United States Department of Agriculture

Natural Resources Conservation Service
Los Lunas Plant Materials Center
2013Annual Technical Report

By: Los Lunas Plant Materials Center Staff

Gregory A. Fenchel, David R. Dreesen, Danny G. Goodson, Keith L. White, and Dennis Price

1036 Miller Road
Los Lunas, NM 87031
Telephone: 505-865-4684/FAX 505-865-5163

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NRCS Soil Health Study

Background

In the winter and spring of 2012, USDA-Natural Resources Conservation Service (NRCS) personnel were involved in three meetings about using cover crops to improve soil health. The attendees were:

- State Agronomist
- Area Agronomists
- State Water Quality and Soil Data Quality Specialists
- Los Lunas Plant Materials Center (LLPMC) staff

Cover crops may be defined as any crop that is planted between periods of regular commodity crop production. This practice can save the producer money and provide for a more sustainable farming operation with fewer inputs (fertilizer, irrigation, cultivation, etc.) compared to traditional farming operations. Cover crops are often used in New Mexico on irrigated lands. However, cover crops are rarely used in New Mexico on dry-land farms because the limited amount of precipitation is inadequate for establishment and sustainability. The limited and irregular precipitation that does occur is often reserved for strictly commodity crop production.

Between cropping systems, the land is often left fallow. The bare topsoil of fallowed land is subject to erosion by severe spring winds (some days above 50 mph) that commonly occur in New Mexico and are particularly damaging to sandy soils. This wind damage commonly occurs both on and off farm and range sites in New Mexico.

About 10 million dollars in destruction were estimated annually on site in New Mexico (Davis and Condra, 1989) and includes:

- Reduced soil productivity because of the loss of water storage capacity for plant available water
- Loss of plant nutrients
- Degradation of soil structure
- Reduced uniformity of soil conditions in the field

Eolian deposits resulting from wind erosion reduces reservoir storage capacity, clogs streams and drainage channels, deteriorates aquatic habitat, muddies recreational waters, increases water treatment costs, damages water distribution systems, and carries agricultural chemicals into water systems.

Annual damages to off-farm property and persons were estimated at 466 million dollars in New Mexico (Huszar and Piper, 1986) and damages included:

- Exterior paint
- Landscaping
- Automotive
- Interior and Laundry
- Health
- Recreation

Sandy soils are common in New Mexico and as well as being subject to wind erosion, have limited water holding capacity because of their coarse texture (soil particle size between 0.05 and 2.0 mm). Because of their large particle size, macro-pores exist between soil particles and aggregates (PEDS) that are too large to have any significant capillary forces and are drained by gravity. Sandy soils hold very little available water, about 1-inch per 1-foot of soil. However, on sandy soils, an increase in soil organic matter provided by cover crops may improve soil water holding capacity by increasing the microspore space which holds the capillary water.

Other potential soil health improvements from cover crops include:

- Additional nitrogen, phosphorus, and sulfur
- Improvement in soil structure by supplying directly or indirectly through microbial action the major soil aggregate forming cements, particularly polysaccharides
- Increased cation exchange capacity which provides increased capability to absorb nutrients for eventual plant use
- Increased microbial activity (i.e., free nitrogen fixers and denitrifiers) by supplying carbon as food source
- Increased buffering capacity against rapid change in acidity, alkalinity, salinity, and damage by pesticides and toxic heavy metals.

Other benefits of cover crops as described in the *NRCS Cover Crop Practice Standard's Manual* include:

- Reduce erosion from wind and water
- Increase biodiversity
- Suppress weeds
- Provide supplemental forage
- Reduce particulate emissions into the atmosphere
- Minimize and reduce soil compaction
- Attract beneficial insects (pollinator, predators, and parasitoids)

The soil health benefits gained by using cover crops may provide for increased net profit from commodity crops.

The group identified nine potential studies regarding the soil health benefits of using cover crops. The purpose of these proposed studies on cover crop practices is to provide New Mexico NRCS Field Staff with practical information which is not currently available for Southwestern climates and soils.

After several meetings, the following three studies were considered to be the most important:

1. **Study #1: Performance of Selected Cover Crops and Cover Crop Mixes Followed by a Selected Cash Crop Under New Mexico Southern High Plains Conditions**

   Compare the performance including soil health benefits, ease of establishment, forage value and other agronomic characteristics of selected cover crops. After termination of the individual cover crops, a selected commodity crop will be seeded into the various cover crop treatments. The growth response of this commodity crop without the addition of fertilizers will provide the final measurement of cover crop performance in this study.

2. **Study #2: Comparison of a Cover Crop/No-till Farming Practices with Conventional Tillage Farming Methods**

   The inputs and products of a cover crop/no-till planting (using a single cover crop species) will be compared with a conventional tillage planting with the same commodity crop. A thorough analysis of economic costs and benefits of both methods will be conducted, and the ecological services provided by the practices will be quantified.

3. **Study #3: Evaluation of Uncommon Cover Crops under New Mexico Conditions**

   Uncommon legume cover crops that are tolerant of drought and alkaline soils will be evaluated under New Mexico conditions. Many of these legume cover crops have been developed in Australia and other arid countries.

Study #1 Study Plan (February 2013)

Performance of Selected Cover Crops and Cover Crop Mixes Followed by a Selected Commodity Crop Under New Mexico Conditions

Introduction

NRCS cooperators are interested in sustainable farming practices that use cover crops to improve soil health. In the New Mexico southern high plains, dryland farming is occurring where the annual average amount of precipitation during this current drought period is only about 15 inches. This seems to be close to the threshold for the minimal amount needed for dryland farming in this hot, arid environment. Even more limiting, most of the precipitation occurs during the summer months (June to August) when the daily temperatures average above 90° F (Western Regional Climate Center, 2012). Because of the high temperatures, the limited amount of precipitation may be lost mostly to evaporation making dryland farming extremely difficult. Area Agronomist Kevin Branum explained dryland farming in this area has been limited to drought tolerant small grain crops. Historically local producers have sold these as silage to dairies. Using cover crops in this area may enhance both the quality and the yield of dryland grain silage crops.

Cover crop mixes are commonly used in the river valleys of northern New Mexico (such as the Rio Grande, Rio Chama, and Mora River) where the temperatures are cooler (-30° to 85° F) and precipitation is typically more abundant (12 to 26 inches annually). Irrigation water also is more available in this area. These cover crop mixes are often highly sophisticated containing both cool-season and warm-season plants, legumes, grasses, and mustards. As reported by Ana Gomes, Northwest Area Agronomist (personal communication 11/2012), some of the commonly used cover crop mixes are:

- Cowpea, sorghum, sudan grass, and millet
- Triticale, rye, and cowpea
- Brassica, ryegrass, sorghum-sudan, small grains and clovers
- Oregon common ryegrass, annual white sweet clover, cowpeas, millet, turnip, radish, cowpeas

Producers are using cover crop mixes because different species provide different attributes that synergistically improve soil health. Examples of plants that lead to particular soil health improvements include:

- Grasses provide the longest lasting residue cover because they have a higher carbon-to-nitrogen ratio in their biomass compared to non-grass species
- Legumes with their rhizobium bacteria relationship (for example clover and common vetch) fix atmospheric nitrogen which feeds into the soil system

- The deeper tap roots of forb species, especially Brassicas (mustards), penetrate and open soils reducing compaction which improves infiltration. They also provide large amounts of carbon that feed micro-organisms
- Cool-season plants (grains, mustards, vetches, and clovers) are able to grow in the fall, winter, and spring which helps to build the soil and manage soil moisture during cold periods
- Warm-season plants (Sudan grass, medics, and cowpeas) are able to grow during the hot summer months which can help to build the soil. This in turn helps to improve soil moisture retention and improves filtration during excessively warm periods

The goal of these studies is to provide NRCS Field Office staff with concrete information about the soil health benefits of using the recommended selection of cover crops. Cover crop single species and cover crop mixes will be grown and evaluated at the LLPMC for use in the southern high plains of New Mexico and the river valleys of northern New Mexico. Cover crops exhibiting superior performance during these field studies will be tested again in the second phase of this study at appropriate field locations in New Mexico.

Study Methods

The cover crops and commodity crop study treatments (Table 1) were selected by the New Mexico NRCS State and Area Agronomists because they are commonly used by New Mexico cooperators. Seeding rates for the cover crop treatments are also listed. The treatments were sown on September 4, 2013 with a Land Pride PSN-2096 Seeder (a two-box broadcaster with a "Brillion" like culti-packer). A broadcast drill was used because the soil had been recently tilled and there was concern about sowing seed too deep if a heavy no-till drill was used. After good surface mulch of organic matter is obtained from repetitive cover crop use in future years, seeding will be done with a Great Plains No-Till Drill 3P605NT which will be able to penetrate the surface residue so seeds are sown into mineral soil.

Table 1: Selected Cover Crops

Common Name	Scientific Name	Variety	Growth Season	PLS/lbs/acre	PLS/sq ft.
Legume/forb/grass mix					
Buckwheat	*Fagopyrum esculentum*	Not Stated	Warm	10	3
Cowpea	*Vigna unguiculata*	Not Stated	Warm	15	3
Cultivated radish	*Raphanus sativus*	Not Stated	Cool	4	3
Foxtail millet	*Setaria italica*	Gernan R Strain	Warm	5	24
Forage sorghum sudangrass hybrid	*Sorghum bicolor x Sorghum bicolor ssp. drummondii*	Wondergraze	Warm	3	1
Total				**37**	**34**
Common barley	*Hordeum vulgare*	Not Stated	Cool	42	14
Winter vetch	*Vicia villosa*	Not Stated	Cool	38	14

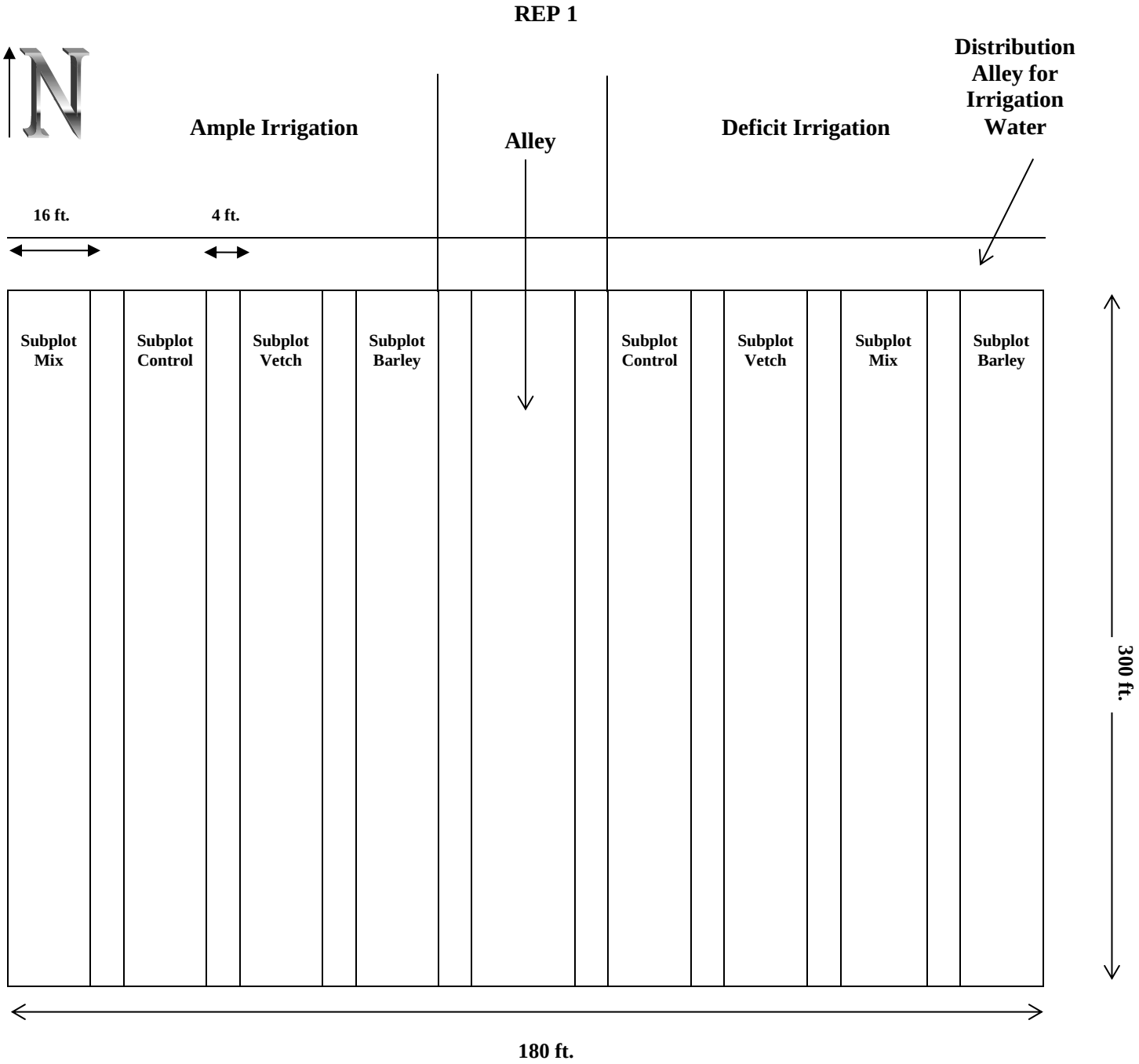
Control plots of bare soil are used to evaluate the soil benefits of the cover crop treatments. Herbicides, mowing and hanSHS-hoeing treatments are being applied to control weeds on all treatment plots. There will be no tillage on any plot during this study. Cover crop treatments will be terminated after they become well-established in late spring, and then they will be replaced by the commodity crop. As with the cover crops, there will be no fertilizer inputs when growing the commodity crop. The resulting production of the commodity crop will be an important factor in measuring cover crop performance.

Cover crops evaluated includes both single species and a mix. Single species cover crops may be easier to establish because selective herbicides can be used, but the more difficult to manage mixes might provide enhanced soil health benefits as previously discussed. Seeding rates were determined by the East New Mexico NRCS Area Agronomist. This rate is traditionally very high, which is necessary to be competitive with the heavy seed bank of common farm weeds that often exist on the surface of disturbed soil. However, eastern New Mexico dryland farmers use low seeding rates because of the very limited moisture that traditionally occurs. However the high percentage of interspacing that may results from low seeding rates has the potential to support a high density of weeds particularly on an irrigated farm such as the LLPMC. Consequently for weed control, the study plots were regularly hand hoed and spot treated with herbicide.

The cover crops will be incorporated into the surface soil with an I.J. Manufacturing roller crimper mounted on the front end loader of a farm tractor in miSHS-May after the conclusion of the severe spring winds and after the soil temperature is warm enough to allow for germination of warm-season commodity crop species. Milo (*Sorghum bicolor*) will be sown immediately after cover crop termination. At maturity, the milo crop grain from individual plots will be combined harvest and cleaned separately. Grain samples from the 32 plots will be sent to the New Mexico Department of Agriculture Seed Laboratory for purity and germination. A pure live seed weight (PLS) among treatment plots will be used to evaluate soil inputs provided by the cover crop treatments.

The study design is a split-plot, randomized, complete-block design with four replications (Figures 1-4) and encompasses approximately 5.0 acres. The main plots are receiving irrigation treatments; either adequate water to prevent wilting or limited water, considering both precipitation and irrigation for a combined total of 20 inches (Figure 5).

