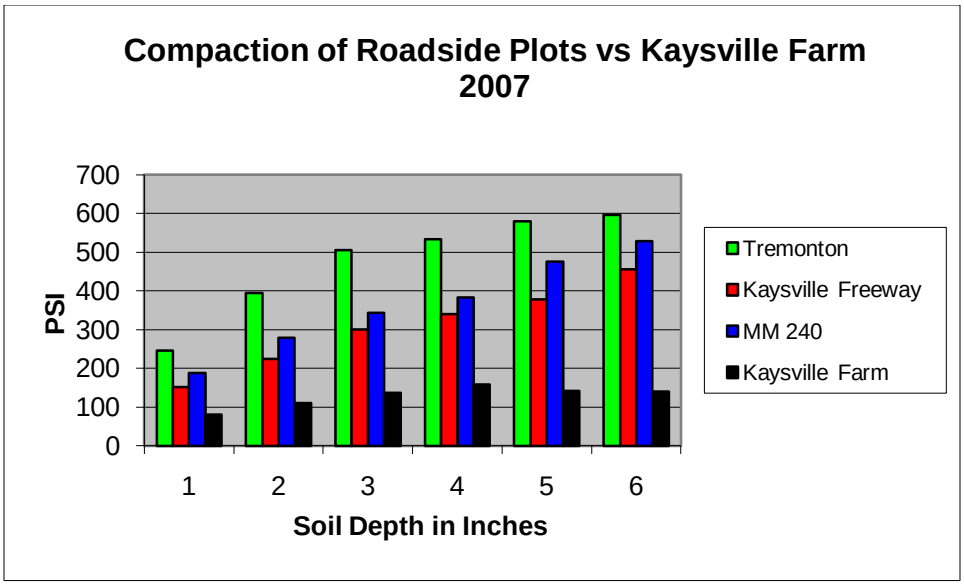

Figure 3.11 Cone penetrometer readings for plot roadside soils vs. control

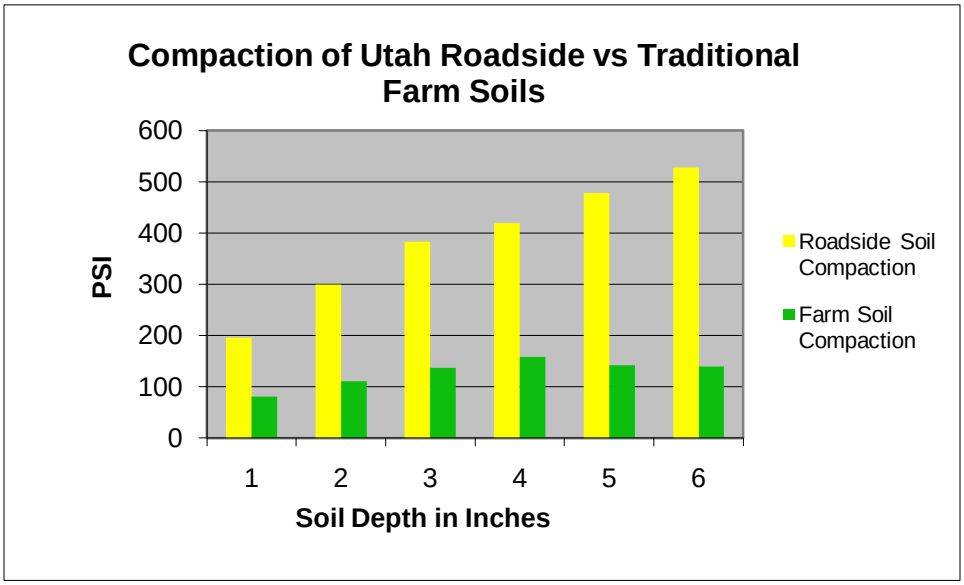

Figure 3.12 Average roadside soil compaction vs. control (farm soil)

ROADSIDE VEGETATION AND ECOLOGY

Soil near roadsides, airports, railways, and military installations are highly disturbed areas that have been engineered for anthropogenic uses. They are non-native environments and are often a safe harbor for pests. This model provides several environments such as, wildlife areas, native habitat areas, open space, and green zones— this can be considered a biofuel

feedstock mosaic. The biofuel feedstock mosaic suggests multi-use of the area with several different functions.

In these areas it was observed that established/native plant species were being displaced by aggressive weedy species such as downy brome. The F2F model may be a strategy to decrease the weed seed pressures and allow for re-establishment of desirable native species.

With the exception of this report, other scientists have not focused on the production of biofuel feedstock crops along roadsides. In developing the F2F model, consideration was given to other professionals already working on these areas. One of the most progressive groups in managing roadside vegetation is the National Roadside Vegetation Management Association, which is a Federal Highway Administration division of maintenance engineers, ecologists, and plant scientists.

In the F2F project, a cursory inventory of vegetation was taken before and after the establishment of plots via visual evaluation (Figure 3.13). This visual evaluation showed alfalfa, bunch grasses (such as perennial wheatgrass), sweet clovers and weedy species such as tumble mustard (*Sisymbrium altissimum)*, dyers woad (*Isatis tinctoria*), and downy brome (*Bromus tectorum)*. Vegetation along roadways in Utah is well established but is generally not native. Often seeded species are hybrids and are established as part of a hydroseeding mix that contains other plant species such as sweet clover (*Melilotus spp)*, alfalfa (*Medicago sativa*), and flax (*Linum usitatissimum*). The most prevalent vegetation observed along the roadsides was crested wheat grass (*Agropyron cristatum).*

Figure 3.13 Picture of plot following glyphosate treatment

It was hypothesized that vegetation shifts might occur if roadside areas are utilized for biofuel crop production. A vegetative shift in the flora was observed within one year of establishment of roadside biofuel crop plots. When established perennial grasses were removed, through glyphosate application, different species of opportunistic vegetation began to dominate the plots. Differences in species invading the open plots included tumble mustard, field bindweed (morning glory) and downy brome.

Figure 3.14 Picture of plot two months after glyphosate application, planting, and non-growth of oilseed crop

Species shifts in the roadside environment are a common occurrence for departments of transportation (DOT). DOT's dedicate a sizeable annual budget to weed control—often noxious weeds—in these areas. One of the objectives the F2F model is to control weeds while producing a renewable, sustainable fuel. Roadside areas will always be disturbed sites because of their function as transportation corridors with disturbed soils. It is proposed that the F2F model be used as a technique to develop a mutualistic relationship that would decrease the carbon footprint of maintenance and increase sustainability by producing a lower emission, renewable energy.

It is biologically unsound to assume that an oilseed crop can be produced on a continual basis without the introduction of a rotational crop. Types of rotational crops could include native plants grown for seed production. As biomass refining technology improves, roadside areas could be used to grow feedstocks for biological/thermal energy conversion platforms. We have even had interest in utilizing these areas for algae production for biofuel feedstock (cellulosic ethanol, torrefaction, pyrolysis, gasification). These technologies are in development, but the first F2F iteration would rotate oilseed crops with grass seed crops and then follow technology developments energy production. Native plants could be utilized for both biomass and ecological activities, but their natural cycle would be disrupted by the operations of harvesting.

In roadside areas, DOT's are trying to discourage wildlife activities for public safety reasons such as auto/wildlife encounters. DOT's have limits on the height, type, and quality of biomass that can be considered for roadside projects. For example, Tennessee, Massachusetts, and other states are considering growing a native prairie grass along roadways for biofuel production. However, the grass will not be able to mature to its maximum yield because its height would be too great and create line of sight hazards

Figure 3.15 Illustration of roadside vegetation

Measurement of existing biomass along F2F plot areas was pursued, but access to this biomass was not permitted by UDOT because it was not within the scope of the current project.

Conclusion

Agronomic conditions along Utah's roadways are conducive to crop growth with the exception of soil compaction. Utah precipitation and climate will be major factors in determining whether F2F will be economically and agronomically successful. However, soil texture, organic matter, pH, and nutrient contents are acceptable for the growth and development of oilseed feedstock crops such as canola and safflower.

4.0 ROADSIDE PLOTS

Introduction

F2F crop establishment for all regions of the United States need to be explored *in situ* (e.g. roadsides, airports, military installations) so that yield and environmental impacts such as soil quality, water quality, wildlife encroachment, structural integrity, local grower concerns, and safety are considered. Proper crop selection and establishment correlates to regional conditions essential to the success of this program.

It was the goal of this project to develop sustainable, agronomic crop growth methods that will allow feasible oilseed feedstock production in marginal or non-traditional agronomic areas (e.g. roadways, railroads, airports, military installations). It was proposed that non-traditional feedstock production for oilseed crops would be evaluated and a process for crop production would be developed in a 3 to 4 year period. It is anticipated that project partners with successful production will remain as long-term biofuel feedstock sources in their respective regions of the United States. If successful, this process would generate four positive outcomes:

- Produce sustainable fuels from idle areas that are costly to maintain.
- Provide a mechanism to economically control weeds harbored by these areas.
- Provide support to the local economy by providing jobs/renewable energy.
- Provide a template/screening process for all related lands that could be used for biofuel production after the current process has been demonstrated successful.

The focus for this project will be an evaluation of the agronomic conditions and growth requirements for biodiesel and other biomass feedstock crops.

Biodiesel is a renewable, high energy input/output ratio (1:4.56) fuel with technology that is currently in use, is economically viable, has an established distribution chain, and has proven processing methods with no waiting or promises of technology “to be developed” in the future (Pradhan et al., 2008). The feedstocks produced from the F2F model will be readily turned into biodiesel which can be used immediately in the fuel supply chain. The fluctuating costs of

petroleum suggest that the use of non-traditional agronomic resources for biofuel production is timely.

Figure 4.1 Laying out roadside plots along I-15 in Utah

In the consideration of the F2F project a multitude of unknowns were identified. Questions regarding biofuel feedstock production on non-traditional crop land that were unanswered are:

- Will the varied soil conditions along roadsides support economically feasible crop yields?
- Will conventional farming equipment satisfy the cropping requirements for oilseed crop production in the roadside setting?
- Will the disturbance of planting and the elimination of current plant populations in these areas change erosion patterns?
- Based upon these questions, a research protocol was developed to address the unknowns identified.