Figure 1: Plot Plan for Cover Crop Trials: Study #1 – New Mexico Southern High Plains Field 32 South



Field Size = 1.24 acre, Plot Size = 0.11 acre

Figure 2: Plot Plan for Cover Crop Trials: Study #1 – New Mexico Southern High Plains Field 32 North

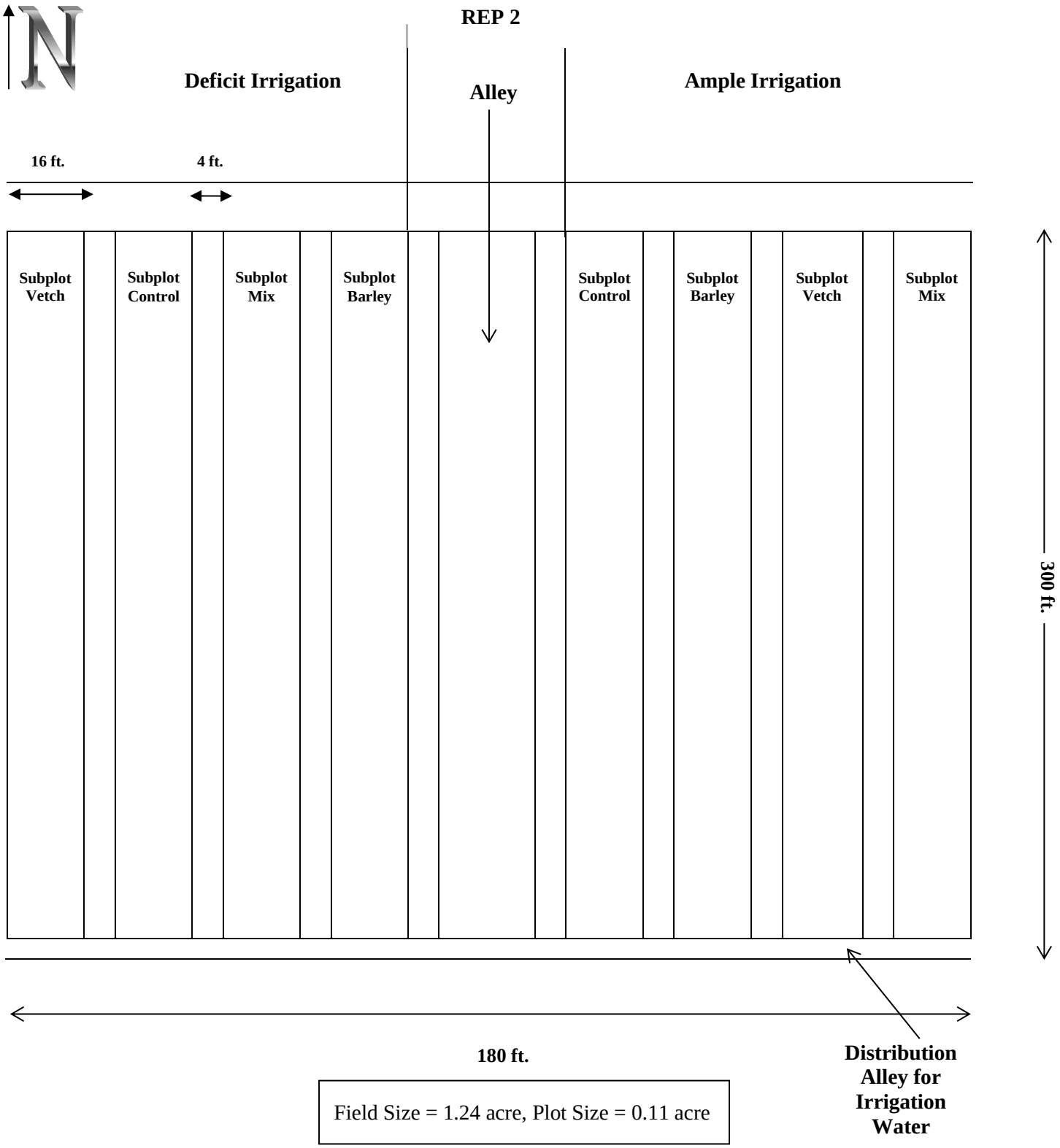
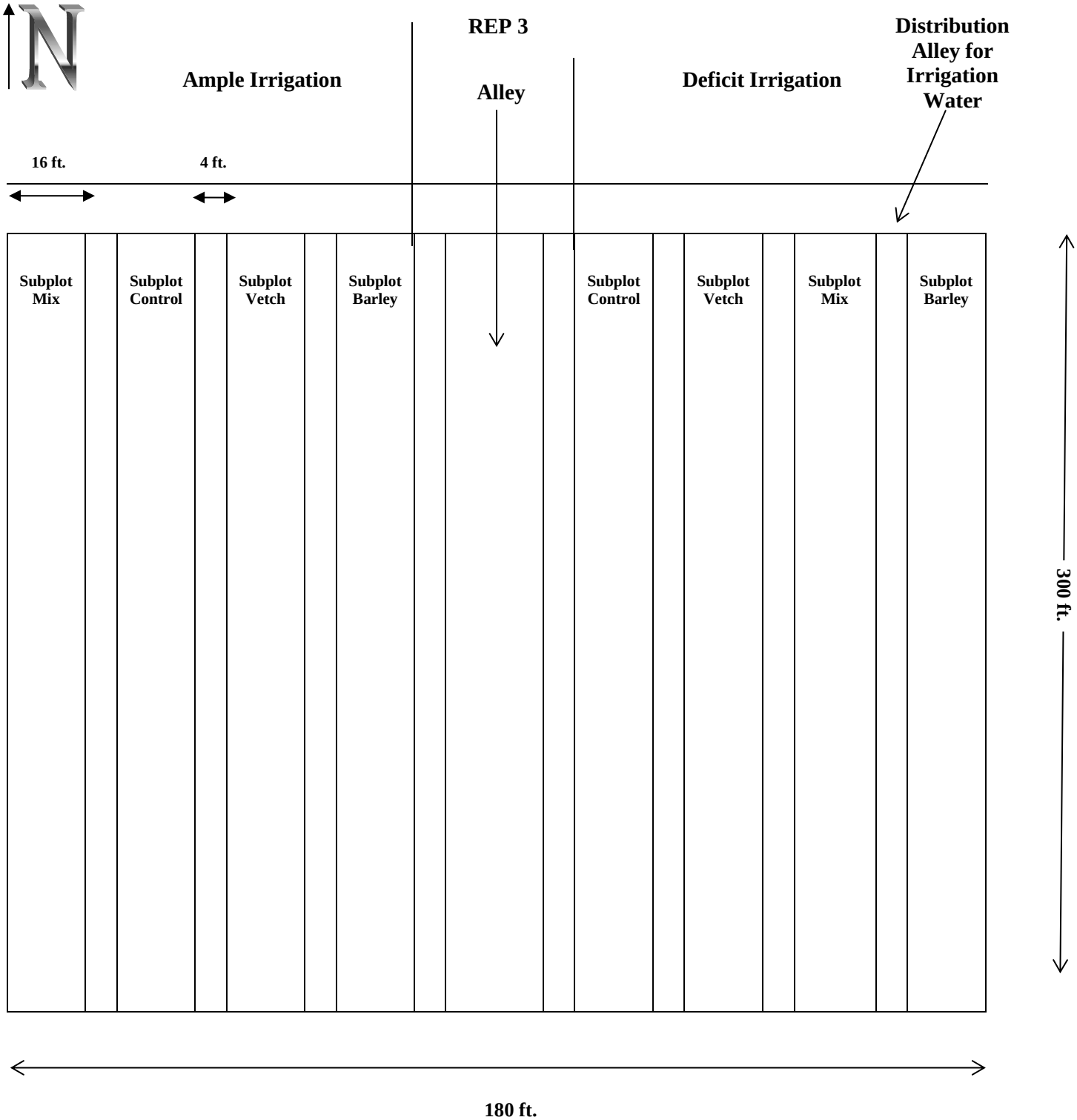


Figure 3: Plot Plan for Cover Crop Trials: Study #1 – New Mexico Southern High Plains Field 36 S



Field Size – 1.24 acre, Plot Size = 0.11 acre

Figure 4: Plot Plan for Cover Crop Trials: Study #1 – New Mexico Southern High Plains Field 36 North

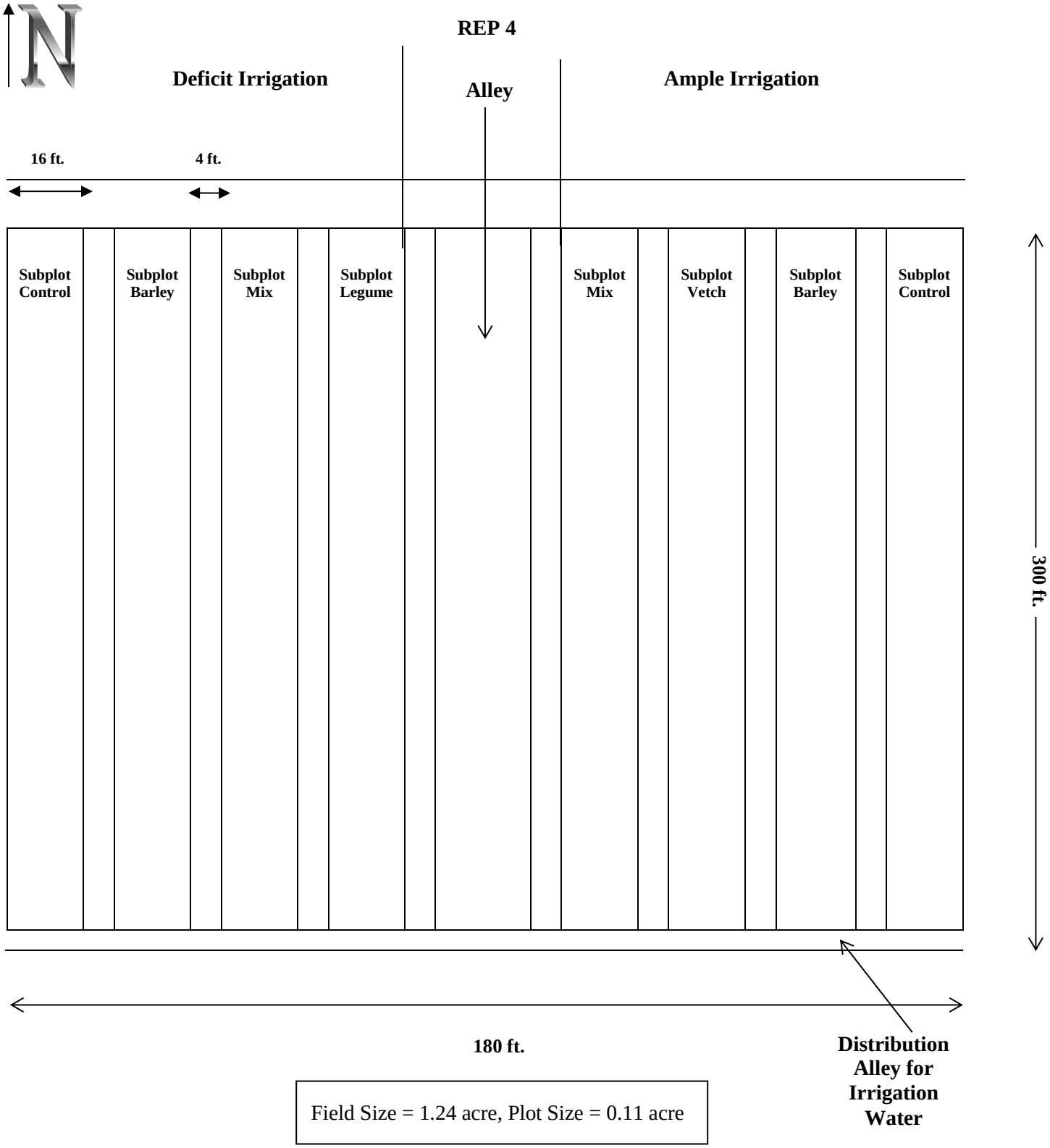


Figure 5: Field 32N east main plot receiving ample irrigation treatment. The west main plot is left dry.

The subplots are the cover crop treatments. Each subplot is approximately 16 ft. by 280 ft. or approximately 0.10 acre (area agronomists requested large plots). For maintenance purposes, there are 4-foot alleyways between the subplots and a 10 - 20-ft. alleyway between main plots depending on field size. Each main plot is 80 ft. by 300 ft. and is composed of four subplots. The study is performed on a 'Vinton' series, loamy-fine sand. All statistical tests were performed using 'Statistics 8' (Analytical Software, 2003). The Shapiro-Wilk Normality test and the Wilcoxon Signed Rank Tests, which were applied to some soil moisture data, were the only statistical tests performed. As the cover crop treatments mature in the spring and show substantial growth, there will be additional results to test.

Irrigation and Rainfall

Cover crop and commodity crop main plot treatments consist of the following:

- **Deficit irrigation** where the crops will be allowed to temporarily wilt, and
- **Ample irrigation** sufficient enough to prevent wilting

The deficit irrigation treatment involves the cover crops and commodity crop together having an annual total of 20 inches of water applied which includes both irrigation and precipitation at the LLPMC to simulate conditions where limited irrigation is available as on the New Mexico Southern High Plains. This deficit irrigation treatment provides for more water than precipitation inputs found on the New Mexico Southern High Plains (15 inches of precipitation), so the results will be applicable to this location where some irrigation water is available or when year with above average precipitation occurs. The irrigation amounts are recorded using flow meters that allow for water inputs to be accurately determined using both the flow meter data and precipitation data that is measured at the NOAA sponsored weather station at the LLPMC.

The cover crop treatments grown under ample irrigation will measure their potential and simulate the conditions of the northern New Mexico river valleys and other irrigated lands in New Mexico. The ample irrigation (the control) will simulate conditions where irrigation is possible and crop response is an expression of potential and not limited by reduced water availability.

To maintain a moist surface soil during the first four week (period of seedling germination, emergence, and establishment) required approximately an irrigation treatment every 3-4 days until seedling roots had achieved a

4-inch depth. Below a 4-inch surface depth is considered to be below the active soil surface evaporation zone, and the seedlings are generally considered to be established. Because water is applied by flood irrigation, it takes a constant two-inch surface depth from the source to cover the length of the 300-ft. plots on laser leveled land with a 0.05 – 0.07 percent down slope. However it only takes 0.25 of an inch of water to recharge the top four inches of a sandy soil to reach field capacity moisture. The remaining 1.6 inches of moisture that was applied is lost to soil percolation below the seedling root zone. Because we are trying to simulate rainfall in the New Mexico southern high plains, the initial irrigation treatments during the 4-week period will all be considered as an 0.25-inch application. This would simulate the several 0.25-inch rainfall events that may occur on the southern high plains of New Mexico during a 4-week period needed to establish cover crops.

See Tables 2 and 3 for the precipitation and irrigation amounts.

Table 2: Precipitation (inches) at the LLPMC for 2013	
September	2.54
October	0.08
November	0.98
December	0.30
January 2014	0.00
Total	3.90

Table 3: Irrigation Amounts for 2013								
Date	**Field 32 North**		**Field 32 South**		**Field 36 North**		**Field 36 South**	
	East	**West**	**East**	**West**	**East**	**West**	**East**	**West**
September 5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
September 9	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
September 17	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
September 20	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
September 27	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
October 11	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
October 25	2.30	3.04	1.90	1.98	2.46	3.12	1.92	1.66
November 19	2.30			2.06	2.16			2.44
January 9, 2014	2.88	3.20	2.36	2.24	2.86	2.96	2.34	3.78
Grand Total	**8.98**	**7.74**	**5.76**	**7.78**	**8.98**	**7.58**	**5.76**	**9.38**

Measured Plant and Soil Elements

Soil Moisture

Soil moisture sensors with data loggers were installed on one set of subplots to measure continual soil moisture for one set of the dry subplots (west) in Field 36 South (Figure 6). Twenty-four S-SMC-M005 Soil Moisture Smart Sensors were installed. The sensors were arranged in pairs: one buried shallow at 4 inches, and the other buried deeper at 10 inches to capture soil moisture loss over time. Three pairs of sensors were used per plot: the first pair was placed one-quarter of the plot length distance from the water source, the second pair was placed one-half the distance from the water source, and the third pair placed three-quarters the distance from the water source. To date, the subplots were also measured twice with the HS2 HydroSense II Moisture Measurement System. The permanent position moisture sensors should provide for a more accurate measurement of soil moisture and will be used to calibrate measurements obtained from the hanSHS-held HydroSense System.

Figure 6: Moisture sensors in Field 36 South buried at 4- and 6-inch depths

Also, each suplot was measured twice to date (Oct. 29 and Dec 17, 2013) by taking five stratified random measurements using the HydroSense System (Figure 7). In October, moisture was measured only at a 4-inch depth (see Section **Soil Health Study Tables**, Table SHS-1); in December, moisture was measured at both a 4" and 8" depth in the same location (See Section **Soil Health Study Tables**, Table SHS-2). However, the permanent position moisture sensors should provide for a more accurate measurement of soil moisture and will be used to calibrate measurements obtained from the hanSHS-held HydroSense System. For the HydroSense System used on sands, a measured value of 7% is considered dry; a value of 15% is considered wet. For use on sandy loams, a measured value of 10% is considered dry; a value of 20% is considered wet.

Figure 7: From left to right, a HydroSense II Moisture Measurement System, a Dicky-John Spring Soil Compaction Tester, and a 'Reotemp' plain bushing thermometer used to measure the soil of the cover crop treatments.

Soil Fertility and Related Elements

A composite sample composed of 25 soil samples were taken from each of the four fields at a depth of 0–12-inches. Soil samples will also be taken from each plot prior to planting the commodity crop, between harvesting the commodity crop, and planting the new cover crops in subsequent years. Selected chemical indicators of soil health will be measured by Ward Laboratories, Inc. and will include the following:

- Total carbon, nitrogen, and sulfur by dry combustion
- pH factor
- Extractable cations (Ca, Mg, Na, K) by NH4OAC
- Cation exchange capacity (pH 7)
- Extractable P by Olsen
- Particulate organic matter
- Soil texture

Two additional soil tests which are measurements of biological activity will be performed by Ward Laboratories, Inc. before the commodity crop is planted in the spring:

- Permanganate organic matter C (active carbon)
- Beta-glucosidase

Soil Compaction

Five stratified soil bulk density samples were taken from each plot by driving a 3”x3” bulk density ring 4 inches into the soil on September 12th and 13th, 2013. The ring was lifted out of the soil without spillage. If the bottom surface of the sample extended past the ring, it was cut and smooth with a trowel to match the ring size. Staff from the NRCS soils lab in Santa Fe, NM supervised and participated in obtaining the samples. Soil samples were dried in a convection oven at 50°C for 48 hours in December 2013. Samples were weighed to the nearest 1/100th of a gram immediately after removal from the oven.

On September 30 and October 1, 2013, soil compaction was measured using a Dicky-John Spring Soil Compaction Tester at depths of 6-inches, 12-inches, and 18-inches while the soil was moist. Because the soil is high in lime, soil moisture was measured at a 6-inch depth for each soil compaction location measurement. Soil with excessive lime becomes hard (cemented) as it dries. Consequently, cemented soil can be misinterpreted as compacted soil. Therefore the soil compaction tester may provide for a more accurate measurement of soil compaction when the soil is moist.

Soil Temperature

Soil temperature was measured at a 6-inch depth using a “Reotemp” plain bushing thermometer with a 6-inch stem. Five stratified random measurements were taken in each plot on September 27, 2013. The time of day was recorded before each set of subplots was measured because both the air temperature and the angle of the sun’s rays may have an effect on surface soil temperature.

Plant Cover

Plant Cover was measured using one 300 ft. transect running diagonal from corner to corner the length of each plot (Figure 8). At 2-ft. interval markings on the tape either bare ground or the plant species intersected was recorded.

Figure 8: Measuring plant cover on a mix plot using a 300-ft. tape set diagonal and counting plant hits by species at 2-ft. intervals.

Plant Density and Height

Plant density was measured by throwing a 2 ft. x 2 ft. sampling frame into the plot at five stratified locations to encompass the entire plot (Figure 9). Plants inside the frame were counted by plant species. Plant height was also measured by selecting a typical plant from each species and measuring its height.

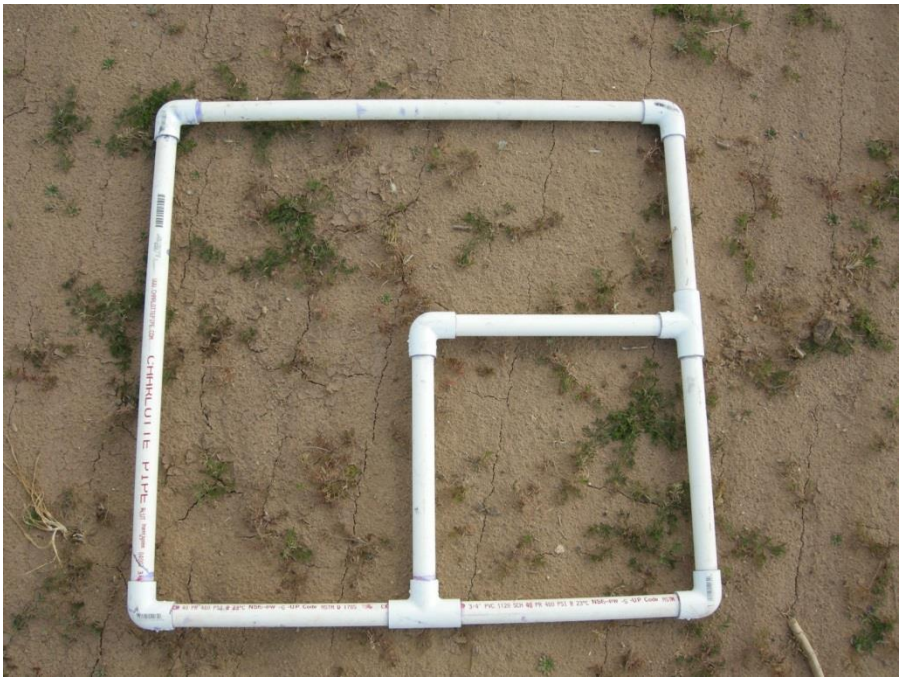


Figure 9: Measuring plant density on a winter vetch plot by counting each species in a 2-ft x 2-ft. plot frame.

Biological Assessments

The microbial activity will be monitored by using a soil microbial activity indicator measured by Ward Laboratories, Inc. The soil also will be measured for water-extractable organic carbon and water-extractable organic N. A soil health calculation will be performed that examines the balance of soil carbon and nitrogen and their relationship to microbial activity. Samples will be assigned a soil health calculation number that will vary from 0 to over 50. A high number is desirable and will increase over time when applying good soil management practices.

Composite samples composed of ten random soil samples for each plot will be taken at a 6-inch depth using the following schedule**:**

- One-to-two weeks prior to planting the cover crop
- After cover crop termination or prior to establishment of a commodity crop
- One-to-two weeks after the commodity crop is harvested.

Cover Crop Biomass

Yield will be determined at cover crop termination by using a U-shaped sampling frame 100 x 50 cm using the method outlined by the National Soil Health Study (2012). Fresh plot clippings will be placed on tarps for an initial green weight (1/10 g). Clippings must be kept out of direct sunlight; they will be then be separated by plant family or genus and placed into separate bags including any weeds. These samples will be dried for 16 hours at 55° to 60° C.

For a sample, take 6–8 bags from oven and allow them to cool to room temperature and then weigh. Place back into the oven for another 4–6 hours and weigh again. Repeat procedure until weight remains constant. Record the weight to the nearest 1/10g for each bag. After all samples have been weighed and recorded, store the sample bags in a sealed container and place in a climate controlled room to protect them from rodents and insects until they can be shipped for analysis. These samples will be used to measure plant tissue nitrogen.

Forage Nitrogen Analysis

This test will be performed on samples separated by plant species and includes the following preparations:

- Use forage samples from the biomass measurement
- Grind samples using Willey Mill with 2 mm screen
- Send a 50 g sample to Ward Laboratories, Inc.

Results and Discussion as of December 2013

Soil Moisture

Soil Moisture was not significantly different ($\alpha<.05$) among cover crop treatments at a 4-inch depth or the 8-inch depth (Table 4 and Tables SHS-1 and SHS-2). However, the 8-inch depth for all treatment on all plots had significantly more moisture ($\alpha<.01$) than the 4-inch depth measurements (see **Soil Health Study Tables**). Depending on the time period from the last irrigation, the 8-inch depth may have twice the amount of moisture as does the 4-inch depth. The top 4 inches of soil is often referred to as the active evaporation zone because water is readily lost to evaporation at this shallow depth, whereas deeper soil depths are less affected. By selecting cover crops with deep root systems of 8 inches or longer, they have access to deep-soil moisture which may reduce irrigation application frequency and lengthen the required time for growth or survival between rainfall events.

Currently, cover crop treatments are not reducing soil moisture by transpiration because the plants are still very small. Measured amounts of soil moisture were not significantly different than the control (bare soil) treatment. Currently, the major loss of soil moisture appears to be from surface evaporation. After the cool-season cover

crop treatments mature and grow larger in the spring, they may have a measurable effect on soil moisture either by an additional loss of moisture from evapotransporation, or possibly a gain of moisture because the cover produced by these crops may reduce surface evaporation.

Table 4: Mean Moisture in Topsoil of Cover Crop Treatments (Per Cent Moisture)

Field Location	October 4-inch depth	December 4-inch depth	December 8-inch depth
Mix	12.2	12.4	20.0
Vetch	12.5	12.4	19.8
Barley	12.3	12.3	20.0
Control	12.6	12.0	20.0

Soil Fertility and Related Elements

The soil of the study site is classified by the NRCS Soil Survey of Valencia County, New Mexico (1969) as a Bluepoint series loamy fine sand. Soil fertility test results of the top 12 inches for all four fields showed nitrogen was low, averaging 14.5 lbs/acre (Table 5). For comparison, 'Solum' barley in Arizona planted at the seeding rate of 20 to 40 lbs/acre had maximum yields when soil nitrogen was at 40 lbs. per acre (Ottman and Husman 1994). Phosphorus was also low, averaging 9.9 ppm which is well below the median Sufficiency Levels of Available Nutrients (SLAN) value. The SLAN values are the national sufficiency levels of available nutrients for turf grasses and are provided in Table 6. They can be used as a reference for soil test interpretation and are based on the past 60 years of soil fertility studies, particularly with forages, agronomic and horticultural crops, and adjustments made by scientists to fit perennial turf grasses. Sulfur was also low, averaging 9.2 ppm which is below the SLAN moderate levels. Soil organic matter was low, averaging 0.7, but expected since it is an aridisol (which are 0.2 to 1.7% organic matter) and had been recently plowed, laser leveled, and left fallowed for two months prior to planting. However, the organic matter composition measured was possibly dominated by charcoal residue because it was very apparent on the soil surface. The presence of these charcoal chips was a result of burning slash of the cottonwood plantation that previously existed on this site. Because this sandy soil has excess lime, the high average pH of 8.5 and the excessive calcium reported is expected. However, the calcium-to-magnesium ratio of greater than 16 to 1 (optimal is 2 to 1) may be interfering with magnesium uptake. Consequently, magnesium levels may also be inadequate. Both growth rates and yields of cover crops may be improved with the additions of organic matter, nitrogen, phosphorus, magnesium, and most likely sulfur.

Table 5: Soil Test Results from the Top 12 Inches of the Four Study Fields

Field	pH	Mmho /CM	Excess lime	Organic Matter	Nitrate Lbs/Ac	P ppm	K ppm	Ca ppm	Mg ppm	Na ppm	Zn	Fe
36N	8.6	0.20	High	0.7	14	8.1	160	2789	186	39	0.17	4.7
36S	8.5	0.20	High	0.7	10	10.4	203	2839	173	35	0.33	6.3
32N	8.4	0.21	High	0.9	16	10.3	173	3079	177	30	0.42	4.4
32S	8.5	0.24	High	0.7	18	10.9	184	3077	188	34	0.72	4.8

Table 6: Sufficiency Levels of Available Nutrients (SLAN) Ranges for Turf Grasses (Carrow etal, 2003)

Nutrient	Soil	Medium Sufficiency range (ppm)	Extract
Phosphorus	All	12 – 28	Olsen
Potassium	Sands	75 -175	Ammonium Acetate
Calcium	All	500 – 750	Ammonium Acetate

Table 6: Sufficiency Levels of Available Nutrients (SLAN) Ranges for Turf Grasses (Carrow etal, 2003)			
Nutrient	**Soil**	**Medium Sufficiency range (ppm)**	**Extract**
Magnesium	Sands	100 – 200	Ammonium Acetate
Sulfur	All	10 – 20	Calcium Phosphate

For complete measurements of results, see Section **Soil Health Study Tables**.

Soil Compaction

Soil bulk density ranged from 1.62 g/cm3 to 1.86 g/cm3 and averaged 1.75 g/cm3 (Section **Soil Health Tables**, Tables SHS-3 to SHS-10). Sands to loamy-sand soils with bulk densities of greater than 1.69g/cm3 may limit root growth (USDA, NRCS, 2012). Because the soil is compacted, average pore size is reduced and at a constant water content, increases the proportion of soil pores filled with water causing aeration stress (Stepniewski etal.,1994). Saturated soil has lower soil temperatures and therefore reduced biological activity (Brussaard and Van Faassen, 1994), increased DE nitrification (Linn and Doran, 1984) and loss of mycorrhizal fungi (Ellis, 1998). The Dickey-John Soil Compaction Tester also measured high values at all depths which indicated compacted soils or cemented soils. Generally, as the soil depth increased, so did the compaction value (Section **Soil Health Study Tables**, Table SHS-11). However, the high values may also be a function of the high amount of lime measured in the soil causing the cementation. This cementation would reduce the ease of penetration by the instrument and increase the measured values. A value of 150 or greater using the half-inch tip is in the red region of the Dickey-John compaction tester indicating very compacted conditions (Table 7).

Table 7: The Dickey-John Soil Compaction Tester Results Using the ½ Inch Tip	
Depth	**Grand Mean**
6-inches	198.5
12-inches	227/6
28-inches	245.1

Soil Temperature

There was no significant difference in soil surface temperature among treatment plots because the soil surface was bare on all treatments on September 26, 2013 (Section **Soil Health Study Tables**, Table SHS-12). Soil surface temperature averaged 66 °F on all treatment plots for fields 36 south, 36 north, and 32 west from 8:00 a.m. to 10:45 a.m. By 11:45 a.m., soil temperature rose to 70°F on all treatment plots on field 32 north due to the warm air temperatures and the radiant heat of the sun's rays during a cloudless period of the day.

Plant Cover

Plant cover was lower than expected possibly due to the poor soil conditions as previously discussed in combination with the relatively low seeding rates (Section **Soil Health Study Tables**, Table SHS-13). The warm-season species had completed their life cycle by October and exposed additional bare ground. The cool-season species appeared to have grown only very little in December and January during the very coldest period of the year. However, once the temperatures begin to warm in February, growth will resume and cover of the cool-season cover crops will improve. If cover improves substantially, the cover crops may be roller mulched and incorporated into the soil in the spring. This addition of organic matter would improve the soil health of each plot. A milo crop would be seeded into the cover crop mulch of each plot in May or June. The performance of the milo crop (grain production and quality) would be another characteristics used to measure how soil health is affected by cover crop treatments.

Plant Density and Height

Nearly sixty days after seeding (October 31) plant density averaged 4.9 plants per square ft (Table 8 and Section **Soil Health Study Tables**, Table SHS-14). The mix averaged about 75% higher density which was anticipated because it was seeded about twice the rate of the two single species treatments. The cow peas and sorghum of the

mix emerged but died during the early hard frost, and seedling remnants during the monitoring were not recognizable. As a result, these were not included in the density count.

Table 8: Mean Plant Density of Plots		
Species	**Mean Plants/sq. ft.**	**Plant Height (Inches)**
Barley	3.7	3.4
Winter vetch	4	1.1
Mix	7	
Millet		3.8
Cultivated radish		2.3
Buckwheat		5.6
Grand Mean	**4.9**	**3.2**

All plant species were short, even with the tallest plants were typically 3 to 5 inches. The early frost, compacted soil, high lime, low nitrogen, low phosphorus, low sulfur, and possibly low magnesium due to the surplus of calcium from the lime, may be limiting plant growth.

Plant growth on the various treatments was evaluated by the New Mexico State Resource Conservationist and East Area Agronomist, and they decided that the cover crop treatments were too sparse and short by November 1, 2013 to provide adequate soil protection during periods of high winds which commonly occur in the spring. We discussed plowing them under; however the treatments are still intact today. The problem was caused because the seeding occurred in early September instead of late July or early August, and at a lower seeding rate than what is required to obtain a stand density of 10 plants per sq. ft. (which is thought to desirable ground cover on dryland in eastern New Mexico).