Materials and Methods

2007 TEST

Plots for FreeWays to Fuel were established in freeway rights-of-way shoulders in Utah during 2007 under the direction of the Utah Department of Transportation. Experimental design for the roadside plots was a completely randomized block design consisting of four treatments replicated in each of four blocks. The blocks were planted on sloping areas of highway shoulders

in five Utah regions along the I-15 UDOT corridor. These locations were near Tremonton, Kaysville, Mona (two locations), and St. George, Utah. A control location at the Utah State University Kaysville Research Farm was established to compare normal agronomic practices and serve as a control measure to highway conditions. All locations were planted with safflower, spring canola (Roundup Ready), and winter canola (Roundup Ready). The treatments at each location are shown in Table 4.1.

Treatment	Variety	Seeding	Glyphosate
Control	-	-	-
spring	Hyola 357	7 lbs/A)	no
spring	Hyola 357	7 lbs/acre	yes
fall canola	DKW 1386	7 lbs/acre	yes
fall canola	DKW 1386	7 lbs/acre	no
Safflower	S-208	15 lbs/acre	no

Table 4.1 F2F Roadside Plot Treatments

The distribution of plot locations allowed for different climatic exposure and public interaction. Plot sizes were 8’ X 45’ and served as areas for two crop years. Each plot was divided into two sections. The first 20’ of each plot was sprayed with glyphosate based herbicide Roundup Weathermax 30 oz/acre in preparation for planting. The remaining 25’ portion was utilized the following season for a second evaluation of each treatment. Varieties planted at both roadside and the control plots included safflower (S-208) and glyphosate tolerant canola (Hyola 357). The roadside plots were planted using a Tye Pasture Pleaser no-till drill equipped ¾” depth bands (Figure 4.1).

Figure 4.2 Tye drill depth bands

2008 TEST

The experimental design for the 2008 roadside plots was a completely randomized block design with four treatments replicated in each of four blocks planted on sloping areas of highway shoulders in four Utah regions along the I-15 UDOT corridor. These locations were near Tremonton, Kaysville, mile marker 240 near Mona, Utah. In 2008, only four roadside sites were utilized compared to 5 in 2007. One of the two Mona sites was eliminated because the soil at the sites contained excessive amounts of aggregate. The 2007 St. George site was removed from the 2008 experimental test because of road construction in the test area. The treatments at each location were identical to 2007 treatments above.

Figure 4.3 Planting roadside plots

Figure 4.4 Tye pasture no till drill with depth bands removed

	Location									
	Tremonton		Kaysville		MM240		St. George		Control	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Spring Planting Information										
Planting Date	5/1	4/3	5/8	4/3	5/1	4/4	11/8		5/2	4/4
Planting Depth (inches)	0.75	2	0.75	2	0.75	2	0.75	2	0.75	2
Spring Canola Planting Rate (lbs/acre)	5	6	5	6	5	6	5	6	5	6
Safflower (lb/acre)	15	15	15	15	15	15	15	15	15	15
Fall Planting Information										
Planting Date	10/4	9/25	10/4	9/25	10/4	9/25	11/8		5/2	4/4
Planting Depth (inches)	0.75	2	0.75	2	0.75	2	0.75	2	0.75	2
fall canola (lbs/acre)	5	6	5	6	5	6	5	6	5	6

Table 4.2 Planting Information for Roadside Plots

Figure 4.5 Planting roadside plots

Results and Discussion

The 2007 spring canola plants emerged in three locations. Although emergence occurred in Kaysville and Tremonton plots, plant populations were low when compared to control plots (Figure 4.6). Emergence at both Mona sites was not measurable.

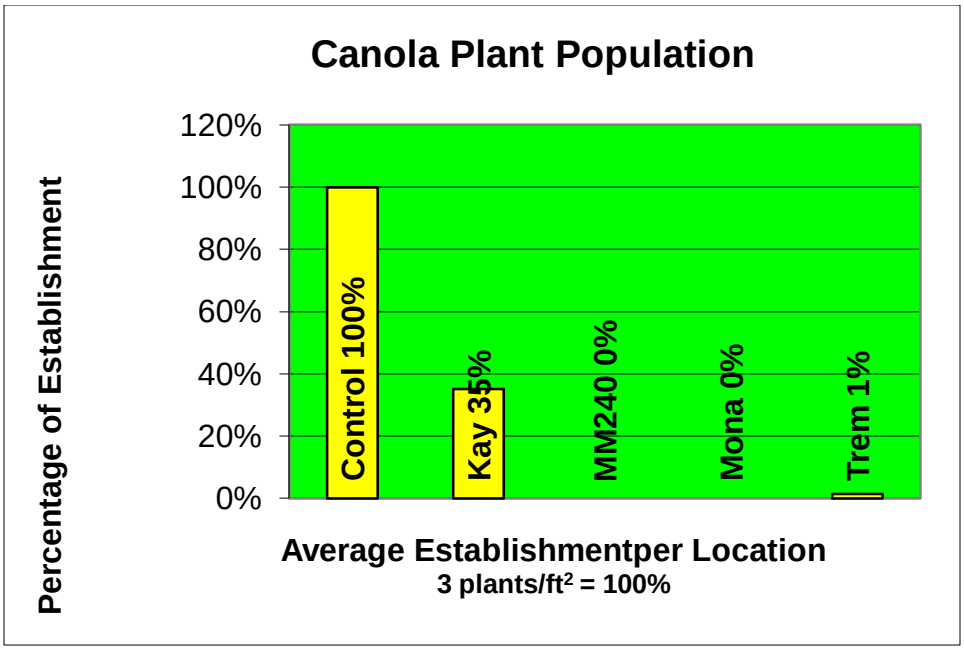

Figure 4.6 Relative canola emergence populations

Figure 4.7 Picture of spring canola emergence

Establishment of canola and safflower was determined by counting the plants when they were at the 2-6 leaf stage of development.

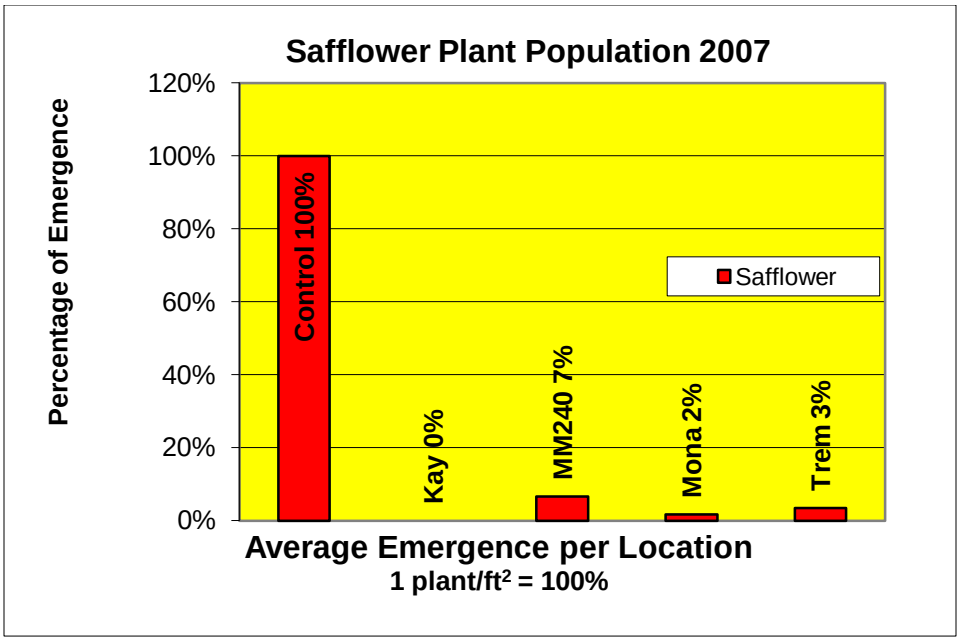

Figure 4.8 Relative safflower emergence populations

The 2007 safflower plants emerged in four locations. All plant populations were low when compared to control plots at the Kaysville Research Farm (Figure 4.8).

In 2008 neither canola nor safflower plants emerged after seeding. Lack of emergence made it impossible to report growth data and thus no establishment data are available for the 2008 crop year at any location.

Figure 4.9 shows the summary of yields from FreeWays to Fuel crops grown along roadsides in Utah. The difference between 2007 and 2008 was the depth of planting. In 2008, the depth bands were removed from the planting equipment to permit deeper seed placement in the soil to access moisture and decrease the influence of compaction. Although seeds were placed at a greater depth to enhance germination and emergence, no plants were established. Control plots were seeded with depth bands removed and crop establishment did not occur. Under optimal conditions or roadside conditions, no plant emergence occurred. Over both years yields were less than acceptable in terms of economic feasibility. In 2007, unusual climatic conditions (figures in Chapter 3) reduced lower production to a yield of 700 lbs/acre. In 2008, no safflower yield was observed because of planting depth.