Seedlings began to emerge three days after sowing, and they appeared to be doing well until a hard frost (29° F) occurred on October 15 and 16, 2013. Frost killed most of the warm-season species in the mix. At Los Lunas, New Mexico, warm-season crop species planted for winter soil protection need to be seeded earlier so they may achieve a significant amount of growth before hard frost occurs. The cool season-species in the mix , cultivated radish, and the other cool-season treatments of barley and winter vetch continued to grow. Seedling establishment was also reduced by the seeding equipment and the irrigation method employed. A 'Land Pride' broadcast seeder with a brillion-like cultipacker which lacks the ability to precisely control seeding depth was selected for the seeding. Also, flood irrigation (used at the LLPMC) has a tendency to reduce establishment of seeded species when compared to sprinkler irrigation. To compensate for broadcast seeding, the seeding rate is typically doubled. To compensate for the floating of some seed, particularly those that are very small and shallow planted, seeding rates may be increased by 20%. For example, the seeding rate of vetch (where 10 plants per sq. ft. is required) should be sown at 24 pls/sq ft. A broadcast seeder was chosen because of the huge variability of seed size, from the very small millet seed to the large barley seed. Typically, the smaller the seed, the shallower it needs to be sown. The cultipacker treatment by the seeder insured that some seed of all species would be planted at various depths which would include the ideal depth for establishment.

- *Biological Assessment* –No Analysis to date
- *Cover Crop Biomass* –No Analysis to date
- *Forage Nitrogen* –No Analysis to date

Equipment and Supplies Required to Perform Soil Health Study

Biological Indicators

Dry Matter Yield and Botanical Composition of Cover Crops

- 0.5 sampling frame (U-shaped)

- Forage plot clippers
- Flat or trenching shovel
- Hanging field scale – 1/10th lb. increments with tarred weighing tub or designated weighing tarp
- Small laboratory scale (> 2000g maximum weight with a minimum of 1/10th g)
- Ten harvesting tarps (minimum size 36-in. x 36-in.) for collecting harvest samples
- Paper sacks of all of one type, do not mix; sizes #20, #25 (lunch box size) or #57 (grocery bag size)
- Drying oven
- Permanent marker
- Gloves

Percent Live Cover and Plant Height of Cover Crops

- Plot map
- Data sheets
- 300 ft. tape with 5 ft. intervals
- T-post to stretch out tape
- Measuring stick with metric units; the numbers need to be visible in photographs
- Digital camera

Biological Assessment

- Plot map
- Plastic gloves
- Soil sampler (Kress etal.2003) needed to build and equipped with a depth indicator
- Re-sealable bags
- Permanent marker
- Box
- Shipping labels
- Packaging tape

Chemical Indicators

Forage Nitrogen Analysis

- Box for shipping samples
- Packaging tape
- Shipping labels

- Data sheet with plot id codes, PMC location, and sampling data

Soil Analysis

- Plot map soil sampler
- Gloves
- Re-sealable bags (quart size) equipped with labeling stripe (white)
- Permanent marker
- Shipping box
- Shipping labels
- Packaging tape

Physical Indicators

Soil Temperature, Soil Moisture, and Soil Compaction

- Plot map
- Data sheets
- Soil moisture probe – HydroSense II at $1,300 each (requires 2 = $2,600)
- Soil thermometer – $16.00 each, one for each plot for Rep 1 (requires 48 = $768)
- Soil penetrometer – Forestry Supplies, Ben Meadows at $250 each (requires 2 = $500)
- S-SMC-M005 Soil moisture smart sensor at $125.10 each (requires 25 = $3,127.50)
- H21-002 Micro Station at $219.45 each (requires 6 - $1,316.70)
- BHW-PRO-CSHS-HOBOware Pro Mac/Win (USB cable included at $99
- ADAPT-SER-USB-USB Interface Cable at $59

Subtotal Cost = $8,470.00

Soil Bulk Density and Soil Moisture Measurement

- Plot map
- Soil data sheet
- 3-inch x 4-6-inch diameter bulk density ring (acquire four (4) from the State Office)
- Hand sledge hammer
- Wood block
- Garden trowel
- Flat blade knife
- Re-sealable bags

- Minimal of 5 oz. paper or plastic cups
- Permanent marker
- Small laboratory scale (> 2000g maximum weight with a minimum of 1/10th g)
- ⅛ cup measuring scoop

Plot Maintenance Equipment

- Roller crimper ($4,000)

Subtotal Cost = $4,000

Seed Cost

- Estimated at $,1500

First Year Cost for Soil Testing at Ward Laboratories

- Routine Olsen Soil Phosphorus at $12.35 per sample (requires 64 = $790.40)
- Soil Organic Carbon at $5.04 per sample (requires 64 = $322.56)
- PLFA-General soil nutrient analysis at $25.68 per sample (requires 64 = $1,643.52)
- Plant Total N at $5.04 per sample (requires 192 = $967.68)

Subtotal Cost = $3,724.00

Total Cost for Study #1

- First Year – Total Cost excluding labor = $18,000
- Second Year – Estimated total cost excluding labor = $5,224

Sampling Procedures

Sampling Procedure for the Soil Health Study										
Indicator Type	**Indicator**	**Time of Sampling (periods) & Sampling Depth**	**Number of Plots**	**Samples /Plot**	**Sample /Period**	**Total Number of Samples**	**Total Number of Lab Samples**	**Equipment Required**	**In-House**	**Comments**
Physical	Soil Moisture	Cover crop planting and termination taken at a 7" depth	32	10	320	640	0	HydorSense 2	X	
Physical	Soil Temperature	Cover crop planting and termination. Taken at 3" depth	32	10	320	640	0	Soil Thermometer	X	
Biological	Percent live cover	Every thirty days after planting until 100% cover is obtained. Use a line transect diagonally	32	100 marks	32	192	0	Tape	X	6 months of monitoring
Biological	Plant Height	Every 30 days until winter dormancy	32	10	320	2,240	0	Height post & Digital camera	X	
Physical	Soil Resistance	Cover crop planting and termination and measured at 3 depths (1-6", 6-12", and 12-18")	32	15	1,440	2,880	0	Penetrometer	X	
Physical	Soil Bulk Density	Cover crop plantings and terminations. Taken at a 0-2" and 2-4" depths	32	10	640	1,280	0	Bulk density ring	X	
Biological	Biological assessment	One to two weeks before planting cover crops, after cover crop termination, one to two weeks after commodity crop harvest Samples taken to a 6" depth	32	30	960	1,920	64	Kress Soil Sampler only by Lincoln Soil Lab	b	Composite sample by plot
Biological	Cover crop yield	At cover crop termination Separate by species and weigh Oven temperature must not exceed 60 degrees C	32	3	96	288	0	Hanging field scale Drying oven Clippers 0.5 m sampling frame with open end	X	
Lab Chemical	Forage N	Termination of cover crop or commodity crop (by species)	32		0	0	128	Commercial lab		3 species/plot

Sampling Procedure for the Soil Health Study										
Indicator Type	**Indicator**	**Time of Sampling (periods) & Sampling Depth**	**Number of Plots**	**Samples /Plot**	**Sample /Period**	**Total Number of Samples**	**Total Number of Lab Samples**	**Equipment Required**	**In-House**	**Comments**
								Oven heat <60° C		
Lab Chemical	Soil – C,N,S,Ca,Mg,Na ,K pH,Organic C Organic matter Betta-glucoidase Soil texture	Prior to cover crop planting in year one, and between harvesting the commodity cropland planting cover crops in subsequent years from two depths 0-2" and 2-4"	32	60	960	1,920	64	Commercial lab Kress Soil Sampler		Composite sample by plot
Lab Chemcial	Soil Phosphorus						64	Commercial lab		
Biological	Commodity crop yield (Milo)	Harvest at maturity Air and dry weigh	32	1	32	32	32	Commercial lab Plot combine		
					Total Samples	**12,032**	**256**			

Soil Health Study Tables

Table SHS-1: Percentage (%) of Soil Moisture Samples Taken at a 4-Inch Depth on October 22, 2013								
Field Location	**Species**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sum**	**Mean**
32 North (East)	Mix	7.5	11	10.3	10.9	12.5	52.2	10.5
	Vetch	13.1	14.3	15.2	13.6	12.9	69.1	13.82
	Barley	12.1	13.1	10.3	10.1	13.2	58.8	11.76
	Control	12.2	13.3	12.9	10.4	15.1	63.9	12.78
32North (West)	Mix	14.6	11.9	9.7	12.9	11.1	60.2	12.04
	Vetch	13.3	13.3	13.2	14.5	11.6	65.9	13.18
	Barley	14.4	12.5	11.5	12.4	14.8	65.6	13.12
	Control	13.5	13.1	14.1	14	13.7	68.4	13.68
32 South (East)	Mix	18.5	20.7	20.4	16.7	17.4	93.7	18.74
	Vetch	15.1	14.6	13.2	17.2	17.3	77.4	15.48

Table SHS-1: Percentage (%) of Soil Moisture Samples Taken at a 4-Inch Depth on October 22, 2013

Field Location	Species	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sum	Mean
	Barley	16.5	19.6	15	11.6	16.9	79.6	15.92
	Control	16.2	12.5	16.4	16.5	21.3	82.9	16.58
32 South (West)	Mix	13.6	13.7	13.1	13.2	18.5	72.1	14.42
	Vetch	17.8	16.9	17	18.2	16.7	86.6	17.32
	Barley	18.4	15.9	16.1	17.9	16.3	84.6	16.92
	Control	17.8	16.7	12.6	17.9	17.3	82.3	16.46
36 North (East)	Mix	10.6	10.5	7.9	9.9	10.8	49.7	9.94
	Vetch	10.8	10.3	9.4	11.5	7.5	49.5	9.9
	Barley	10.3	8.6	11.1	9.4	10.2	49.6	9.92
	Control	10	11.1	11.4	11.3	10.3	54.1	10.82
36 North (West)	Mix	12.5	7.3	7.5	8.4	10.2	45.9	9.18
	Vetch	10.1	7.8	6.8	8.9	11	44.6	8.92
	Barley	9.6	7.9	10.7	7.8	10.5	46.5	9.3
	Control	8.9	9.9	9.5	8.8	10.8	47.9	9.58
36 South (East)	Mix	13.9	11.1	13.7	12.9	9.7	61.3	12.26
	Vetch	11.4	8.9	11.2	10.6	10.6	52.7	10.54
	Barley	8.8	8.9	12.2	12.7	13.1	55.7	11.14
	Control	10.3	12.3	10.8	10.8	10.3	54.5	10.9
36South (West)	Mix	9.8	9.9	11	11.4	12.3	54.4	10.88
	Vetch	9.3	12.5	13.4	9.7	10.1	55	11
	Barley	9.8	10.1	11.4	11.9	9.5	52.7	10.54
	Control	8.7	10.2	11.9	11.6	7.6	50	10

Table SHS-2: Percentage (%) of Soil Moisture Samples Taken at a 4-Inch and 8-Inch Depths on December 17, 2013

		Samples							Samples						
Field Location	**Species**	**1**	**2**	**3**	**4**	**5**	**Sum**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Sum**	**Mean**
		4-Inch Depth							**8-Inch Depth**						
32 North (East)	Mix	11.6	11.6	14.9	13.3	14.9	66.3	13.26	14.7	18.3	22.9	22.9	20.1	99.2	19.84
	Vetch	14.4	15.5	14.7	14.2	14.6	73.4	14.68	23.9	25.1	26.6	26.6	19.6	118.1	23.62
	Barley	15.6	12.8	12.9	11.9	13.2	66.4	13.28	23.2	22.5	22.8	22.8	20.1	106.4	21.28
	Control	13.2	11.6	12.6	11.1	13.2	61.7	12.34	20.1	19.6	19.8	19.8	21.6	102.1	20.42
32North (West)	Mix	14.9	12.3	15.4	14.9	10.9	68.4	13.68	24.7	22.8	27.3	27.3	22.4	117	23.4
	Vetch	13	13.5	12.3	16.6	11.4	66.8	13.36	21.5	21.4	22.6	22.6	19.4	108.2	21.64
	Barley	16.9	10.9	13.7	13.8	14.1	69.4	13.88	23.9	19.1	21	21	23.5	110.2	22.04
	Control	13.4	13.9	11.7	12.6	14.9	66.5	13.3	22.6	22.1	21.9	21.9	25.5	114.5	22.9
32 South (East)	Mix	15.1	14.3	15.5	14.4	13.9	73.2	14.64	24.6	21.6	24.5	24.5	18.5	113.1	22.62
	Vetch	13.9	14.4	13.3	13.8	13.4	68.8	13.76	21.5	19.2	22.3	22.3	20.3	106.8	21.36
	Barley	12.7	11.5	13.8	10.4	11.9	60.3	12.06	20	21	21	21	21.3	100.7	20.14
	Control	11.6	11.7	13.1	14.1	14.2	64.7	12.94	20.5	19.9	18.5	18.5	21.9	103.7	20.74
32 South (West)	Mix	12.1	11.8	10.9	12.2	13.7	60.7	12.14	20.2	18.8	14.1	14.1	19.5	93.6	18.72
	Vetch	14.5	10.9	12.3	13.4	15.9	67	13.4	20.3	17.9	19	19	21.5	99.6	19.92
	Barley	15.6	14.4	15.7	14.5	16.4	76.6	15.32	24.7	24.1	24.2	24.2	25.1	119.2	23.84
	Control	14.6	9.5	11.7	11.5	13.7	61	12.2	22.1	18.1	19.2	19.2	21.9	100.1	20.02
36 North East	Mix	13.1	11.6	8.4	10.9	10.5	54.5	10.9	21.1	18.9	15.2	15.2	20.4	94.7	18.94
	Vetch	9.9	11.4	10.5	11.1	9.7	52.6	10.52	17.6	20.5	15.3	15.3	17.9	89.8	17.96
	Barley	10.6	11.2	11.4	10.5	10.1	53.8	10.76	18.3	18.9	18.6	18.6	20.2	93.9	18.78
	Control	10.1	11.4	11	12.4	10.5	55.4	11.08	16.4	16.3	19.1	19.1	19.9	91.7	18.34
36 North West	Mix	11.7	12.3	11.1	10.8	10.6	56.5	11.3	19.1	17.7	19.9	19.9	19.5	94.7	18.94
	Vetch	10.9	11	10.3	11.3	9.6	53.1	10.62	18.8	18.4	15.3	15.3	20.2	90.8	18.16
	Barley	11.2	10.2	12.9	10.3	10.5	55.1	11.02	18.4	18.3	20.1	20.1	17.9	92.1	18.42
	Control	11.3	9.9	9.9	11.3	10.7	53.1	10.62	17.5	20.4	16.3	16.3	18.7	91.5	18.3
36 South East	Mix	10.9	11.4	10.6	11.5	13.8	58.2	11.64	19.9	19.4	14.8	14.8	24.5	97.8	19.56
	Vetch	12.1	13.7	10.7	10.4	11.8	58.7	11.74	18.8	18.8	18.6	18.6	16.3	89.1	17.82

Table SHS-2: Percentage (%) of Soil Moisture Samples Taken at a 4-Inch and 8-Inch Depths on December 17, 2013

		Samples							Samples						
Field Location	**Species**	**1**	**2**	**3**	**4**	**5**	**Sum**	**Mean**	**1**	**2**	**3**	**4**	**5**	**Sum**	**Mean**
		4-Inch Depth							**8-Inch Depth**						
	Barley	10	11.5	13.8	9.2	9.5	54	10.8	20.5	20.3	14	14	16.4	86.5	17.3
	Control	10.6	11.3	10.9	12.3	15.7	60.8	12.16	19.9	21.4	16.2	16.2	22	100.5	20.1
36 South West	Mix	13.1	10.8	10.5	11.5	13.4	59.3	11.86	20.3	18.6	17.1	17.1	19.4	91.9	18.38
	Vetch	11.9	11.2	11.6	11.8	9.4	55.9	11.18	18.9	16.4	19.1	19.1	19.2	92.1	18.42
	Barley	13.5	11.2	9.9	10.9	10.8	56.3	11.26	18.4	23.4	15.9	15.9	16.4	91	18.2
	Control	13.4	11.7	11.2	12	9.6	57.9	11.58	20.5	20.7	19.4	19.4	15.3	94.7	18.94

Table SHS-3: Soil Bulk Density – Field 32 North (West)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Vetch	1	513.63	126.9	116.63	8.09	472.06	1.64
Vetch	2	544.18	135.1	122.32	9.45	492.70	1.71
Vetch	3	538.35	133.03	123.53	7.14	499.90	1.74
Vetch	4	551.44	133.27	121.34	8.95	502.07	1.74
Vetch	5	548.08	132.12	121.04	8.38	502.11	1.74
Control	1	509.51	129.96	118.76	8.61	465.60	1.62
Control	2	563.89	136.26	125.09	8.19	517.66	1.80
Control	3	571.68	129.0	118.55	8.10	525.36	1.82
Control	4	555.18	136.06	124.13	8.76	506.50	1.76
Control	5	547.82	135.91	125.04	7.99	504.00	1.75
Mix	1	574.1	128.91	117.68	8.71	524.08	1.82
Mix	2	529.8	131.64	120.68	8.32	485.69	1.69
Mix	3	566.26	126.03	116.42	7.62	523.08	1.82
Mix	4	553.88	129.25	117.92	8.76	505.32	1.75
Mix	5	551.27	133.96	122.08	8.86	502.38	1.74
Barley	1	555.12	129.83	116.71	10.10	499.02	1.73
Barley	2	538.40	133.72	123.47	7.66	497.13	1.73
Barley	3	559.71	129.63	117.7	9.20	508.19	1.76
Barley	4	566.14	132.2	119.57	9.55	512.05	1.78

Table SHS-3: Soil Bulk Density – Field 32 North (West)							
Plot	**Sample**	**Field Weight**	**Sample Weight**	**Sample Oven Dry Weight**	**Percent Water**	**Field Oven Dry Weight**	**Bulk Density**
Barley	5	529.44	128.43	119.37	7.05	492.09	1.71
						Total	**34.85**
						Mean	**1.75**

Table SHS-4: Soil Bulk Density – Field 32 North (East)							
Plot	**Sample**	**Field Weight**	**Sample Weight**	**Sample Oven Dry Weight**	**Percent Water**	**Field Oven Dry Weight**	**Bulk Density**
Vetch	1	550.80	133.69	119.81	10.38	493.61	1.71
Vetch	2	514.20	126.85	117.36	7.48	475.73	1.65
Vetch	3	546.87	126.65	116.47	8.03	502.91	1.75
Vetch	4	566.21	133.61	122.55	8.27	519.34	1.80
Vetch	5	535.04	128.49	118.04	8.13	491.52	1.71
Barley	1	553.23	137.55	124.01	9.84	498.77	1.73
Barley	2	543.61	126.93	116.22	8.43	497.74	1.73
Barley	3	553.37	127.29	116.37	8.57	505.89	1.76
Barley	4	556.86	126.98	116.01	8.63	508.75	1.77
Barley	5	527.14	126.73	115.41	8.93	480.05	1.67
Vetch	1	576.58	125.12	112.72	9.91	519.43	1.80
Vetch	2	568.01	126.83	116.51	8.13	521.79	1.81
Vetch	3	548.81	129.41	118.82	8.18	503.89	1.75
Vetch	4	530.81	130.68	119.39	8.63	484.95	1.68
Mix	1	572.43	132.10	119.89	9.24	519.52	1.80
Mix	2	543.86	131.59	120.06	8.76	496.20	1.72
Mix	3	546.83	127.21	116.35	8.53	500.14	1.74
Mix	4	560.0	135.4	126.22	6.77	522.03	1.81
Mix	5	532.3	127.45	117.22	8.02	489.57	1.70
						Total	**34.88**
						Mean	**1.74**

Table SHS-5: Soil Bulk Density – Field 32 South (West)							
Plot	**Sample**	**Field Weight**	**Sample Weight**	**Sample Oven Dry Weight**	**Percent Water**	**Field Oven Dry Weight**	**Bulk Density**
Mix	1	569.81	128.22	117.89	8.06	523.90	1.82
Mix	2	533.29	132.32	122.95	7.08	495.53	1.72
Mix	3	536.29	129.49	118.49	8.49	490.73	1.71
Mix	4	544.62	125.99	115.4	8.41	498.84	1.74
Mix	5	547.69	129.42	119.17	7.92	504.31	1.76
Control	1	549.5	134.78	124.07	7.95	505.84	1.76
Control	2	557.07	128.79	117.72	8.60	509.19	1.77
Control	3	553.94	124.62	113.44	8.97	504.24	1.76
Control	4	523.92	133.04	122.32	8.06	481.70	1.68
Control	5	563.94	124.47	113.74	8.62	515.33	1.79
Vetch	1	542.39	127.3	117.23	7.91	499.48	1.74
Vetch	2	552.65	131.79	121.02	8.17	507.49	1.77
Vetch	3	539.22	127.69	116.82	8.51	493.32	1.72
Vetch	4	561.42	132.21	120.67	8.73	512.42	1.78
Vetch	5	576.23	133.83	121.3	9.36	522.28	1.82
Barley	1	570.24	128.51	116.3	9.50	516.06	1.80
Barley	2	562.95	127.02	117.01	7.88	518.59	1.81
Barley	3	571.98	132.44	120.21	9.23	519.16	1.81
Barley	4	552.42	133.58	123.63	7.45	511.27	1.78
Barley	5	549.72	124.68	113.83	8.70	501.88	1.75
						Total	**35.27**
						Mean	**1.76**

Table SHS-6: Soil Bulk Density – Field 32 South (East)							
Plot	**Sample**	**Field Weight**	**Sample Weight**	**Sample Oven Dry Weight**	**Percent Water**	**Field Oven Dry Weight**	**Bulk Density**
Control	1	576.6	127.0	114.12	10.14	518.12	1.80
Control	2	546.11	135.1	125.13	7.38	505.81	1.76
Control	3	566.7	133.24	120.21	9.78	511.28	1.78
Control	4	554.45	128.47	118.21	7.99	510.17	1.78
Control	5	552.88	124.0	113.89	8.15	507.80	1.77
Vetch	1	556.43	133.15	120.99	9.13	505.61	1.76
Vetch	2	570.18	140.91	129.19	8.32	522.76	1.82
Vetch	3	575.35	127.37	115.96	8.96	523.81	1.82

Table SHS-6: Soil Bulk Density – Field 32 South (East)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Vetch	4	569.75	130.71	118.98	8.97	518.62	1.81
Vetch	5	578.95	136.83	125.08	8.59	529.23	1.84
Mix	1	579.04	139.75	127.08	9.07	526.54	1.83
Mix	2	576.91	130.42	118.45	9.18	523.96	1.82
Mix	3	576.57	129.08	118.27	8.37	528.28	1.84
Mix	4	565.11	134.37	122.55	8.80	515.40	1.79
Mix	5	560.83	137.18	126.33	7.91	516.47	1.80
Barley	1	568.97	124.72	114.46	8.23	522.16	1.82
Barley	2	568.48	134.33	122.99	8.44	520.49	1.81
Barley	3	570.38	124.15	114.89	7.46	527.84	1.84
Barley	4	511.56	129.31	120.1	7.12	475.12	1.65
Barley	5	559.8	133.46	122.36	8.32	513.24	1.79
						Total	**35.93**
						Mean	**1.79**

Table SHS-7: Soil Bulk Density – Field 36 North (West)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Control	1	520.38	139.39	129.34	7.21	482.86	1.68
Control	2	529.03	138.72	128.3	7.51	489.29	1.70
Control	3	544.77	136.28	125.26	8.09	500.72	1.74
Control	4	535.06	138.77	128.41	7.47	495.11	1.72
Control	5	536.58	136.29	126.96	6.85	499.85	1.74
Barley	1	519.12	136.72	126.24	7.67	479.33	1.67
Barley	2	547.8	138.45	128.14	7.45	507.01	1.76
Barley	3	550.67	137.93	127.43	7.61	508.75	1.77
Barley	4	528.92	139.0	128.94	7.24	490.64	1.71
Barley	5	548.2	138.74	126.59	8.76	500.19	1.74
Mix	1	549.65	137.97	125.39	9.12	499.53	1.74
Mix	2	533.26	139.3	127.32	8.60	487.40	1.70
Mix	3	540.28	137.02	123.6	9.79	487.36	1.70
Mix	4	547.25	137.71	126.83	7.90	504.01	1.75
Mix	5	533.94	136.38	126.78	7.04	496.36	1.73
Vetch	1	536.26	137.21	125.75	8.35	491.47	1.71

Table SHS-7: Soil Bulk Density – Field 36 North (West)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Vetch	2	539.2	138.28	128.15	7.33	499.70	1.74
Vetch	3	522.43	139.91	128.07	8.46	478.22	1.66
Vetch	4	561.36	136.65	126.97	7.08	521.59	1.82
Vetch	5	537.18	137.21	127.78	6.87	500.26	1.74
						Total	**34.53**
						Mean	**1.72**

Table SHS-8: Soil Bulk Density – Field 36 North (East)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Mix	1	549.86	129.92	117.96	9.21	499.24	1.74
Mix	2	553.33	139.09	127.51	8.33	507.26	1.77
Mix	3	545.4	129.19	119.0	7.89	502.38	1.75
Mix	4	548.92	136.73	123.98	9.32	497.73	1.73
Mix	5	537.35	137.8	128.01	7.10	499.17	1.74
Vetch	1	542.84	133.82	122.25	8.65	495.91	1.73
Vetch	2	548.32	124.5	113.81	8.59	501.24	1.74
Vetch	3	531.34	138.2	128.22	7.22	492.97	1.72
Vetch	4	548.52	132.52	122.06	7.89	505.22	1.76
Vetch	5	545.1	132.99	119.71	9.99	490.67	1.71
Barley	1	586.19	127.9	114.03	10.84	522.62	1.82
Barley	2	554.37	132.94	123.43	7.15	514.71	1.79
Barley	3	530.22	126.84	117.51	7.36	491.22	1.71
Barley	4	550.33	137.4	126.5	7.93	506.67	1.76
Barley	5	560.35	129.72	117.59	9.35	507.95	1.77
Control	1	559.14	134.47	121.73	9.47	506.17	1.76
Control	2	525.95	139.88	130.9	6.42	492.19	1.71
Control	3	515.93	126.34	117.29	7.16	478.97	1.67
Control	4	547.13	136.99	127.78	6.72	510.35	1.78
Control	5						
						Total	**33.15**
						Mean	**1.74**

Table SHS-9: Soil Bulk Density – Field 36 South (East)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Control	1	579.52	136.88	124.49	9.05	527.06	1.83
Control	2	556.51	139.4	128.14	8.08	511.56	1.78
Control	3	532.03	138.09	129.72	6.06	499.78	1.74
Control	4	537.22	137.01	125.47	8.42	491.97	1.71
Control	5	546.97	138.98	128.2	7.76	504.54	1.76
Vetch	1	583.39	140.75	125.6	10.76	520.60	1.81
Vetch	2	537.88	142.8	131.34	8.03	494.71	1.72
Vetch	3	556.28	138.02	125.95	8.75	507.63	1.77
Vetch	4	545.89	135.46	124.23	8.29	500.63	1.74
Vetch	5	542.46	135.28	125.16	7.48	501.88	1.75
Mix	1	588.0	139.71	120.72	13.59	508.08	1.77
Mix	2	573.5	138.7	120.76	12.93	499.32	1.74
Mix	3	570.62	138.77	123.67	10.88	508.53	1.77
Mix	4	541.96	141.87	129.54	8.69	494.86	1.72
Mix	5	589.52	135.9	123.38	9.21	535.21	1.86
Barley	1	582.78	138.82	126.98	8.53	533.07	1.86
Barley	2	556.6	135.12	123.39	8.68	508.28	1.77
Barley	3	537.64	136.65	125.65	8.05	494.36	1.72
Barley	4	571.85	137.73	122.7	10.91	509.45	1.77
Barley	5	582.97	139.17	124.33	10.66	520.81	1.81
						Total	**35.41**
						Mean	**1.77**

Table SHS-10: Soil Bulk Density – Field 36 South (West)

Plot	Sample	Field Weight	Sample Weight	Sample Oven Dry Weight	Percent Water	Field Oven Dry Weight	Bulk Density
Mix	1	519.53	129.26	120.61	6.69	484.76	1.69
Mix	2	565.25	135.79	124.47	8.34	518.13	1.80
Mix	3	534.9	137.36	125.78	8.43	489.81	1.71
Mix	4	562.27	134.02	123.34	7.97	517.46	1.80
Mix	5	569.84	136.62	125.05	8.47	521.58	1.82
Control	1	546.13	138.39	126.49	8.60	499.17	1.74
Control	2	538.8	135.71	125.33	7.65	497.59	1.73
Control	3	530.67	135.17	123.41	8.70	484.50	1.69
Control	4	584.26	135.02	123.41	8.60	534.02	1.86
Control	5	541.56	134.65	123.49	8.29	496.67	1.73
Vetch	1	523.69	136.71	126.49	7.48	484.54	1.69
Vetch	2	560.66	137.24	126.94	7.51	518.58	1.81
Vetch	3	539.3	131.67	120.61	8.40	494.00	1.72
Vetch	4	518.7	134.3	124.26	7.48	479.92	1.67
Vetch	5	524.83	135.78	125.13	7.84	483.66	1.68
Barley	1	563.63	133.35	121.04	9.23	511.60	1.78
Barley	2	556.82	133.56	123.9	7.23	516.55	1.80
Barley	3	529.75	135	123.69	8.38	485.37	1.69
Barley	4	538.24	137.83	127.15	7.75	496.53	1.73
Barley	5	534.49	135.43	125.73	7.16	496.21	1.73
						Total	**34.85**
						Mean	**1.74**
						Grand Total	**14.04**
						Grand Mean	**1.75**

Table SHS-11: Soil Compaction (October 22, 2013)

		Sample 1			Sample 2			Sample 3			Sample 4			Sample 5				
Field Location	**Treatment**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**Sum**	**Mean**
Field 32 North (East)	Mix	300	300	300	200	300	300	200	250	250	180	240	300	180	250	300	3850	256
	Vetch	200	250	300	150	200	200	200	280	300	150	250	300	150	180	50	3160	210
	Barley	150	200	250	180	220	300	200	250	300	220	200	300	150	300	300	3520	234
	Control	200	250	300	200	250	300	180	250	300	220	250	250	200	250	250	3650	243
Field 32-North (West)	Mix	200	250	200	220	250	250	200	200	170	200	250	220	180	150	190	3130	208
	Vetch	200	220	250	250	250	250	200	300	300	200	250	150	180	220	200	3130	208
	Barley	150	150	200	200	280	300	180	120	100	150	200	250	150	200	250	3420	228
	Control	200	250	200	160	180	200	220	200	200	220	200	170	250	220	220	2880	192
Field 32-South (East)	Mix	180	160	220	200	230	250	240	220	175	250	200	100	180	230	270	3105	207
	Vetch	200	190	300	180	210	275	200	225	150	190	200	225	150	200	300	3195	213
	Barley	210	200	175	210	200	190	200	230	290	200	300	300	250	300	300	3555	237
	Control	175	180	300	150	150	200	190	150	200	150	150	150	125	150	225	2645	176
Field 32-South (West)	Mix	150	200	300	175	200	300	190	250	300	175	220	300	175	200	300	3435	229
	Vetch	190	250	300	200	220	300	170	180	180	150	220	250	190	200	250	3520	216
	Barley	190	200	250	190	220	300	150	150	280	200	220	300	130	190	300	3270	218
	Control	175	150	300	175	300	300	200	220	250	150	150	220	180	220	220	3210	214
Field 36-North (East)	Mix	200	220	300	210	230	230	250	250	280	150	250	300	150	200	300	3520	234
	Vetch	200	180	150	220	280	300	170	200	300	200	280	180	150	200	300	3310	220
	Barley	180	200	220	180	200	250	200	240	300	180	220	220	180	250	230	3250	216
	Control	180	220	250	200	250	220	180	250	270	200	220	250	240	230	270	3430	228
Field 36-North (West)	Mix	250	250	300	150	250	300	250	280	300	200	200	250	150	200	300	3630	242
	Vetch	200	220	250	200	220	300	180	250	250	200	250	300	200	300	300	3620	241
	Barley	180	200	220	180	200	250	200	240	300	180	220	220	180	250	230	3250	216
	Control	180	220	250	200	250	220	180	250	270	200	220	250	240	230	270	3430	228
Field 36-South (East)	Mix	250	250	200	250	250	250	200	200	300	250	250	300	250	250	250	3700	246
	Vetch	250	200	200	220	250	200	250	250	200	250	220	250	250	250	150	3390	226
	Barley	150	300	300	200	200	250	250	300	300	250	300	300	200	250	300	3850	256