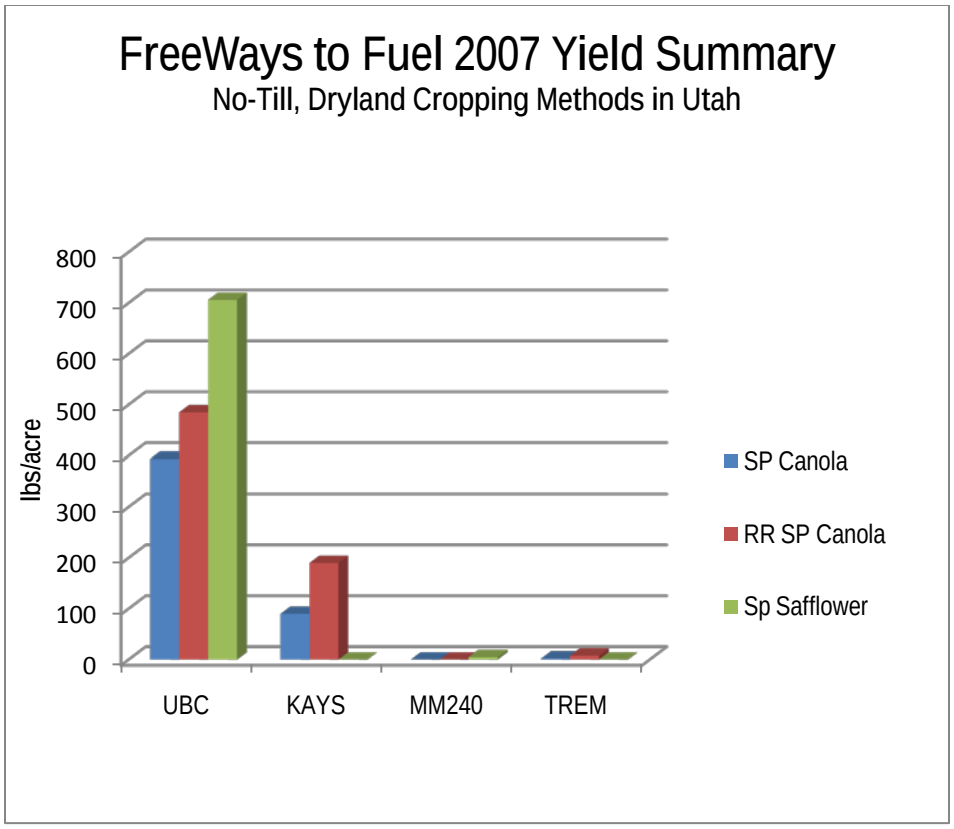

Figure 4.9 Yield for 2007 F2F crops

The extreme compaction reported in Chapter 3 also affected the planting of the oilseed crops along the roadsides. The Tye Pasture Pleaser Drill was able to penetrate the compacted soils, but the press wheel was unable to seal the furrow created (Figure 4.10). This left the seed without seed cover and germination did not occur.

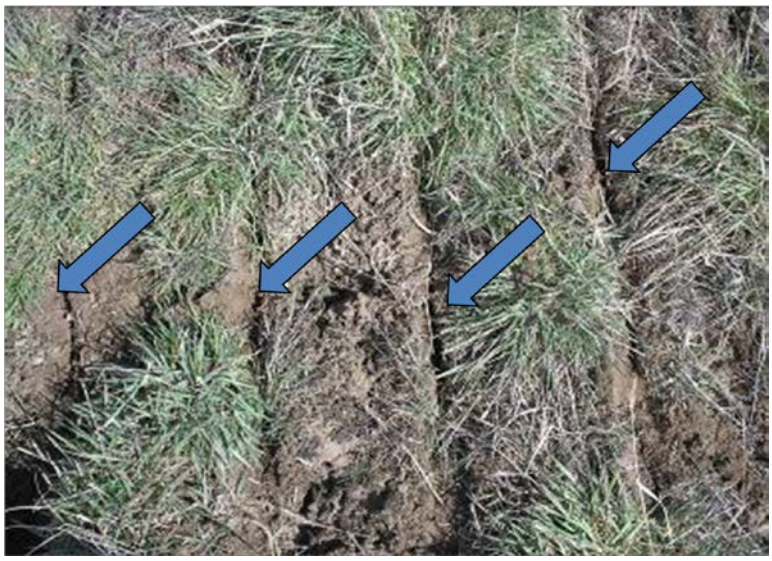

Figure 4.10 Open furrow left post planting in roadside plots

Conclusion

After evaluation and analysis of these data it was possible to conclude that spring canola production along UDOT rights-of-way was not profitable under reported conditions for 2007 and 2008. Field data, combined with greenhouse data (see chapter 5), made it possible to conclude that soil compaction and seeding depth had the most significant effect on safflower establishment, growth and development.

5.0 GREENHOUSE

Introduction

The next phase of F2F research took place in the USU greenhouses. In this phase of research the objective was to evaluate issues related to low crop emergence/establishment and reduced yields in the roadside plots during the 2007–2008 growing seasons. Issues considered during this research were the effects of soil moisture, compaction, planting methods and effects on emergence of safflower in roadside plot conditions. The goal was to simulate roadside conditions during the 2007/2008 growing season and explore the causes and possible solutions to compaction and drought that decreased crop growth and development. This activity helped explain some of the effects of roadside conditions and climate on crop production.

Materials and Methods

Experiments were conducted in 10 inch X 2.5 inch rigid plastic conetainers filled with road base in the lower half and topsoil from Kaysville roadside plot areas on top. Both materials were compacted to desired bulk density during filling of the conetainer. Seeds were planted at 0”, 0.39”, 0.79”, 1.81”, 1.57”, 1.97” inch (0, 1, 2, 3, 4, and 5 cm respectively) in the soil portion of the conetainer to determine optimum planting depth under roadside conditions using various planting techniques.

Each of the depths were replicated four times to ensure confidence and statistical significance and the experiment was repeated 2X. Seeds were placed into two soil moisture regimes. One set of treatments was grown in soils that were brought to field capacity level of moisture before planting and another set was grown under drought conditions exhibited in 2007–2008. Successful establishment was measured by plant seedling dry weight biomass.

VOLUME OF CONETAINER

The volume of the 10” conetainer was measured by taping the bottom openings and filling with water at $\approx 41^0$ F (5^0C). The volume of the water was weighed. This was repeated four times and weights were averaged. The resultant weight of the water in the conetainer was

20.46 oz ((580 gm) assume 1 cm^3 of water = 1 gm of water). Volume of the cone was 20.46 oz (580 cm^3) = 19.61 fl oz.

Figure 5.1 The Ray Leach Single Cell Conetainer™

Bulk Density was calculated by the following:

- Volume of conetainer = 19.61 fl oz (580 cm^3). Desired bulk density of soil in conetainer = 0.98 oz/in^3 (1.7 gm/cm^3). 19.61 fl oz (580 cm^3) x 0.98 oz/in^3 (1.7 gm/ cm^3) = 35.80 oz (1015 gm).
- Calculating bulk density for ½ conetainer volume = desired bulk density = 0.98 oz/in^3 (1.7 gm/cm^3) x 0.5 x 35.80 oz (1015 gm) = 17.92 oz (508 gm) per ½ of conetainer.

Determining the level of soil corresponding to appropriate bulk density in the conetainer was considered. Half volume of the conetainer was determined volumetrically and marked on the exterior of the conetainer.

FILLING THE CONETAINER

Pre-weighed road base was placed into conetainers and compacted to the correct level by dropping a 2.0 inch (5.08 cm) × 5.0 inch (12.7 cm) piece of steel rod with a total weight of 1095 gm. (Figure 5.3).

An adjustment for Soil and Road Base moisture content was determined according to the following steps:

- 17.70 in^3 (290 cm^3) = ½ volume of the conetainer
- Roadbase ((¾ minus which is aggregate material that will pass a 0.75 in (1.90 cm) screen))
- Wet weight of roadbase = 12.10 oz (343 gm)

- Dry weight of roadbase = 11.92 oz (338 gm)
- 12.10 oz (343 gm) – 11.92 oz (338 gm) ÷ 11.92 oz (338 gm) ≈ 1.5% moisture
- Correct for moisture = 17.88 oz (507 gm) of material x 9.81 fl oz (290 cm^3) of conetainer
- Soil at 9.8×10^{-4} oz/in^3 (1.7 gm/cm^3)
- Wet = 10.02 oz (84 gm)
- Dry = 9.92 oz (253 gm)
- 10.02 oz (284 gm) – 9.92 oz (253 gm))/13.51 oz (338 gm) ≈ 11% moisture
- Correct for moisture = 17.92 oz (508 gm) x 1.11 = 19.89 oz (564 gm) of soil per 9.81 fl oz (290 cm^3) of conetainer
- Soil at agronomic compaction 0.75 oz/in^3 (1.3 gm/cm^3) bulk density
- 9.81 fl oz (290 gm/cm^3) per ½ of conetainer
- 9.81 fl oz (290 cm^3) x 0.75 oz/in^3 (1.3 gm/ cm^3) = 13.30 oz (377 gm)
- Adjust for initial soil moisture @ 11%
- 13.30 oz (377 gm) x 1.11 = 14.74 oz(418 gm) will allow bulk density of (1.3 gm/ cm^3) in the conetainer

Figure 5.2 Picture of roadbase utilized in greenhouse experiments

The topsoil was placed in the conetainer on top of the roadbase. The conetainer bottom openings had previously been sealed to eliminate leakage of materials. During the filling and to establish proper bulk density, the conetainer was placed inside a mold. Initial conetainer filling to

the required bulk density ruptured the sides of the conetainer vessel because of the stress on the plastic. Therefore, a mold was constructed in a 12” greenhouse pot that had been filled with a wet concrete mixture around an empty conetainer. After the concrete had cured, the empty conetainer was removed. As they were filled, individual conetainers were placed in the mold filled and, compacted to desired bulk density.

Figure 5.3 Picture of Concrete Filled Pot that was used for placing materials into conetainers.

Following the placement of the roadbase, pre-weighed topsoil was placed into the conetainer. This was done in multiple steps to obtain the required bulk density. If all pre-weighed topsoil was placed in the conetainer at once, the volume of the soil exceeded the capacity of the conetainer. Approximately 1/3 of the topsoil was placed into the conetainer and compacted. This step was repeated 3X until the topsoil was at the correct level and properly compacted. The final level of the soil in the conetainer was standardized to be ≈ 0.2” (0.5 cm) below the lip of the conetainer by pressing a 3” (7.62 cm) x 2.5” (6.35 cm) plastic rod into the top of the conetainer (Figure 5.4).

Figure 5.4 Compacting Tool - Pipe handle and Steel Rod

Figure 5.5 Leveling Plastic Rod used to normalize tops of containers after materials had been placed and simulates press wheel effects

Moisture standardization of the material in the conetainer was carried out by soaking the conetainers in a water filled tub until complete soil saturation had taken place. Holes were made in the seals around the bottom of the conetainers and gravitational water was allowed to drain for 24 hours. Moisture level in the combined roadbase and topsoil stabilized at field capacity.