Table SHS-11: Soil Compaction (October 22, 2013)

		Sample 1			Sample 2			Sample 3			Sample 4			Sample 5				
Field Location	**Treatment**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**6”**	**12”**	**18”**	**Sum**	**Mean**
	Control	250	200	220	250	250	150	200	220	250	220	220	150	250	150	100	3080	205
Field 36-South (West)	Mix	180	250	250	250	220	100	200	300	300	250	300	300	250	300	300	3750	250
	Vetch	150	150	200	180	200	150	250	250	150	250	250	250	220	250	150	3050	203
	Barley	200	250	250	250	250	200	250	250	200	250	250	250	200	200	200	3500	233
	Control	200	220	170	200	200	180	250	250	200	200	300	300	170	200	230	3270	218
	Sum	6270	6930	7875	6380	7360	7765	6580	7455	7915	6435	7450	7855	6100	7220	7805		
	Mean Value	195	216	246	199	230	242	205	232	247	201	232	245	190	225	243		

Table SHS-12: Soil Temperature Samples Taken at a 6-Inch Depth on September 27, 2013

Field Location /Time of Sampling	**Treatment**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sum**	**Mean**
Field 32-North (East) 11:45 am – 12:30 pm	Mix	71	71	70	70	71	353	71
	Vetch	71	71	70	70	71	353	71
	Barley	70	70	71	70	70	351	70
	Control	70	70	70	70	70	350	70
Field 32-North (West) 11:45 am – 12:30 pm	Mix	70	70	70	70	70	350	70
	Vetch	71	70	70	70	70	351	70
	Barley	69	70	70	70	70	349	70
	Control	68	68	70	70	70	346	69
Field 32-South (East) 9:30 am – 10:45 am	Mix	66	66	68	66	66	332	66
	Vetch	65	66	66	67	67	331	66
	Barley	66	68	65	68	68	335	67
	Control	66	68	65	68	68	335	67
Field 32-South (West) 9:30 am –10:45 am	Mix	64	65	64	66	66	325	65
	Vetch	66	66	68	66	66	332	66
	Barley	66	66	66	68	70	336	67
	Control	65	66	66	66	66	329	66

Table SHS-12: Soil Temperature Samples Taken at a 6-Inch Depth on September 27, 2013

Field Location /Time of Sampling	Treatment	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sum	Mean
Field 36-North (East) 8:05 am – 9:15 am	Mix	66	65	66	66	66	329	66
	Vetch	65	66	68	66	65	330	66
	Barley	66	67	65	66	65	329	66
	Control	66	67	66	66	67	332	66
Field 36-North (West) 8:05 am – 9:15 am	Mix	66	67	68	67	66	334	67
	Vetch	67	66	66	66	66	331	66
	Barley	65	66	66	66	66	329	66
	Control	65	66	65	65	65	326	65
Field 36-South (East)	Mix	64	65	66	64	66	325	65
	Vetch	64	68	65	64	67	328	66
	Barley	64	65	66	65	65	325	65
	Control	64	67	64	64	66	325	65
Field 36-South (West)	Mix	65	65	65	66	66	327	65
	Vetch	65	66	66	65	64	326	65
	Barley	66	66	66	67	64	329	66
	Control	66	64	66	64	65	325	65
	Sum							**2141**
	Mean Value							**67**

Table D13: Plant Cover by October 30, 2013

Field Number	Mix	Vetch	Barley	Sum	Mean
32N East	17.0	18.0	34.0	69.0	23.0
32N West	9.6	4.6	13.0	27.2	9.1
32S East	21.6	16.4	8.0	46.0	15.3
32S West	17.7	9.7	32.8	60.2	20.1
36N East	8.7	6.1	6.9	21.7	7.2
36N West	7.8	2.9	8.1	18.8	6.2
36S East	8.1	1.8	9.6	19.5	6.5

Table D13: Plant Cover by October 30, 2013					
Field Number	**Mix**	**Vetch**	**Barley**	**Sum**	**Mean**
36S West	10.2	2.6	4.8		
Sum	**100.7**	**62.1**	**117.2**		
Mean	**12.59**	**7.76**	**14.65**		

Table SHS-14: Plant Density After 60 Days										
	Single Species		**Mix**							
	Barley	**Winter Vetch**	**Millet**	**Cultivated Radish**	**Buckwheat**	**Cowpea**	**Sorgham**			
	PLS Seeding Rate –Seeds Per Square. Foot		**PLS Seeding Rate – Seeds Per Square Foot**							
	13.0	9.0	13.0	3.0	3.0	3.0	1.0			
Field Location	**Plot Plants Per Square Foot**		**Plot Plants Per Square Foot**					**Mix Sum**	**Single Species and Mix Sum**	**Single Species and Mix Mean**
Field 32 North (East)	4.7	3.8	4.2	1.2	2.0	0	0	7.4	15.9	5.3
Field 32 North (West)	4.5	4.3	3.9	1.2	1.4	0	0	6.5	15.3	5.1
Field 32 South (East)	3.9	3.0	3.6	1	1.1	0	0	5.7	12.6	4.2
Field 32 South (West)	4.2	3.5	4.4	1.2	1.2	0	0	6.8	14.5	4.8
Field 36 North (East)	2.8	5.0	6.7	0.7	2.0	0	0	9.4	17.2	5.7
Field 36 North (West)	3.2	4.0	5.4	1.0	1.2	0	0	7.6	14.8	4.9
Field 36 South (East)	2.4	4.5	3.6	0.7	1.2	0	0	5.5	12.4	4.1
Field 36 South (West)	4.2	4.2	5.2	0.8	1.3	0	0	7.3	15.7	5.2
Sum	29.9	32.3	3.7	7.8	11.4	0	0	56.2	**Grand Sum**	**Grand Mean**
Mean	3.7	4.0	4.6	1.0	1.4	0	0	7.0	**14.7**	**4.9**

Soil Test Results

WARD Laboratories, Inc.

Ag Testing - Consulting

Account No. : 56205

Soil Analysis Report

NMSU AG SCIENCE CENTER
1036 MILLER ST SW
LOS LUNAS NM 87031

Invoice No. : 1138042
Date Received : 08/22/2013
Date Reported : 08/26/2013

Results For : GREGORY FENCHEL
Location :

Field #	Sample ID / Lab No.	Soil pH 1:1	Modified WDRF BpH	Soluble Salts 1:1 mmho/cm	Excess Lime Rating	Organic Matter LOI-%	FIA Nitrate ppm N	Depth Nitrate Lbs N/A	Method Phosphorus ppm P	-Ammonium Acetate- K ppm	Ca ppm	Mg ppm	Na ppm	Ca-P Sulfate ppm S	----------DTPA---------- Zn ppm	Fe ppm	Mn ppm	Cu ppm	Hot Water Boron ppm B	$CaNO_3$ Chloride ppm Cl	Sum of Cations me/100g	% Base -----Saturation----- H	K	Ca	Mg	Na
36 S	1							0 - 12 in	O-P																	
	65263	8.5		0.20	HIGH	0.7	2.8	10	10.4	203	2839	173	35	11	0.33	6.3	2.4	0.15			16.3	0	3	87	9	1
32 N	2							0 - 12 in	O-P																	
	65264	8.3		0.22	HIGH	0.7	5.8	21	12.2	208	2994	173	24	11	0.24	5.1	2.4	0.14			17.0	0	3	88	8	1
32 S	3							0 - 12 in	O-P																	
	65265	8.5		0.24	HIGH	0.7	4.9	18	10.9	184	3077	188	34	10	0.72	4.8	2.5	0.20			17.6	0	3	87	9	1
32 N	4							0 - 12 in	O-P																	
	65266	8.4		0.21	HIGH	0.9	4.4	16	10.3	173	3079	177	30	9	0.42	4.4	1.7	0.19			17.4	0	3	88	8	1
32 S	5							0 - 12 in	O-P																	
	65267	8.5		0.25	HIGH	0.8	8.0	29	14.1	243	2940	178	23	14	0.20	4.5	2.2	0.12			16.9	0	4	86	9	1
36 N	6							0 - 12 in	O-P																	
	65268	8.6		0.20	HIGH	0.7	4.0	14	8.1	160	2789	166	39	7	0.17	4.7	1.5	0.14			15.9	0	3	87	9	1
36 S	7							0 - 12 in	O-P																	
	65269	8.5		0.22	HIGH	0.4	5.1	18	11.0	173	2926	180	33	9	0.64	5.4	2.2	0.20			16.7	0	3	87	9	1
36 N	8							0 - 12 in	O-P																	
	65270	8.6		0.22	HIGH	0.6	3.4	12	7.2	167	2868	170	38	6	0.14	4.9	1.4	0.13			16.4	0	3	87	9	1

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Bureau of Land Management "Seeds of Success" Activities

The Natural Resources Conservation Service (NRCS) entered into an Interagency Agreement with the Bureau of Land Management (BLM) "*Seeds of Success"* (SOS) Program in 2010 to establish seed production fields at the Los Lunas Plant Materials Center (LLPMC) of native species selected by BLM in an effort to improve the commercial availability of seed adapted to the Colorado Plateau. The LLPMC has been producing seed of several forb species, some of which are rarely produced under agronomic conditions:

- *Oenothera pallida* – Pale evening primrose
- *Ipomopsis aggregata* – Scarlet gilia
- *Sphaeralcea parvifolia* – Smallflower globemallow
- *Ratibida columnifera* - Upright prairie coneflower.

Oenothera pallida – Pale evening primrose

Our seed production efforts started with 0.3 g of primrose seed received from SOS in 2010 which produced an initial 20 containerized transplants. By 2012 we had sufficient seed to produce 800 seedlings in 2.5"dia. x 3" deep (12 $in^{3)}$ containers. The seedlings were transplanted into the field in late August 2012 using a water wheel transplanter that set the plants 12-inches apart in rows with between row spacing of 76 inches. The final planting contained 2.75 rows each 300 feet in length. Figure 1 shows the primrose plants in July 2013.

In 2013, we initially tried to harvest the seed using the vacuum harvester described in another Section of this report. The large distance (>3 ft) between the vacuum intake and the blower outlet required by the width of plants resulted in negligible seed dispersal out of the seed capsules into the air stream. The small seed size, the vining nature of the species, and the need to harvest green stems precluded the use of a combine harvester. Therefore, the plot was harvested with a forage harvester in late August. The green material was spread on a tarp in a hot greenhouse to be dried before storage. This material yielded 4.5 lb (2.0 kg) of cleaned seed, a 7,000 fold increase from the initial seed weight.

Figure 1. *Oenothera pallida* – Pale Evening Primrose in early July 2013, seedlings planted in August 2012.

Ipomopsis aggregata – Scarlet gilia

In spring of 2012, the miniscule amount of seed from our failed initial field planting was used to produce 155 transplants in 2.5" dia. and 5.0" deep (19 in^3) containers. The seedlings were transplanted as a double row into a Weed Guard Plus Heavy Weight Creped Organic paper mulch in mid July 2012. A row of T-tape drip tape was placed adjacent to each row. The transplants were drenched initially with 'Subdue Maxx' fungicide and later with 'Banrot' fungicide with approximately 6 oz. of drench solution per plant at the labeled rate for preventative care. As of early fall 2012, 135 out of the 155 plants (87%) were still alive (Figure 2). This biennial sent up flowering stems in 2013 which reached heights of up to 6 ft. and produced numerous flowers and appreciable activity from hummingbirds for pollination (see Figure 3).

Entire stems were hand harvested on October 23, 2103 and placed in woven polyethylene bulk bags for drying. These approximate 100 plants yielded 0.4 lbs of cleaned seed with an estimated PLS percentage of 30%.

Figure 2. *Ipomopsis aggregata* – scarlet gilia planting mid October 2012.

Figure 3. *Ipomopsis aggregata* – scarlet gilia test plot October 1, 2013.

Ratibida columnifera - Upright Prairie Coneflower

In 2013 two seed fields of *Ratibida columnifera* were in production at the LLPMC: Field 23S with 0.50 acre and Field 8 with 0.55 acre for a total of 1.05 acres. Figure 4 shows the Field 8 prairie coneflower planting in miSHS-October 2012. These fields were harvested in late October 2013 with a Gleaner K2 combine. The harvesting head was modified with crop lifting snouts to lift the spreading stems to allow more seedheads to be swathed. The PLS (pure live seed) yield from the two fields for 2013 was 129 lbs.

Figure 4. *Ratibida columnifera* - upright prairie coneflower planting in Field 8 on October 15, 2012

***Sphaeralcea parvifolia* – Smallflower Globemallow**

With the 0.6 grams of seed that was originally obtained from SOS in 2010, 80 transplants were produced in 2011 and installed in a two-row planting. Seed was collected off of these two rows of plants in the late summer and early fall of 2011 and used to grow seedlings in 2.5" dia. x 3" deep (12 in^3) containers in the spring of 2012. The seedlings were transplanted in late August 2012 using a water wheel transplanter to set the seedlings 12 inches apart in rows with a between row spacing of 76 inches. The final planting contained 11.75 rows and comprised about 3,500 plants. Figure 5 shows the planting in early July 2013.

The field was harvested initially in late June 2013 with a Kincaid XP2 row plot combine, because the vacuum harvester was still being fabricated. The vacuum harvester described in a later Section in this report was used several times between late August and early October 2013 to collect mature seed. A final combine harvest was completed at the end of the growing season in late October 2013. The total amount of cleaned seed was 39 lb. (17.7 kg) or a 30,000 fold increase from the initial seed weight.

Figure 5. *Sphaeralcea parvifolia* – smallflower globemallow field on July 5, 2013

Figure 6. Sphaeralcea parvifolia – smallflower globemallow being collected with the vacuum harvester on October 1, 2013

Vacuum Harvester with Blower Facilitated Seed Detachment

One of greatest limitations in obtaining high seed yields from production fields is the indeterminate seed maturation of many native plants. Seed harvesters such as the Woodward Flail-Vac Seed Stripper can be used to attempt to repeatedly harvest a seed production field as the seed matures. The brushes on seed strippers can damage ripening seedheads as well as developing flowers especially on some forb species. We have attempted to use a PTO driven vacuum to harvest forb seed using a handheld collection vacuum hose as well as a toolbar mounted vacuum intake hood. Two principal problems encountered with these approaches were the:

1) Vacuum hose or collection hood had to brush the plant to dislodge most of the seed

2) seed and chaff had to go through the vacuum blower impellers where unknown damage could occur to the seed.

To address these issues, we fabricated a vacuum system based on the same PTO driven vacuum but incorporated a seed collection cyclone in the intake airstream upstream of the blower and used the exhaust from the vacuum blower to dislodge seed and blow the seed into the vacuum collection hood. The harvester uses a Trac Vac Model 854 leaf vacuum with 8" diameter intake and exhaust hoses, approximate 2000 cfm capacity, and a cost of $3000 (not including shipping). The collection cyclone (designed for 1200-1900 cfm) and cyclone stand, 8" and 10" steel ducts and fittings, and collection drum were purchased from Oneida Air Systems for $1,700 (not including shipping). The system was designed to be 3 point hitch mounted to allow ease of height adjustment (see Figure 7).