Seeds were placed into the containers. A variety of tools were prototyped for simulation of planting actions that took place in the plot trials including colter, planting disk furrow, and

press wheel effects. These were designed to simulate the Tye Pasture Pleaser No Till Drill effects on soil conditions. Hereafter in the document these are referred to as drill effects and no drill effects.

Colter effects of the Tye Pasture Pleasure No Till Drill (Figure 5.6) were simulated using a 0.25” (0.635 cm) metal blade that had been beveled on the insertion end. The colter simulation device was attached to a handle so that it could be pushed into the conetainer simulating the colter prior to seeding disks. The purpose of the colter was to open and loosen the soil prior to planting in the no-till operation.

Figure 5.6 Colter Simulation Tool

Planting discs from the Tye Pasture Pleaser and resultant furrow were simulated by using a hatchet type device. This furrowing tool was created with a six degree angle opening at the top narrowing to bottom of the tool that is inserted end into the soil first (Figure 5.7).

Figure 5.7 Soil Furrow Tool

PLANTING TECHNIQUES

Compaction vs. non-Compaction + depth treatments were simulated using a beveled, 1” (2.54 cm) diameter soil coring tool (Figure 5.8). The tool was inserted into the top of the conetainer and soil from the appropriate depth was extracted. Two safflower seeds were placed at prescribed depth left by the removal of the soil core. The soil was replaced and then compacted to treatment specification with the plastic rod previously described.

Figure 5.8 Soil Coring Tool

Furrow + compaction + depth treatments were seeded by placing the furrowing tool into a prepared conetainer to the appropriate depth, and two safflower seeds were placed at the bottom of the furrow (Figure 5.9).

Figure 5.9 Image of Furrow Treatment Conetainer with seeds inserted

Compaction + depth + furrow + colter treatments were performed by compacting materials to specification, placing the colter tool to a depth of 6 cm for all colter treatments followed by the furrow tool to prescribed depth and two safflower seeds were placed in the bottom of the furrow.

Compaction + depth + furrow + colter + press wheel were performed by placing the colter tool into a prepared conetainer followed by the furrowing tool, and placing two safflower seeds in the bottom of the furrow. The conetainer was recompressed using the plastic rod tools as described above to simulate the press wheel effects.

Results and Discussion

The goal with the greenhouse project was to simulate roadside conditions and explore the causes and possible solutions that have made it so difficult to establish a crop on the roadside. Data from this experiment were collected over the summer of 2009 and has been analyzed as a linear mixed model. These data confirmed our hypothesis that depth of seed placement and compaction does affect the plant biomass production

Figure 5.9 shows the significant effects of compaction coupled with depth of seeding influences. None of the depth values are different ($p = .05$) from each other as illustrated by the error bars in 5.10—compaction was the obviously the overriding factor.

Figure 5.11 shows the significance of no compaction coupled with depth of seeding influences on biomass production. In evaluating this data: hand placing seed at the 1 cm (0.39”) depth produced highest biomass yields. The 1 cm (0.39”) depth of seed placement without compaction treatment was significantly higher ($p = .05$) than all other treatments. No Compaction + depth + furrow + colter + press wheel at the 2 cm (0.79”) depth was the same as all other treatments at the equal depth.

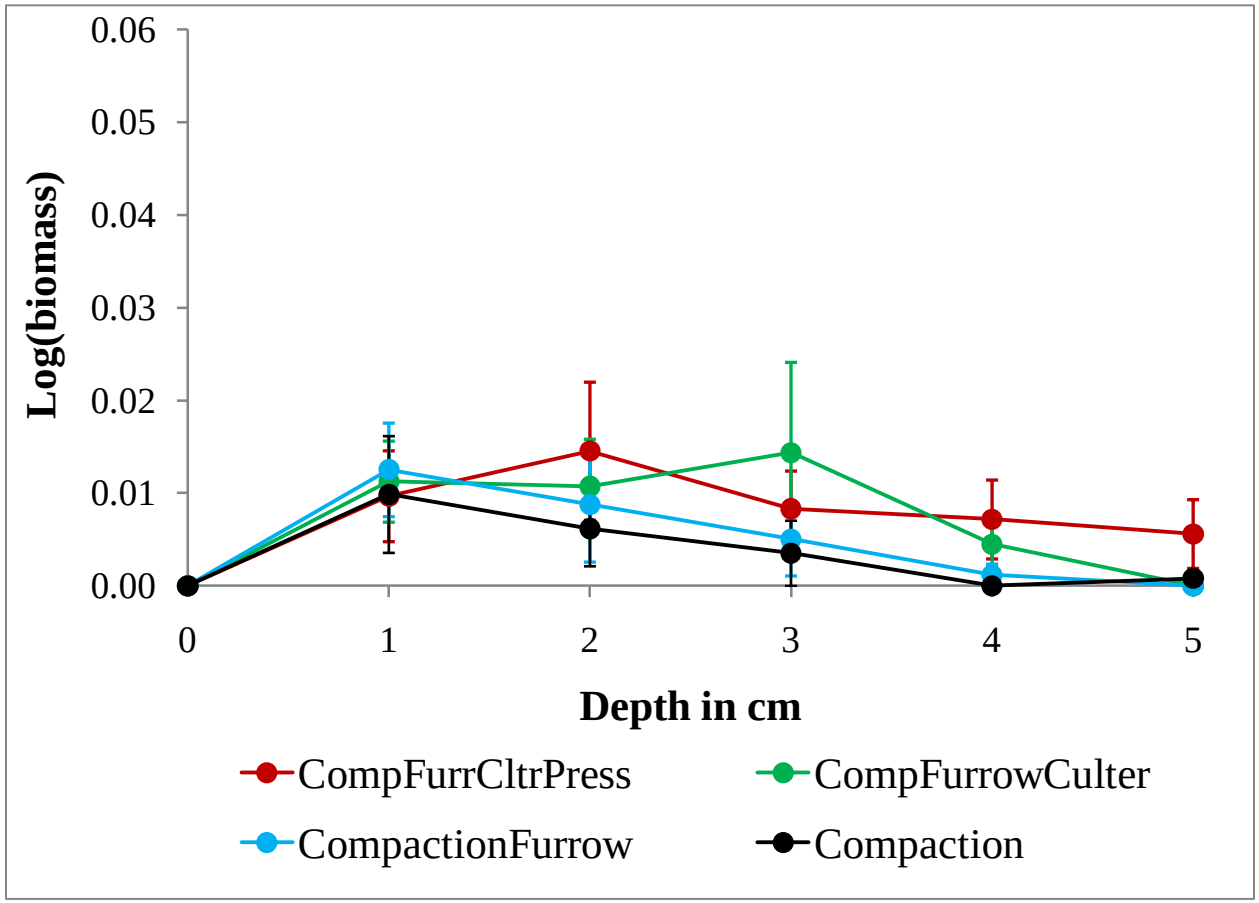

Figure 5.10 Compaction Data (Compaction = effects of Compaction, CompactionFurrow = effects of compaction and furrow effect, CompFurrowColter = effects of compaction, furrow and colter, CompFurrCltrPress = effects of compaction, furrow, colter and press wheel).

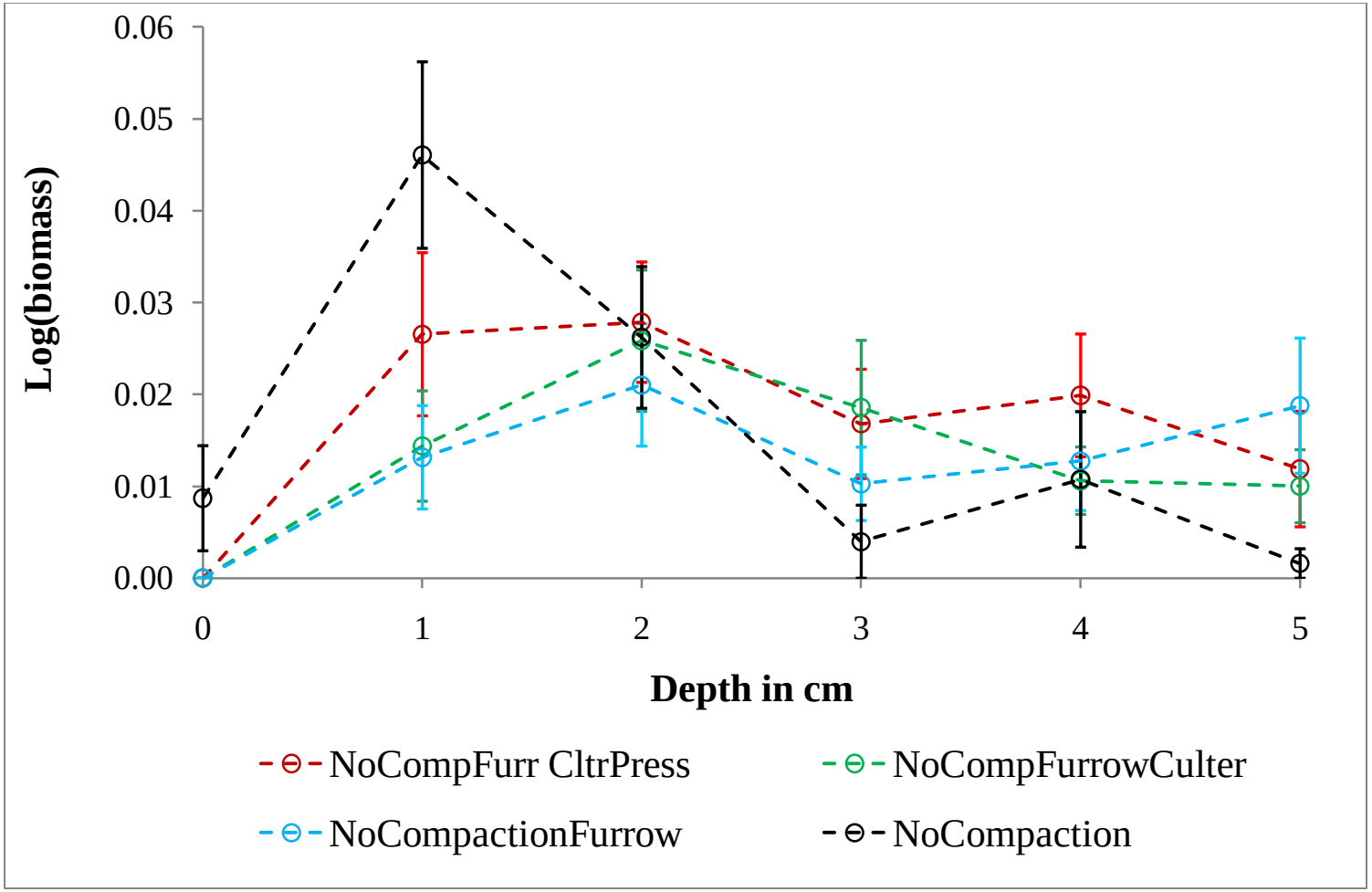

Figure 5.11 No Compaction Data ((No Compaction = effects of No Compaction, No CompactionFurrow = effects of no compaction and no furrow effect, No CompFurrowColter = effects of no compaction, no furrow and no colter, No CompFurrCltrPress = effects of no compaction, no furrow, no colter and no press wheel)

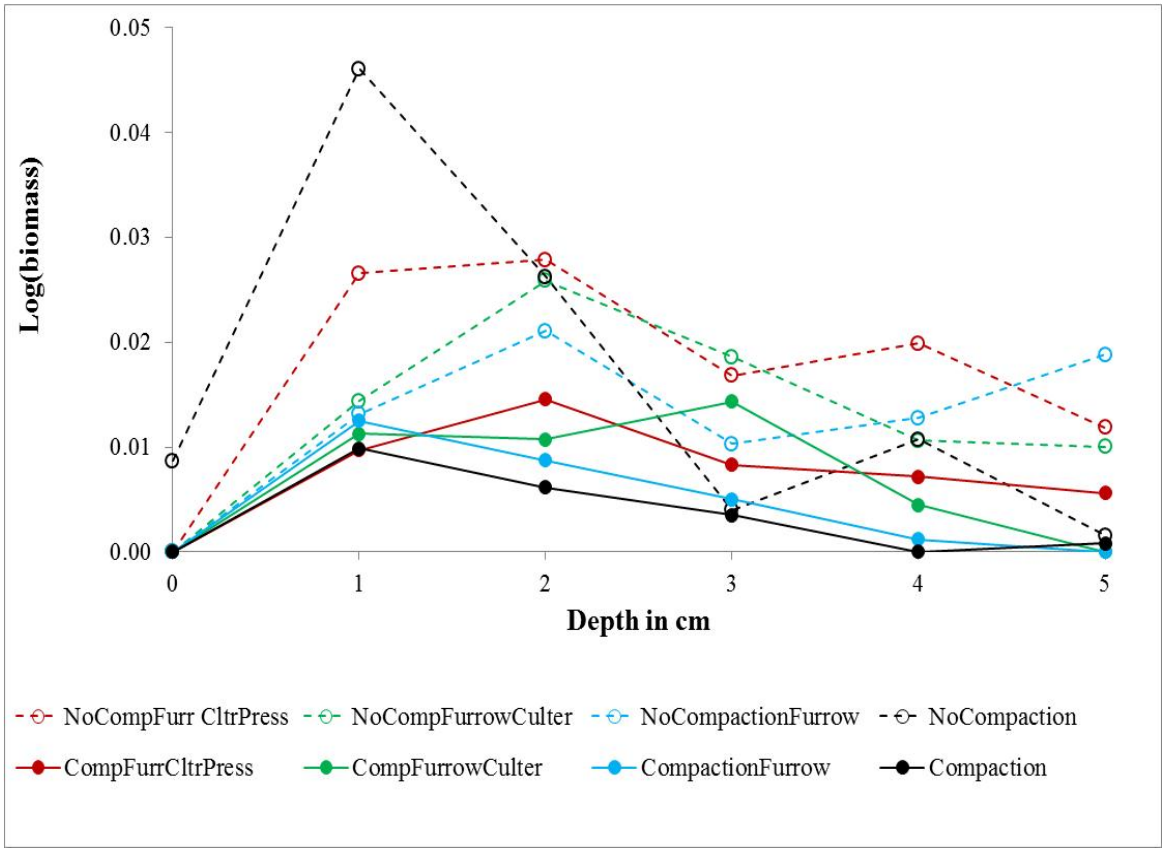

Figure 5.12 Combination Data (Compaction = effects of Compaction, CompactionFurrow = effects of compaction and furrow effect, CompFurrowColter = effects of compaction, furrow and colter, CompFurrCltrPress = effects of compaction, furrow, colter and press wheel, No Compaction = effects of No Compaction, No CompactionFurrow = effects of no compaction and no furrow effect, No CompFurrowColter = effects of no compaction, no furrow and no colter, No CompFurrCltrPress = effects of no compaction, no furrow, no colter and no press wheel)

Figure 5.11 is a combination of Figure 5.9 and Figure 5.10 and consolidates the response of depth of seeding and compaction. Fig 5.11 shows differences between combination of colter, furrow and press wheel (simulated no till drill effects) and non drill effects compaction vs. non compaction since the treatment x depth interaction is significant, treatment effects were examined at each depth level. The results indicate that the treatments have only significant effects on logbiomass at depth 0.39 in (1 cm) and 0.79 in (2 cm) at alpha=0.05. Results are listed in attached spreadsheet 'slices'.

From the Figures 5.9, 5.10 and 5.11 listed above, it was hypothesized that (1) non-compacted soils produce more biomass; and (2) seeds planted at shallow depths at 0.39 in (1 cm) and 0.79 in (2 cm) produced more biomass than other depths. The hypothesis were tested using ESTIMATE in PROC MIXED. Results are listed in the spreadsheet 'estimates'. Note that depth 2 & 3 in the table represent depths level 2 and 3, which are 0.39 in (1 cm) and 0.79 in (2 cm), respectively. The analysis results showed that (1) soils without compaction produces more biomass than soils treated with compaction; and (2) seeds planted at 0.39 in (1 cm) and 0.79 in (2 cm) produce more biomass than those planted at other depths. All conclusion were made at alpha=0.05.

Pairwise comparisons of each treatment pair are found in attached spreadsheet Appendix E. Note that only significant different treatment pairs were listed.

Testing the null hypothesis that none of the treatment factors have an effect on biomass yield, produced a p-value of less than .0001, which implies we can reject this null hypothesis and conclude that at least one of the factors has a significant effect on the yield.

Depth and Compaction are significant in their effect on the yield between their different levels. The means comparisons between the different levels may not be 100% accurate.

These data suggest that no compaction produces a slightly higher yield than using compaction. Mean yield for no compaction was 0.037 gm, and using compaction produced a mean yield of 0.018 gm.

For Depth, these data showed that planting at a depth of 0.39 in (1 cm) and 0.79 in (2 cm) is better than planting at 0 in or > 0.79 in (2 cm) depths. This shows that the mean yield decreases as planting depth increases.

The highest mean yield of $0.1.85 \times 10^{-3}$ oz was with no compaction and a 0.79 inches (2 cm) depth. Treatment (compaction vs. non-compaction), seeding depth and their interaction are all significant. Results are listed in Table 5.1.

Effect	NumDF	DenDF	FValue	ProbF
treatment	7	335	6.350796	0.0000005
depth_cm	5	335	13.19368	0.0000000
treatment*depth_cm	35	335	1.506019	0.037003

Table 5.1 Type 3 Fixed Effects

Conclusion

The depth of the seed and compaction of soil had the most significant effects on biomass produced. This supports our initial hypothesis that a limiting factor of the roadside plots was compaction. This experiment confirms that the depth of seed placement in and the level of soil compaction is a critical to plant establishment and growth.

6.0 ROADSIDE SIMULATION

Introduction

To more closely control experiments and evaluate alternative agronomic practices restricted by UDOT, a Roadside Simulation Laboratory (RLS) was constructed at the Utah State University Utah Botanical Center. The RSL was essentially the "laboratory" portion of the F2F design to more closely examine combined methods of planting and fertilization. In addition, the RSL permitted research into planting methods, germination rates and crop establishment in a roadside environment.

The experimental activities for the simulated roadside laboratory plot explored alternative planting methods to relieve compaction and improve growth conditions. One of the research questions related to the F2F project involved utilization of composted material for crop fertility. Parties engaged in this discussion included local waste water treatment managers, crop and soil scientists, and UDOT regarding application of composted material from waste water treatment operations. It was anticipated that use of composted materials would increase yield and decrease erosion events in oilseed production. From resultant discussions, the following research questions were formulated:

1. Can the banding of composted material over the seeded row improve seed emergence and crop yield?
2. Will aeration of soil be effective in relieving compaction prior to planting?
3. Will the combination of compost and aeration be more effective at crop production than either alone?

Based on these questions, the following hypothesis was developed:

If soil were aerated prior to planting and then compost was applied over seedbeds during planting to improve soil quality, nutrient content, water retention, germination, and decrease crusting and erosion—all in one pass—then yields would increase.

Materials and Methods

The RSL was established in 2008. It consisted of a compacted 6 inch layer of ¾ inch minus road base covered by a 6 inch layer of compacted topsoil. Bulk densities of the topsoil on the RSL were compacted to bulk to 1.12 oz/in^3 (1.94 g/cm^3)

Figure 6.1 Illustration of Road Simulation Laboratory Construction.

Figure 6.2 illustrates what the functional RSL looked like when construction was finished and it had a season of natural plant growth during 2008.

Figure 6.2 Functional Commercial Safflower Rooting Depth RSL

Figure 6.3 is a cross section cut of the RSL illustrating stratified layers of different materials used to build the RSL. The top 6” of soil is clearly visible when contrasted against the lighter 6” layer of roadbase below.