Our initial trials were performed on smallflower globemallow (*Sphaeralcea parviflora*). The system was configured to maintain a distance of 24" between the blower exhaust outlet and vacuum collection hood. This distance appeared to be near the maximum distance between inlet and outlet and still attain good seed detachment. We will attempt to install some snouts to gather the stems and reduce this span in future trials to obtain greater seed detachment. The typical harvesting speed was about 3 mph and it took 20 minutes to harvest a one-half acre field (twelve 300 ft rows at 6.3 ft row spacing).

With globemallow the vacuum-collected material appeared to be 20 to 25% seed with the remainder being seedhead parts. Most of the seed harvested by the vacuum system had reached maturity. When the globemallow is harvested with a combine, 90% of the uncleaned weight is stems and much of seed is immature.

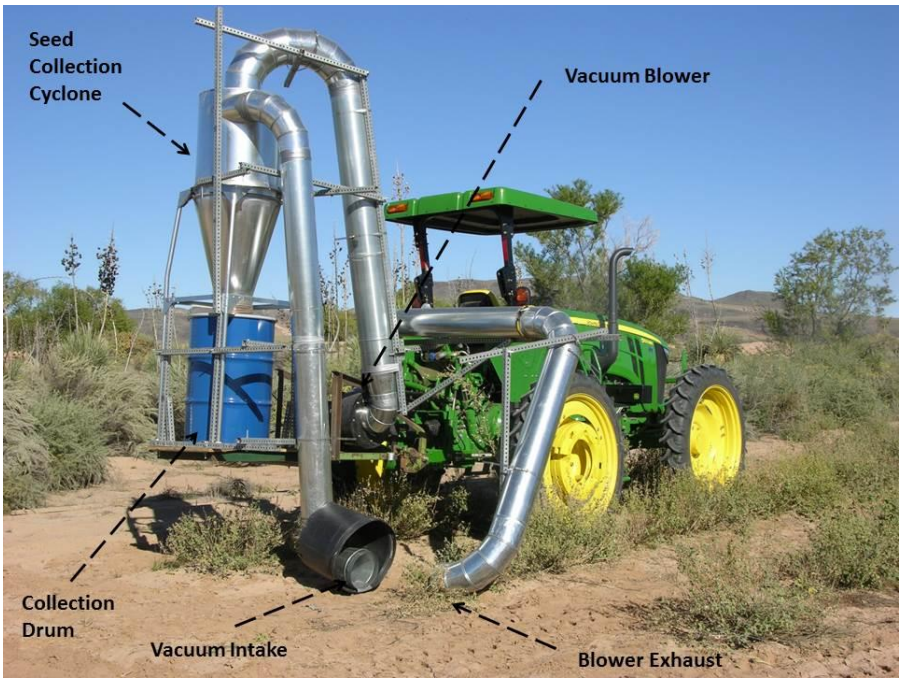

Figure 7. Vacuum harvester components

Proposed Future Activities

The following activities will be performed for each of the species listed:

***Oenothera pallida*–Pale evening primrose**

- Maintain existing field and expand seed production field to a total of one acre. This expansion of 20 rows would require about 6,000 transplants.
- Attempt to modify vacuum harvester to allow periodic seed harvest as the seed capsules mature.

***Ipomopsis aggregata*–Scarlet gilia**

- Establish a 0.25 acre seed field on raised beds and apply preventative fungicide treatments to reduce root rot pathogen mortality that plagued the first planting.
- This planting would require about 1,500 transplants.

***Ratibida columnifera*–Upright prairie coneflower**

- Maintain the newer seed field of 0.55 acre and continue harvesting seed.

***Sphaeralcea parvifolia*–Smallflower globemallow**

- Maintain existing field and expand seed production field to a total of one acre. This expansion of 12 rows would require about 3,600 transplants.
- Compare seed yield between periodic vacuum harvesting (biweekly) and combine harvesting (2 or 3 times per growing season.
- Begin initial increase of 3 additional smallflower globemallow accessions in isolated fields to limit cross pollination.

***Plueraphis jamesii* – James' galleta**

- Begin initial increase of accessions deemed representative of Colorado Plateau populations in isolated fields to prevent cross pollination
- Accessions on hand would yield initial increase field sizes ranging from one row to 0.5 acre

Field Plantings on Colorado Plateau

- Direct seeding trials would be conducted to ascertain how the four forb species perform on test sites on the Colorado Plateau.

Seed Production for Boulder County Little Bluestem and Prairie Dropseed

Introduction

The Natural Resources Conservation Service (NRCS) and the Boulder County Parks Department (BCPD) of Colorado have a cooperative agreement which requests the Los Lunas Plant Material Center (LLPMC) to produce foundation quality seed for the BCPD. Little bluestem (*Schizachyrium scoparium*) and prairie dropseed (*Sporobolus heterolepis*) seed was locally collected by the BCPD and sent to the LLPMC for cleaning. The cleaned seed was then used as the source for establishing two seed production fields at the LLPMC; a half-acre of little bluestem and a half-acre of prairie dropseed.

- Little bluestem – A native, warm-season, cross-pollinated, long-lived perennial bunchgrass found on prairies, dry hills, fields and open woods in the eastern half of Colorado as far west as Larimer, Chaffee and Archuleta Counties at elevations of 3,500 to 8,000 feet. It prefers well-drained sunny sites and can grow up to three feet in height.
- Prairie dropseed is a native, cross-pollinated, warm-season, long-lived perennial bunchgrass found on prairies, dry hills and plains. In Colorado, prairie dropseed has been found along the foothills from the city of Boulder to Pueblo County at elevations of 5,300 to 7,200 feet on dry-to-medium well drained soils. It is slow growing and slow to establish with maturity requiring up to five years when it may grow to its' maximum height of three feet.

Propagation Methods

In June of 2010, the LLPMC began to produce 8,000 little bluestem plug transplants and 8,000 prairie dropseed plug transplants. The plug soil mix contained two parts of Sunshine #1 media to one part of perlite. One pound of a three-month controlled release fertilizer (17-16-12) was added per four cubic feet of the plug soil mix.

After ten days in the greenhouse, most of the seeds of both species had germinated, and the seedlings had emerged. The seedlings were placed on a bench and kept damp with an automatic sprinkler system for three weeks. They were then moved outside to the nursery to harden off for an additional six weeks.

In September 2010, the transplants were installed in the two half-acre production fields at the LLPMC using a Holland Transplanter Model 1265. During the winter and spring of 2011, approximately five to ten percent of the prairie dropseed plants had died. Using the seed harvested in 2012, the LLPMC propagated 1,500 transplants of little bluestem and 1,000 transplants of prairie dropseed. The prairie dropseed transplants were inter-planted within the existing rows to fill in the areas where the plants had died. The little bluestem transplants were used to complete the final rows of the half-acre planting.

Field Maintenance

During 2013, the fields (Figures 1 and 2) were hanSHS-hoed approximately once every three weeks during the active growing period (April – November). During the winter (December – March) they were hoed twice to control cool-season grasses and other weeds, primarily species in the mustard plant family. Irrigation was applied by flooding; fertilization was applied by broadcasting. See Tables 1 and 2.

Table 1. Little Bluestem 2013 Field Irrigation and Fertilization

2013 Date	**3/13**	**5/9**	**5/29**	**6/24**	**7/10**	**7/23**	**8/16**	**8/26**	**9/18**	**10/3**
Flood irrigation	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches
2013 Date	**6/13**	**5/7**	**10/18**	**6/13**		**10/18**				
Fertilization lbs. per acre	P@40	N@40	P@40	N@40	P@40	N@50				

Table 2. Prairie Dropseed 2013 Irrigation and Fertilization										
Date	**3/12**	**4/30**	**5/22**	**6/13**	**7/3**	**9/5**	**9/17**	**9/30**	**10/18**	
Flood Irrigation	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches	3 inches
Date	**5/22**	**5/22**	**7/23**	**7/23**	**10/18**	**10/18**				
Fertilization lbs. per acre	P@40	N@40	P@40	N@40	P@40	N@40				

To maintain seed purity, both fields are being managed by adhering to National Foundation Seed Standards. The fields were inspected in July 2013 by the New Mexico State University Seed Certification for isolation requirements and the absence of noxious weeds. Little bluestem was harvested in October 2013 using a Kincade 8-XP plot combine. Prairie dropseed was harvested in August 2013 using an Almaco Forage Harvester. Seed of each species was placed on an air drying table for four days until it was dry enough to prevent molding. During the winter of 2014, the seed will be cleaned and samples will be analyzed for purity and germination by the New Mexico State University Seed Certification in Las Cruces, New Mexico.

Figure 1: Five new rows (foreground) were added to the little bluestem seed production field (February 2013)

Figure 2: Prairie dropseed seed production field (February 2014)

Results and Discussion

The little bluestem and prairie dropseed seed production fields yielded a disappointing 1.1 bulk pounds and .1.9 PLS pounds respectively. See Table 3.

Mr. David Hirt, Restoration Ecologist for Boulder County Parks and Open Space, is concerned that warmer temperatures during the previous few years may be interfering with the pollination process. This interference may reduce seed production at the LLPMC. The global warming effect on the pollination process has been a major concern by environmental scientists, and as a result, there have been many publications addressing this issue.

Global warming may disrupt the overlap in seasonal timing of flower production and of pollinator flight activity, thus altering the opportunity for interaction between plants and animals (Wall et al. 2003). This may occur particularly at high elevations (subalpine and alpine) in the temperature zones where productivity of vegetation occurs during the snow free growing season. At these high elevations, spring snowmelt is a cue that initiates growth and flowing of many species which may now happen earlier and for a longer period as a consequence of climate change (Galen and Stanton, 1995).

The two species of our concern are pollinated mainly by wind, and so the mechanism disrupted may be a physiological change in the plants caused by exposure to warmer temperatures. To address this concern, we have looked at the LLPMC's daily temperatures of high and low records for 2012 and 2013 and have compared seed production results with these temperatures for little bluestem. We were not able to compare the production of prairie dropseed because we only have the 2013 production year.

The daily high and low temperatures from June to September are listed in Section **Climatological Data**. The daily high temperature averaged 1.5 degrees warmer in 2012 (94.7° F) than in 2013 (93.2° F). However, 2012 averaged cooler lower temperatures by 1.3 degrees. The beginning of the flowering period for the little bluestem at the LLPMC begins in August and ends when the seed is harvested; September 17, 2013 and September 19, 2012. For the time period of August 1 through September 19, thirty-one out of the forty-eight days were warmer in 2012 than in 2013. Three of these days were hotter than 100° F in 2012. There was not any 100° F temperatures recorded for this time period in 2013. Even though 2012 was warmer than 2013 during the flowering development period for little bluestem, the seed harvest was four times greater in 2013.

Table 3: Boulder County Little Bluestem Seed Yield and Analysis Results

Species	Year	Bulk Wt. (lbs.)	% Other Crop	% Inert Matter	% Weed Seed	% Germ.	% Dormant Seed	% Pure Live Seed (PLS)	Pure Live Seed (PLS) Wt. (lbs.)
little bluestem	2012	19.0	0	0	0	47	0	96.81	8.6
little bluestem	2013	1.1	0	0	0	-	-	-	-
prairie dropseed	2012	1.0	0	0	0	90	69	86.76	0.9
prairie dropseed	2013	2.4	0	0	0	82	68	97.20	1.9

It could be a soil fertility issue that is affecting seed production. The little bluestem transplants in 2012 were grown inside the greenhouse in a soilless potting medium with a complete nutrient slow-release fertilizer treatment. The residual fertilizer from this treatment may have provided the essential nutrients that improved field conditions that may have led to the improvement in 2012 seed production. By 2013, the greenhouse fertilizer may have been depleted causing seed production to severely decline and responding only to the nitrogen and phosphorus which was applied. This fertilization treatment may be inadequate for seed production of these grass populations from Boulder County because they may not be adapted to the LLPMC's desert soils. The grass stands appeared healthy in stature and in color for 2012 and 2013, but they have produced only limited amounts of seed. Possibly a more complete fertilizer treatment may be required for improvement in seed production which the LLPMC is willing to test without any additional charges.

These two plantings are located on sandy soils which are classified by the NRCS Soil Survey of Valencia County, New Mexico (1969) as Bluepoint series loamy fine sand which have excessive lime (calcium carbonate). Soil fertility of phosphorus and nitrogen was maintained at sufficiency levels for native grasses and usually that is enough for most adapted desert species that have evolved on this type of soil. However, species that are not adapted may have nutrient deficiency challenges, particularly with the high 8.5 pH factor. A standard soil test was performed on adjacent fields of the same soil type at the LLPMC (Table 4 and Section **Soil Test Results**). The sufficiency levels of available nutrients (SLAN) values are the national sufficiency levels of available nutrients for turf grasses and are provided in Table 5. They can be used as a reference for soil test interpretation and are based on the past sixty years of soil fertility studies, particularly with forages, agronomic and horticultural crops, and adjustments made by scientists to fit perennial turf grasses. Sulfur was low averaging 9.2 ppm which is below the SLAN moderate levels. Because these sandy soils have excess lime (calcium carbonate), the excessive calcium reported is expected. Consequently, the calcium-to-magnesium ratio of greater than 16 to 1 (optimal is 2 to 1) may be interfering with magnesium uptake. Subsequently, both growth rates and seed yields may be improved with the additions of magnesium, most likely sulfur, and possibly a cocktail of micronutrients including iron which becomes unavailable for most plant species in high pH soil conditions. The fertilization treatment will be applied by banding at a four- to six-inch depth in the root zone of these plant species.

Table 4: Soil Test Results from the Top 12 Inches of an Adjacent Field

Field	pH	Mmho/CM	Excess lime	Organic Matter	K ppm	Ca ppm	Mg ppm	Na ppm	Zn	Fe
36N	8.6	0.20	High	0.7	160	2789	186	39	0.17	4.7
36S	8.5	0.20	High	0.7	203	2839	173	35	0.33	6.3
32N	8.4	0.21	High	0.9	173	3079	177	30	0.42	4.4
32S	8.5	0.24	High	0.7	184	3077	188	34	0.72	4.8

Table 5: Sufficiency Levels of Available Nutrients (SLAN) Ranges for Turf Grasses (Carrow etal, 2003)			
Nutrient	**Soil**	**Medium Sufficiency range (ppm)**	**Extract**
Potassium	Sands	75 -175	Ammonium Acetate
Calcium	All	500 – 750	Ammonium Acetate
Magnesium	Sands	100 – 200	Ammonium Acetate
Sulfur	All	10 – 20	Calcium Phosphate

Fertilizers with the potential to improve future seed production include:

- Granular majors and sulfur
- Granular minor and trace elements
- Soluble minors and trace elements
- Magnesium fertilizers

See the Section **Fertilizer Mixes** for more information.