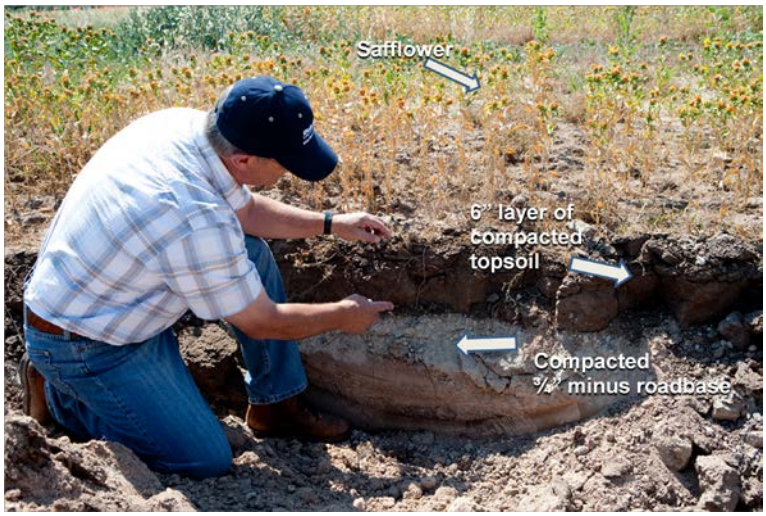

Figure 6.3 Cross Section of RSL Showing Compacted Topsoil and Roadbase Layers

The experimental design for the RSL was a complete split plot randomized block design with 4 split plot treatments replicated in each of the three blocks. Safflower (variety S-208) was planted at a rate of 15 lbs/acre in the various treatments. The treatments for the simulated roadside laboratory are shown in Table 6.1.

Treatment	Compost	Aerway Offset (degrees)
Control/No Till	no	0
Biosolids Banding/No Till	5 tons/acre	0
Aerway/No Till (culti-planting)	no	0
Aerway/No Till/Biosolis Banding (culti-banding)	5 tons/acre	0
Control/No Till	no	15
Biosolids Banding/No Till	5 tons/acre	15
Aerway /No Till (culti-planting)	no	15
Aerway/No Till/Biosolis Banding (culti-banding)	5 tons/acre	15

Table 6.1 RSL Plot Treatments

×Compost was banded by hand over the tops of the respective treatments post planting

Other crops researched under RSL conditions were spring and winter canola, winter safflower and camelina (*Camelina sativa)*. Planting of the plots was conducted with a New Holland tractor, an Aerway Aerator, and a Tye Pasture Pleaser no-till Drill on respective treatments (Figure 6.4).

Figure 6.4 Equipment used for Planting Roadside Simulation Laboratory Plots. Aerway Aerator Followed by a Tye Pasture Pleaser No Till Drill.

PHOTOS OF TREATMENT ESTABLISHMENT

Figure 6.5 No Till Drill Only

Figure 6.6 Culti-Planting—Aerway Aerator before No Till Drill. Right side of picture illustrates 0 degree offset and left side of photo shows 15 degree offset

Figure 6.7 Culti-Planting—Aerway Aerator before No Till Drill followed by Compost Banding. Right side of picture illustrates 0 degree offset and left side of photo shows 15 degree offset

Plots were harvested using an Almaco Research Combine with a 4 ft wide head (Figure 6.8). Split plots were harvested in their respective treatment keeping the header between the middle open row spaces separating the treatments.

Figure 6.8 Almaco Research Combine used to Harvest Safflower

In order to monitor safflower seed loss and combine efficiency, one row of safflower per plot in replication three was hand harvested and compared to the yields of the rest of the representative plot. Table 6.2 shows data comparing the combine efficiencies.

Plot Number	306	309	312
4 row harvest with combine gms	300	228	207
1 row harvest by hand gms	95	148	105
1 row adjusted to 4 rows gms	380	592	420
adjustment factor	1.3	2.6	2.0
average adjustment factor			2.0

Table 6.2 USU Almaco Research Combine Efficiency

Plots were measured for soil bulk density post-harvest for compaction disturbance within each treatment. Bulk density measurements were conducted using an AMS 2" x 6" Signature SCS Soil Coring Tool.

Results and Discussion

Crops tested under RSL conditions included spring and winter canola, spring and winter safflower, and camelina. Only spring safflower (S208 variety) trials produced significant enough yields to report. Spring safflower crops were harvested during the month of September 2009. Data from the 2009 harvest was collected and formatted in Figure 6.9.

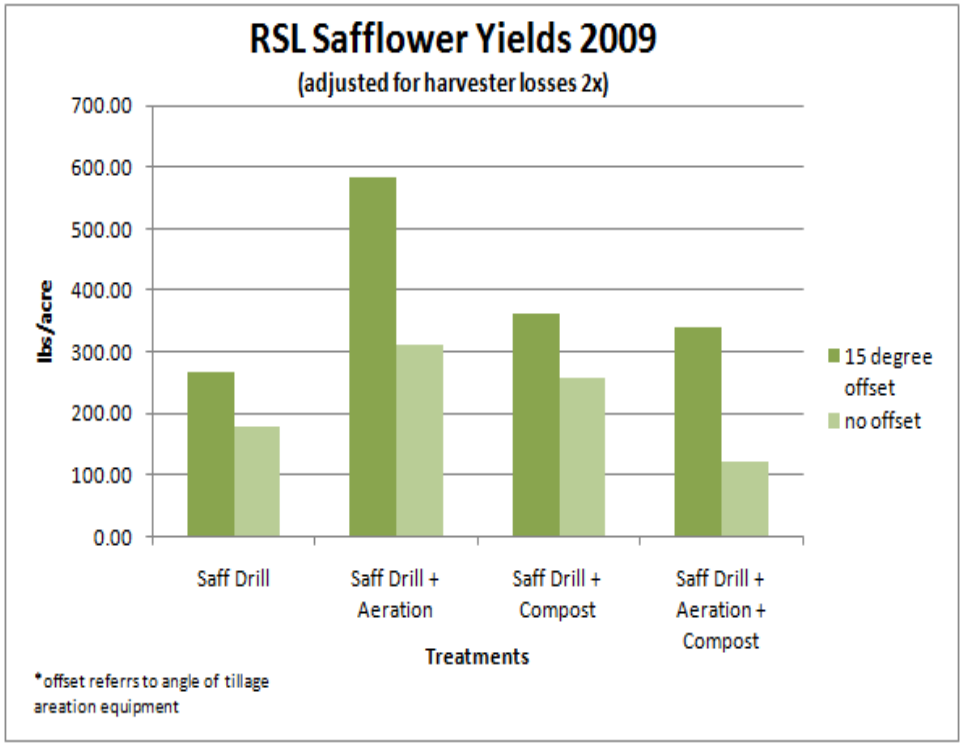

Figure 6.9 Yields of 2009 Roadside Simulation Laboratory Safflower Plots

The safflower + aeration (culti-planting) technique yielded the highest amount of safflower. It was anticipated that the safflower + aeration + compost (culti-banding) treatment would be the highest yielding treatment. It is probable that the compost was not mature (C:N ratio was >20) and should have been placed on soils months before planting. This would have allowed for mineralization of the nutrients in the compost to occur providing necessary nutrients for plant growth. Compost has been reported to immobilize the nutrients during mineralization. This may have affected safflower growth because of nutrient unavailability. Immature compost can lead to nitrogen immobilization for a few months due to microbial transformations in the soil (Eghball et al., 2002).

Bulk density measurements between disturbed RSL soils (Aerway treatment) and undisturbed soils (no Aerway treatment) remained unchanged post-harvest in 2009.

Conclusion

The safflower + aeration treatment yielded the highest amount (583 lbs/acre) under RSL conditions. This is a milestone because this yield represents a breakeven point financially for the

F2F method. No other treatments to date have obtained this goal under RSL or roadside conditions.

In addition, newly developed culti-planting methods showed financially viable yields while preserving compaction for roadside structure.

*baseline values compared to 2006 Eastern Washington Estimates by Kathleen Painter and Dennis Roe:									
http://cff.wsu.edu/Publications/budgets/dryland%20winter%20canola%20budget_14inch.xls									
Cost/Acre									
processing costs/acre	$35.70		**Operating Costs**	units/acre	cost/unit	total/acre			
gallons of B100/acre*	25.5		Aerator/Spreader/Seeder	1	$2.00	$2.00			
meal for cattle feed	$39.60		Canola Seed	12	$2.00	$24.00		adjusted to untreated prices	
cost of B100/acre	**$71.46**		Nitrogen ((NH4)2SO4	40	$0.55	$22.00			
worth of B100/acre	**$70.13**		P2O5	10	$0.30	$3.00			
profit/acre	**-$1.33**		Sulfur	10	$0.20	$2.00			
cost B100/gal	**$2.80**		Herbicide - glyphosate	2	$5.00	$10.00		adjusted to generic prices	
			Insecticides	0.4	$7.00	$2.80		adjusted to generic prices	
Cost/Mile			Fuel - Diesel/Gasoline	2	$2.30	$4.60			
market diesel value	**$2.75**		Machinery Repair	1	$5.98	$5.98			
width of grow area(ft)	**100.0**		Labor (machine)	1.04	$12.00	$12.48		this may be modified down	
acres of grow area/mile	**12.1**		Labor (non-machine) hrs	0.25	$12.00	$3.00			
yield per mile cwt	**72.7**		Interest on Capital @ 5.50%	0	$2.50	$0.00			
gallons of oil/mile	**309.1**		**Total Operating Costs/Acre**			**$91.86**			
cost B100 production/mile	**$866.18**								
worth of B100/mile	**$850.00**								
profit/mile to grower	**-$16.18**		**Fixed Costs**						
Savings to DOT/Mile	**$283.82**		General Overhead		$2.00	$2.00			
			Lease Payment/Depreciation		$6.00	$6.00		alternative cropping methods	
			Machinery Interest		$0.00	$0.00		all equipment leased	
Assumptons:			Land Rent		$0.00	$0.00		state owned	
yield cwt/acre**	6.0		Management Fee		$1.00	$1.00			
cost of maint/mile	$300.00		Fallow Cost		$0.00	$0.00		state owned - no rent due	
cost of maint/acre	$24.75		Property Taxes		$0.00	$0.00		state owned	
pressing/gal	$0.50		Insurance		$0.00	$0.00		state owned	
processing costs/gallon	$0.90		**Total Cash Ownership Costs/Acre**			**$9.00**			
fuel tax credit	$1.00								
weight of oil per gal	7.6		**Total Cost/Acre**			**$100.86**			
seed oil content (%)	40.0%								
extraction efficiency (%)	85.0%		**Total Cost/Acre less Cost of Maint**			**$76.11**			
value of meal/ton	$200.00								

Table 6.3 Economic Model of FreeWays to Fuel

The degree of offset on the aerator appears to affect the yield of safflower. The more aggressive the offset seemed to increase yields. Why did this occur? This area needs further investigation.

7.0 FUTURE RESEARCH NEEDS AND COLLABORATION

The F2F project has generated local, regional and national attention. Clearly soil, cropping systems and environmental conditions vary from region to region. As the F2F model has matured dissemination of this projects research has lead to interest from other entities. National interest in utilizing nontraditional agriculture lands for biofuel feedstock production has allowed partnerships with other departments of transportation, land grant universities, departments of agriculture and energy, economic development, sustainability groups, military and municipalities. This has encouraged the development of a national alliance between interested parties for developing F2F projects in other parts of the United States.

F2F National Alliance

It is anticipated that project partners, from other states and organizations, with successful production will remain as long-term biofuel feedstock sources in their respective regions.

Various feedstocks need to be evaluated by scientific comparison of different agronomic cropping locations and a host of oilseed feedstock crops, under the management of various university partners, and guidance from Utah State University. Collection, transportation and storage of these feedstocks will be conducted with conventional equipment.

Researchers should evaluate what planting methods/crop combinations will provide the most benefit to sustainable plant establishment and yield. Recommendations and implementation strategies will also be included in a final report to all partners and disseminated at public forums and in scientific sources. A national F2F alliance would promote beneficial collaboration across industry, government, and academia. The list of collaborators reported below, indicates the interest in this technology.

To date, the national F2F alliance teams that have showed interest in researching the viability of this concept include:

- Lynn Averbeck – Oregon Department of Transportation
- Glen Caufmann – Penn State University
- Charles Gould – Michigan State University

- Shauna Lindsey – Utah Department of Transportation
- Stan Johnson PhD – Special Asst. to Gale Buchanan
- Michael McCaskey, PhD – State University of New York – Cobbleskill
- Glenn Miller, PhD – University of Nevada – Reno
- Peter Moulton – Washington State Department of Community, Trade and Economic Development
- Bill Pan, PhD – Washington State University
- Alice Pilgram, PhD – Montana State University
- Joel Schumacher – Montana State University
- Steven Taylor, PhD – Auburn University
- Matt Veal, PhD – North Carolina State University
- Alan Weber – National Biodiesel Board Ray Willard – Washington State Department of Transportation
- Don Wyoski, PhD – Oregon State University

The F2F Mosaic

It is obvious that all nontraditional agronomic lands are not suited for biofuel feedstock production. To mitigate this issue we feel the F2F Mosaic concept should be pursued further. The F2F Mosaic concept embraces issues related to:

- Safety
- Structural Integrity
- Establishment and Harvesting
- Economics
- Wildlife Impacts
- Ecology/Environmental Impacts
- Water Quality
- Local Grower Concerns

The F2F mosaic would integrate these topics in nontraditional agronomic land settings seeking to reach a sustainable balance between variables introduced by the specific situations.

One iteration of the F2F mosaic would be to grow vegetation from the roadside to the right of way boundary in height steps. By design, low growing perennials would be closest to the road, then taller crops could be grown in the next step of the mosaic. Finally, as risk factors become decreased with distance from roadside, taller or denser crops could be grown.

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8.0 CONCLUSIONS AND RECOMMENDATIONS

With the information elucidated above, the private contractor utilizing inexpensive public biosolids for fertility brings the most total savings/profit for the parties involved in both the state operated and public/private scenario.

UDOT can potentially save 1.7 million dollars per year in maintenance fees ($300/mile) by public/private relationships that produce 6.0 cwt given the information in Table 2.0 and growers can profit $67 per mile given the same assumptions.

After evaluation and analysis of these data it was possible to conclude that spring canola production along UDOT rights-of-way was not profitable under reported conditions for 2007 and 2008. Field data, combined with greenhouse data (see chapter 5), and made it possible to conclude that soil compaction and seeding depth had the most significant effect on safflower establishment, growth and development.

The depth of the seed and compaction of soil had the most significant effects on biomass produced. This supports our initial hypothesis that a limiting factor of the roadside plots was compaction. This experiment confirms that the depth of seed placement in and the level of soil compaction is a critical to plant establishment and growth.

The safflower + aeration treatment yielded the highest amount (583 lbs/acre) under RSL conditions. This is a milestone because this yield represents a breakeven point financially for the F2F method. No other treatments to date have obtained this goal under RSL or roadside conditions.

In addition, newly developed culti-planting methods showed financially viable yields while preserving compaction for roadside structure.

It is the opinion of the authors that the following should be explored further under Utah freeway conditions:

F2F Mosaic concept should be pursued further. The F2F Mosaic concept embraces issues related to:

a. Safety
b. Structural Integrity
c. Establishment and Harvesting
d. Economics
e. Wildlife Impacts
f. Ecology/Environmental Impacts
g. Water Quality
h. Local Grower Concerns

Culti-planting techniques developed during this study need to be explored in situ

Timing of planting such as utilization of fall plantings and bi-annual techniques need to be developed

Use of biosolids along roadsides is already precedented and needs to be accepted by UDOT

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APPENDICES

APPENDIX A: Weather Data

Weather Conditions

Station	Mar	Apr	May	Jun	Jul	Aug
42-2726-03 Farmington 3NW	**1.34**	**1.25**	**1.02**	**2.42****		
of normal	*51%*	*47%*	*34%*	*191%*	*0%*	*0%*
42-5194-	**1.49**	**0.85**	**1.23**	**0.74**		
of normal	*80%*	*43%*	*57%*	*59%*	*0%*	*0%*

Station Na	**Avg Temp**	from Norr	**Precip**	from Norr	Pct	**HDD**	from Norr	**CDD**
FARMINGT	52.24	3.6	3.87	-4.26	47	1111	-383	73
LOGAN UT	48.84	2.55	4.02	-2.49	61	1356	-340	32
NEPHI	51.77	2.84	2.44	-2.4	50	1226	-247	71

APPENDIX B: Yield DATA

Canola Data for 2007 - hand thresed 10 canola plants using round screen and shook 10 times back and forth. Then used air blower to get rid of chaf

	UBC			KAYS			MM240			TREM		
Plot #	# plants	grm/10	lbs/acre	# plants	grm/10	lbs/acre	# plants	grm/10	lbs/acre	# plants	grm/10	lbs/acre
102	350	0.58	349.99	150	4.01	149.91	0	0.00	0.00	2	0.45	1.99
103	647	0.59	646.99	175	2.97	174.93	0	0.00	0.00	0	0.00	0.00
202	679	0.27	678.99	205	1.85	204.96	0	0.00	0.00	8	1.03	7.98
206	199	0.34	198.99	190	7.11	189.84	0	0.00	0.00	0	0.00	0.00
301	492	0.36	491.99	75*	0.00	0.00	0	0.00	0.00	0	0.00	0.00
303	594	0.76	593.98	125*	0.00	0.00	0	0.00	0.00	0	0.00	0.00
401	302	0.33	301.99	210*	0.00	0.00	0	0.00	0.00	0	0.00	0.00
402	534	0.35	533.99	200*	0.00	0.00	0	0.00	0.00	0	0.00	0.00
avg.	475	0.45	474.62	180	1.99	89.96	0	0.00	0.00	1	0.18	1.25

*plants did not mature

2007 Safflower Yeild Data

	UBC			KAYS			MM240			TREM		
Plot #	# plants	gm	lbs/acre	# plants	gm	lbs/acre	# plants	gm	lbs/acre	# plants	gm	lbs/acre
106	80	137.2	664.65	0	0	0.00	0	0.00	0.00	3	2.00	0.36
201	147	93.7	834.08	0	0	0.00	0	0.00	0.00	0	0.00	0.00
304	152	95	874.41	0	0	0.00	8	8.40	4.07	0	1.03	0.00
406	112	66.3	449.66	0	0	0.00	0	0.00	0.00	0	0.00	0.00
avg.	123	98	706	0	0	0	2	2	1	1	1	0.00

2007 Yield Data from Roadside Plots

2008 Spring Canola Data

	UBC			KAYS			MM240			TREM		
Plot #	# plants	grm/10	lbs/acre	# plants	grm/10	lbs/acre	# plants	grm/10	lbs/acre	# plants	grm/10	lbs/acre
8102	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8103	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8202	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8206	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8301	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8303	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8401	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8402	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
avg.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00

*plants did not mature

2008 Safflower Yeild Data

	UBC			KAYS			MM240			TREM		
Plot #		gm	lbs/acre		gm	lbs/acre		gm	lbs/acre		gm	lbs/acre
8106		0	0.00		0	0.00		0.00	0.00		39.94	23.94
8201		0	0.00		0	0.00		0.00	0.00		23.00	13.79
8304		0	0.00		0	0.00		8.40	5.04			0.00
8406		0	0.00		8	4.99		0.00	0.00		0.00	0.00
avg.		0	0		2.1	1.2		2.1	1.3		21.0	9.4

2008 Yield Data from Roadside Plots

Summary Table 2008 Yield Data in lbs/acre						Summary Table 2007 Yield Data		
	UBC	KAYS	MM240	TREM			UBC	KAYS
SP Canola	0	#REF!	0	0		SP Canola	394	90
RR SP Can	0	0	0	0		RR SP Can	485	190
Sp Safflow	#REF!	1.2	1.3	9.4		Sp Safflow	706	0
2008 Spring Canola Data								
		UBC			KAYS			MM240

Yield Summary Data for 2007 – 2008 from Roadside Plots

APPENDIX C: Soil Analysis Data

Soil Analysis																			
	Mona R1	Mona R2	Mona R3	Mona Avg	MM 240 R1	MM 240 R2	MM 240 R3	MM 240 .	kay R1	Kay R2	Kay R3	Kay R4	Kay AVG	Trem R1	Trem R2	Trem R3	Trem R4	Trem AVG	Control Kaysville
Texture	l	l	l	l	l	l	l	l	sl	sl	sl	sl	sl	sl	sl	sl	sl	sl	sl
Organic Matter	2.1	2.6	1.8	2.17	2.1	2.3	2.4	2.2667	2.2	2.1	2.2	1.6	2.03	2.5	2.5	2.8	2.9	2.68	1.6
pH	7.94	7.92	7.92	7.93	7.87	7.94	7.9	7.9033	7.7	7.68	7.58	7.97	7.73	7.96	7.88	7.85	7.89	7.9	7.26
EC	0.8	0.7	0.75	0.75	1.76	1.49	0.9	1.3833	0.75	0.6	0.9	1.43	0.92	0.79	0.94	0.91	1.15	0.95	0.8
Phosphorus - P	10.5	14.2	9.8	11.5	27	22	17.6	22.2	15.6	25	16.8	10.8	17.1	20.1	12.9	17.5	20.4	17.7	25
Potassium - K *10	226	247	210	11.4	442	296	265	16.717	184	196	167	144	8.45	890	669	695	765	35.5	24
Nitrate Nitrogen - N	8.89	8.38	8.49	8.59	19.5	12.9	9.22	13.873	3.32	4.02	2.7	4.02	3.52	9.38	5.73	7.82	10.8	8.43	26.3
Zinc - Zn	1.66	1.71	1.78	1.72	2.06	3.03	3.36	2.8167	2.35	1.7	3.58	2.81	2.61	0.99	0.73	0.8	1.25	0.94	8.2
Iron - Fe	7.46	5.04	5.03	5.84	7.13	8.75	6.54	7.4733	13.4	10.4	9.84	9.58	10.8	6.89	6.61	8.21	7.43	7.29	12.5
Copper - Cu	1.01	1.19	1.2	1.13	1.44	1.43	1.45	1.44	1.91	1.86	2.64	2.29	2.18	1.18	1.26	1.2	1.34	1.25	1.81
Maganese - Mn	12.3	13	12.4	12.6	11	12.2	12.3	11.833	15.4	11.1	8.72	6.32	10.4	11.5	9.38	10.3	11.5	10.7	6.25
Sulfate - Sulfur - S	4.4	3.6	3.4	3.8	5.9	4.8	3.9	4.8667	5	4.2	4.6	5.2	4.75	3.9	3.9	3.3	4.3	3.85	5.3

Soil Conditions along Roadsides

Prototype of Soil Conetainer Preparation apparatus

APPENDIX D: Safflower Variety Trials Utah

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Table 1. 2008 Dryland Safflower Variety Trial at Blue Creek, Utah (Box Elder Co.).
GPS 41°56'08.94" N 112°26'18.62" W
Planting Rate 15 lbs PLS/A, Planted 5/15/08, Harvested 10/29/08.
Soil Type: Timpanogos Silt Loam. Elevation 5138 ft.
Applications 50 units of N (16-16-8), and 2 pts of Sonalan herbicide at pre-planting.
Previous crop: Fallow.

Variety	Seed Production lb DM/ac	Color Score	Oil Content %	Lbs of Oil	Gross Income /acre*
HYBRID 16	1182	5.0	37.9	449.0	355
SEEDTEC 5241	1117	1.0	39.3	439.5	335
HYBRID 90	1053	4.0	34.9	367.5	316
SEEDTEC S-333	1047	1.0	43.2	451.8	314
HYBRID 9022	1002	3.0	33.9	340.3	300
HYBRID 9049	988	2.0	35.9	355.0	296
SEEDTEC 3151	982	4.0	42.4	414.5	295
C/W 99-0L	948	6.0	42.6	403.3	284
SEEDTEC S-719	923	5.0	41.5	383.0	277
C/W 88-0L	919	7.0	42.9	394.5	276
MONTANA 3538	905	1.0	38.0	344.5	271
S-208	885	1.0	41.6	369.0	266
MONTANA 7446	871	2.0	39.1	340.8	261
SEEDTEC 2106	861	1.0	44.2	379.8	258
SEEDTEC 4409	840	1.0	41.5	348.5	252
FINCH	789	1.0	38.0	300.3	237
MONTANA 3842	719	10.0	47.6	340.8	216
MONTANA 2003	699	2.0	40.3	281.3	210
Mean	**929**	**3.2**	**40.3**	**372.4**	**279**
Significance of F test					
LSD (0.05)	234		0.8	93.0	70
LSD (0.30)	122		0.4	49.0	37
CV (%)	17.7		1.5	17.6	17.8

* Gross income is figured on seed production at $30.00 per cwt. Crop inputs (fertilizer, pesticides, equipment costs), color score, test weight and oil content were not figured into the gross income figure.

A special thanks is extended to Art Weisker, SeedTec; Jerry Bergman, Safflower Technologies; Bill Meadows, Mountain States Oilseeds; Tom Hickman, CalWest Seeds; Utah Agricultural Experiment Station; Boyd Kitchen, USU Extension; for their advice, expertise, equipment, time and supplying seed for this trial.

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Planting Rate 15 lbs PLS/A, Planted 4/26/07 , Harvested 9/17/07.
Soil Type: Timpanogos Silt Loam. Elevation 5138 ft.
Applications 50 units of N (16-16-8), and 2 pts of Sonalan herbicide at pre-planting.
Previous crop: Fallow.

Variety	Seed Production lb DM/ac	Color Score	Oil Content %	Gross Income /acre*
SeedTec 5244	516	2.3	38.0	96
Hybrid 9049	503	2.3	34.0	93
SeedTec S-719	498	3.0	38.9	92
Hybrid 16	485	4.3	36.6	90
SeedTec 3151	484	4.0	39.9	90
SeedTec 1133	462	3.0	41.9	86
S-208	460	1.6	39.0	85
Finch	454	1.0	35.6	84
SeedTec 2106	432	1.0	42.4	80
Oleic 5	425	6.0	41.4	79
SeedTec 5232	424	1.5	39.3	78
Cardinal	422	1.0	34.7	78
MonDak	422	2.3	37.8	78
SeedTec 4409	400	2.0	39.5	74
Montola 2003	369	1.3	37.8	68
Nutrasaff	353	10.0	45.6	65
Mean	**444**	**2.9**	**38.9**	**82**
Significance of F test		<0.01	<0.01	
LSD (0.05)	166	0.5	1.0	31
LSD (0.30)	86	0.3	0.5	16
CV (%)	26.3	13.0	1.8	26.2

* Gross income is figured on seed production at $18.50 per cwt. Crop inputs (fertilizer, pesticides, equipment costs), color score, test weight and oil content were not figured into the gross income figure.

A special thanks is extended to Art Weisker, Seed Tec; Jerry Bergman, Safflower Technologies; Bill Meadows, Mountain States Oilseeds; Utah Agricultural Experiment Station; Shyrl and Justin Clawson, USU Plant Soil and Climate Dept; for their advice, expertise, equipment, time and supplying seed for this trial.

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APPENDIX E: Safflower Variety Trials Utah

treatment	depth_cm	_treatment	_depth_cm	Estimate	StdErr	DF	tValue	Probt	Adjustme	Adjp
CompFurrCltrPress	1	NoCompFurr CltrPress	1	-0.01624	0.007649	144	-2.12322	0.035446	Tukey	0.99335
CompFurrCltrPress	1	NoCompaction	1	-0.03492	0.007649	144	-4.56517	1.06E-05	Tukey	0.008594
CompFurrowCulter	1	NoCompaction	1	-0.03278	0.007649	144	-4.28489	3.33E-05	Tukey	0.023863
Compaction	1	NoCompFurr CltrPress	1	-0.01558	0.007649	144	-2.03688	0.043494	Tukey	0.996896
Compaction	1	NoCompaction	1	-0.03426	0.007649	144	-4.47883	1.52E-05	Tukey	0.011878
CompactionFurrow	1	NoCompaction	1	-0.03142	0.007649	144	-4.1079	6.67E-05	Tukey	0.043411
NoCompFurr CltrPress	1	NoCompaction	1	-0.01868	0.007649	144	-2.44196	0.01582	Tukey	0.944068
NoCompFurrowCulter	1	NoCompaction	1	-0.03019	0.007649	144	-3.94658	0.000123	Tukey	0.072311
NoCompaction	1	NoCompactionFurrow	1	0.030746	0.007649	144	4.019467	9.37E-05	Tukey	0.057672
CompFurrowCulter	2	NoCompFurr CltrPress	2	-0.01615	0.007649	144	-2.11123	0.03648	Tukey	0.993985
Compaction	2	NoCompFurr CltrPress	2	-0.02101	0.007649	144	-2.74636	0.006795	Tukey	0.800093
Compaction	2	NoCompFurrowCulter	2	-0.01941	0.007649	144	-2.5371	0.012242	Tukey	0.910962
Compaction	2	NoCompaction	2	-0.01962	0.007649	144	-2.56434	0.011361	Tukey	0.899501
CompactionFurrow	2	NoCompFurr CltrPress	2	-0.01904	0.007649	144	-2.48879	0.013957	Tukey	0.929089
CompactionFurrow	2	NoCompFurrowCulter	2	-0.01744	0.007649	144	-2.27953	0.024105	Tukey	0.978658
CompactionFurrow	2	NoCompaction	2	-0.01765	0.007649	144	-2.30677	0.022494	Tukey	0.974501
Compaction	4	NoCompFurr CltrPress	4	-0.01963	0.007649	144	-2.56645	0.011296	Tukey	0.898578
CompactionFurrow	4	NoCompFurr CltrPress	4	-0.01837	0.007649	144	-2.4016	0.017599	Tukey	0.955037
CompFurrowCulter	5	NoCompactionFurrow	5	-0.01883	0.007649	144	-2.46186	0.015003	Tukey	0.938007
Compaction	5	NoCompactionFurrow	5	-0.01808	0.007649	144	-2.36331	0.019449	Tukey	0.9639
CompactionFurrow	5	NoCompactionFurrow	5	-0.01883	0.007649	144	-2.46186	0.015003	Tukey	0.938007
NoCompaction	5	NoCompactionFurrow	5	-0.01733	0.007649	144	-2.26622	0.024929	Tukey	0.980486