Climatological Data

Table 6. 2012 and 2013 Maximum and Minimum Temperatures at the LLPMC								
	Max Temperature		**Difference**	**Hottest Day[1]**	**Minimum Temperature**		**Difference**	**Hottest Day[1]**
Date	**2012**	**2013**			**2012**	**2013**		
1-Jun	97	90.9	6.1	1	54.8	46.5	8.3	0
2	98.2	89.3	8.9	1	56.4	54.3	2.1	0
3	97.9	96.2	1.7	1	52.4	58	-5.6	1
4	94.4	95.6	-1.2	0	56.2	55	1.2	0
5	95.3	94.2	1.1	1	53.1	58.4	-5.3	1
6	97.3	93.1	4.2	1	56.9	54.5	2.4	0
7	98.1	95.6	2.5	1	51.6	63.2	-11.6	1
8	98.9	99.4	-0.5	0	52.2	56.4	-4.2	1
9	97.1	99.9	-2.8	0	47.5	64.6	-17.1	1
10	93.6	105.3	-11.7	0	50.4	64	-13.6	1
11	96.1	103	-6.9	0	51.1	61.1	-10	1
12	97.3	102.4	-5.1	0	57.7	54.6	3.1	0
13	99.1	99.7	-0.6	0	59.7	60.9	-1.2	1
14	98.6	95.5	3.1	1	55.2	65.2	-10	1
15	96.2	96.5	-0.3	0	51.3	59.9	-8.6	1
16	94.6	95	-0.4	0	60.3	62.2	-1.9	1
17	98.8	98.3	0.5	1	54.8	57.7	-2.9	1
18	98.4	95.1	3.3	1	53.9	65.1	-11.2	1
19	98.2	99.5	-1.3	0	62.4	54.6	7.8	0
20	103.9	99.2	4.7	1	51.7	51.7	0	0
21	97	98.7	-1.7	0	69.3	53.7	15.6	0
22	97.7	97	0.7	1	59.3	50.2	9.1	0
23	100.6	96.9	3.7	1	61.9	49.2	12.7	0
24	102.8	95.8	7	1	58.2	59.2	-1	1
25	99.2	97.3	1.9	1	59.2	54.1	5.1	0
26	86.7	102.1	-15.4	0	40	54.7	-14.7	1

[1] 1=2012 day hotter than 2013; 0=2013 day hotter than 2012 day

Table 6. 2012 and 2013 Maximum and Minimum Temperatures at the LLPMC								
	Max Temperature		Difference	Hottest Day[1]	Minimum Temperature		Difference	Hottest Day[1]
Date	2012	2013			2012	2013		
27	102.9	110.1	-7.2	1	59.2	56.3	2.9	0
28	103.2	100.3	2.9	1	60.7	67.6	-6.9	1
29	102	102.6	-0.6	0	66.1	68.2	-2.1	1
30	104.4	100.9	3.5	1	64.8	67.4	-2.6	1
1-Jul	102.8	92	10.8	1	63.8	60.9	2.9	0
2	101	93.6	7.4	1	66.4	59.1	7.3	0
3	96.9	92.9	4	1	61.5	59.9	1.6	0
4	96.7	96.4	0.3	1	66	59.6	6.4	0
5	91.2	99.5	-8.3	0	62.8	67.8	-5	1
6	87.1	96.9	-9.8	1	62.9	65.6	-2.7	1
7	86.5	98.6	-12.1	1	60.2	64.9	-4.7	1
8	91.2	98.9	-7.7	1	62.6	68.7	-6.1	1
9	94.5	100	-5.5	1	64.9	64.3	0.6	0
10	89.7	99.1	-9.4	1	64.9	64.2	0.7	0
11	91.1	90	1.1	1	62.3	64.7	-2.4	1
12	94.1	96.1	-2	0	61.4	63.2	-1.8	1
13	95.1	98.7	-3.6	0	62.1	65.2	-3.1	1
14	95	99.6	-4.6	0	67.9	64.8	3.1	0
15	95.4	80.1	15.3	1	61.6	65.1	-3.5	0
16	93.5	86.4	7.1	1	60	60.2	-0.2	0
17	95.4	86	9.4	1	60.6	58.6	2	1
18	96.7	84.8	11.9	1	60.8	59.8	1	1
19	96	92.3	3.7	1	62.7	61.5	1.2	1
20	96.9	92.5	4.4	1	61.5	64.9	-3.4	0
21	97.7	96.1	1.6	1	62.8	64.5	-1.7	0
22	96.9	95.9	1	1	62.4	64.5	-2.1	0
23	97.9	99.7	-1.8	0	59.6	62.1	-2.5	0
24	94	91.1	2.9	1	58.3	64.1	-5.8	0
25	96.3	87.2	9.1	1	61.6	63	-1.4	0
26	95.3	90.7	4.6	1	66	60.5	5.5	1
27	97.5	84	13.5	1	63.1	60.9	2.2	1
28	94.8	89.4	5.4	1	64	63.9	0.1	1
29	95.2	92.9	2.3	1	64.2	61.8	2.4	1
30	100.1	98.4	1.7	1	60.6	61.5	-0.9	0
31	100.2	98.4	1.8	1	66.3	64.7	1.6	1
1-Aug	99	90.1	8.9	1	64.2	63.4	0.8	1
2	101.3	91.2	10.1	1	61.6	62.1	-0.5	0
3	92.7	94	-1.3	0	61.5	61.6	-0.1	0
4	97.7	96.7	1	1	62.3	64.6	-2.3	0
5	95.6	93.7	1.9	1	66.3	62.9	3.4	1
6	98.2	90.7	7.5	1	65.4	65	0.4	1
7	100.2	85.7	14.5	1	64.2	59	5.2	1
8	98.5	90.4	8.1	1	65.6	60.9	4.7	1
9	99.8	86	13.8	1	60	57.7	2.3	1
10	99.3	85.1	14.2	1	58.3	60.4	-2.1	0
11	100	86.2	13.8	1	58.7	59.9	-1.2	0
12	100.6	84.4	16.2	1	58.1	62.2	-4.1	0
13	95	92.5	2.5	1	65.5	57.8	7.7	1
14	98.6	89.1	9.5	1	65.5	60.1	5.4	1
15	98.4	93.1	5.3	1	58.8	57.6	1.2	1
16	96.6	98.1	-1.5	0	63.6	56.9	6.7	1

Table 6. 2012 and 2013 Maximum and Minimum Temperatures at the LLPMC

	Max Temperature		Difference	Hottest Day[1]	Minimum Temperature		Difference	Hottest Day[1]
Date	**2012**	**2013**			**2012**	**2013**		
17	92.4	98.8	-6.4	0	65.6	66.9	-1.3	0
18	93.8	97.1	-3.3	0	58.1	64.4	-6.3	0
19	95	97.8	-2.8	0	63	62.1	0.9	1
20	91.1	95	-3.9	0	63.2	60.9	2.3	1
21	92	94.2	-2.2	0	60.6	60.3	0.3	1
22	81.2	92.5	-11.3	0	63.5	59.4	4.1	1
23	82.6	92.6	-10	0	59.9	54.9	5	1
24	83.6	88.3	-4.7	0	59.1	61.5	-2.4	0
25	97.1	90.7	6.4	1	56.9	65.8	-8.9	0
26	96	92.3	3.7	1	65.1	61.2	3.9	1
27	95.3	91.9	3.4	1	61.5	58.5	3	1
28	95.6	88.3	7.3	1	57.3	57.5	-0.2	0
29	95.1	85.4	9.7	1	54.7	65.1	-10.4	0
30	95.1	95.1	0	x	52.6	59.5	-6.9	0
31	95.3	97.8	-2.5	0	53	59.7	-6.7	0
1-Sep	96.9	98.7	-1.8	0	56.7	57.4	-0.7	0
2	98.7	96.4	2.3	1	59.7	67.9	-8.2	0
3	95.8	94.4	1.4	1	65	60.7	4.3	1
4	98	94.4	3.6	1	64	61	3	1
5	94.1	95.2	-1.1	0	65.7	54.5	11.2	1
6	96.7	93.3	3.4	1	64.3	54.3	10	1
7	95.3	91.9	3.4	1	61.4	57.6	3.8	1
8	76.1	92.4	-16.3	0	54.5	55.9	-1.4	0
9	77.2	90.7	-13.5	0	54.6	58.5	-3.9	0
10	83.8	73.5	10.3	1	56.3	61	-4.7	0
11	88.7	86.5	2.2	1	52.8	61.4	-8.6	0
12	78.6	78.3	0.3	1	56.6	59.2	-2.6	0
13	70.5	75.5	-5	0	53	60.3	-7.3	0
14	73	78	-5	0	44.4	56.2	-11.8	0
15	82.4	82.3	0.1	1	43.8	57.5	-13.7	0
16	91.3	82.5	8.8	1	43.4	55.8	-12.4	0
17	87.1	84	3.1	1	47	56.3	-9.3	0
18	85.3	84.4	0.9	1	48	59.5	-11.5	0
19	90.2	87.1	3.1		43.5	58.5	-15	0
				75 days				55
	10510.6	10347.9		35 days	6562.5	6706.3		54
Mean =	94.69009	93.22432			59.12162	60.41712		

Soil Test Results

See the following example for soil test results:

WARD Laboratories, Inc.

Ag Testing - Consulting

Account No. : 56205

Soil Analysis Report

NMSU AG SCIENCE CENTER
1036 MILLER ST SW
LOS LUNAS NM 87031

Invoice No. : 1138042
Date Received : 08/22/2013
Date Reported : 08/26/2013

Results For : GREGORY FENCHEL
Location :

Field #	Sample ID Lab No.	Soil pH 1:1	Modified WDRF BpH	Soluble Salts 1:1 mmho/cm	Excess Lime Rating	Organic Matter LOI-%	FIA Nitrate ppm N	Depth Nitrate Lbs N/A	Method Phosphorus ppm P	-Ammonium Acetate- K ppm	Ca ppm	Mg ppm	Na ppm	Ca-P Sulfate ppm S	---------DTPA--------- Zn ppm	Fe ppm	Mn ppm	Cu ppm	Hot Water Boron ppm B	$CaNO_3$ Chloride ppm Cl	Sum of Cations me/100g	% Base ----Saturation---- H	K	Ca	Mg	Na
36 S	1							0 - 12 in	O-P																	
	65263	8.5		0.20	HIGH	0.7	2.8	10	10.4	203	2839	173	35	11	0.33	6.3	2.4	0.15			16.3	0	3	87	9	1
32 N	2							0 - 10 in	O-P																	
	65264	8.3		0.22	HIGH	0.7	5.8	21	12.2	208	2994	173	24	11	0.24	5.1	2.4	0.14			17.0	0	3	88	8	1
32 S	3							0 - 12 in	O-P																	
	65265	8.5		0.24	HIGH	0.7	4.9	18	10.9	184	3077	188	34	10	0.72	4.8	2.5	0.20			17.6	0	3	87	9	1
32 N	4							0 - 12 in	O-P																	
	65266	8.4		0.21	HIGH	0.9	4.4	16	10.3	173	3079	177	30	9	0.42	4.4	1.7	0.19			17.4	0	3	88	8	1
32 S	5							0 - 12 in	O-P																	
	65267	8.5		0.25	HIGH	0.8	8.0	29	14.1	243	2940	178	23	14	0.20	4.5	2.2	0.12			16.9	0	4	86	9	1
36 N	6							0 - 12 in	O-P																	
	65268	8.6		0.20	HIGH	0.7	4.0	14	8.1	160	2789	166	39	7	0.17	4.7	1.5	0.14			15.9	0	3	87	9	1
36 S	7							0 - 12 in	O-P																	
	65269	8.5		0.22	HIGH	0.4	5.1	18	11.0	173	2926	180	33	9	0.64	5.4	2.2	0.20			16.7	0	3	87	9	1
36 N	8							0 - 12 in	O-P																	
	65270	8.6		0.22	HIGH	0.6	3.4	12	7.2	167	2868	170	38	6	0.14	4.9	1.4	0.13			16.4	0	3	87	9	1

Fertilizer Mixes

Table 7 shows the fertilizer mixes used for this project.

Table 7. Fertilizer Mixes	
Granular Majors and Sulfur	• Monoammonium Phosphate, $NH_4H_2P0_4$, 11-53-0 - deep placement • Potassium Sulfate, K_2S0_4, 0-0-50, 17 to 18% S - deep placement • Ammonium Sulfate, (NH_4hS0_4, 21-0-0, 21% Nand 24% S - near surface
Granular Minors and Trace Elements - mix with granular majors	• Micromax –Ca 6%, Mg 3%, S 12%, B 0.1%, Cu 1%, Fe 17%, Mn 2.5%, Mo .05%, Zn 1% STEP Hi Mag, Mg 12%, Cu 0.5%, Fe 8%, Mn 3%, Zn 1%
Soluble Minors and Trace Elements - foliar spray or drench	• S.T.E.M. (Soluble Trace Element Mix) - S 13%, B 1.35%, Cu 2.3%, Fe 7.5%, Mn 8%, Mo 0.04%, Zn 4.5% • Microlink Micro 500 , B .02%, Cu 0.25%, Fe 0.37%, Mn 1.2%, Zn 1.8% • TJ Micromix Liquid Wheat, Chelated cations Ca 0.7%, Mg 0.3%, Cu 0.9%, Fe 0.6%, Mn 0.5%, Zn 0.9% and soluble anion, B 0.1% • TJ Micromix Liquid Corn, Chelated cations Ca 0.6%, Mg 0.25%, Cu 0.25%, Fe 0.5%, Mn 0.42%, Zn 2.14% and soluble anion, B 0.08%
Magnesium Fertilizers	• Magnesium Sulfate, Epsom Salt, 9.5% Mg and 12.5% S • Magnesium Nitrate, 11-0-0,9.4% Mg • Sul-Po-Mag, 0-0-18,11% Mg and 22% S • Microlink Magnesium, 2.5% Mg - foliar spray magnesium sulfate

References

Galen, C., and M.L. Stanton. 1995. Responses of snowbed plant species to change in growing-season length. Journal of Ecology 76: 1546-1557.

Wall, M.A., Timmerman-Erskine, M. & Boyd, R.S. (2003). Conservation impact of climate variability on pollination of the Federally endangered plant, Clematis socialis (Ranunculacea). Journal of Southeast Naturalist 416:389-395.

Walker, M.D., R.C. Ingersoll, and P.J. Webber 1995. Effects of interannual climate variation on phenology and growth of two alpine forbs. Journal of Ecology 76:1067-1083.

Revegetation Recommendations for Santa Clara Creek Canyon

Essential Preliminary Activities

We advise that it is too early to initiate revegetation treatments on the canyon floor. Our recommendation is to wait until regular canyon flash flooding, active gullying, and sheet erosion with rock slides on the canyon walls and slopes subsides. Currently there is too much water and debris (boulders more than 10-feet in diameter and logs more than 40 feet in length) that flow down the canyon floor during intense rainstorms which may occur in the spring time, summer, or fall.

These activities are identified in the following Sections.

Eliminate Invasive Weeds in the Canyon

Watch for the infestation of invasive weeds that can quickly colonize the vast areas of bare ground in the canyon and surrounding mountains, particularly those species on the New Mexico noxious weed list that are common to this area. These species include:

- Canada thistle (*Cirsium arvense*)
- Russian knapweed (*Acroptilon repens*)
- Dalmation toadflax (*Linaria dalmatica*)
- Perennial pepperweed (*Lepidium latifolium*)

A pocket guide containing pictures of these species of noxious weeds would help workers to identify them and notify their supervisor to promptly apply treatments. Herbicides are the only effective treatment against these weeds. By treating promptly, less herbicide will have to be used because the plant colony will have less time to spread, particularly at higher elevations which receive more precipitation than do lower elevations. The use of the proper herbicide labeled for a particular weed is the only way to control these rhizomatous, invasive species.

The tribes that we have worked with in the past were initially opposed to using herbicides. It would be advisable to get approval as soon as possible to use these herbicides (if not already approved) before the situation arises where herbicide treatment needs to be applied promptly.

Develop Plant Materials at the Pueblo

The Tribe is interested in using local germplasm for the development of the plant materials that will be used for the revegetation treatments and have been collecting local seed. We suggest that they continue to collect seed from plants in the canyon and surrounding mountains and to include grasses, forbs, shrubs, and trees. During our brief visit, I observed colonies of very healthy mountain muhly, muttongrass, and woods rose. This seed would be very easy to collect with the proper timing. The Pueblo is welcome to come to the LLPMC, and with training, would be able to use our seed cleaning equipment. If there is a decision to produce containerized transplants or install grass and forb seed production fields at the Pueblo, they are always welcome to come and visit us again. Our plant ecologist, Dr. David Dreesen, has his PhD in horticulture from Cornell University, and he was a Research Associate of horticulture at Cornell. He has been successfully propagating native plant materials from all elevations in New Mexico for the past 25 years and has written many Scientific Journal articles on innovative propagation strategies for New Mexico native plants.

Generally, just regular hay and corn farming equipment with a seed harvester is all that is needed to install and maintain most grass and forb seed production fields. For a seed harvester, we would suggest the purchase of a $3,000 Trac Vac or something similar (Figure 1). This is a PTO driven vacuum machine and is very easy to operate, affective, and it relatively inexpensive compared to a $100,000 plot size combine. Seed harvested by this equipment may be directly planted without any additional processing.

Figure 1: Harvesting bottlebrush squrreltail seed with a vacuum harvester

Initiate Vegetation Trials–Upper Watershed

Begin vegetation trials on slopes and flat areas of the upper watershed to determine what vegetation can be successfully established before spending a considerable amount of resources on revegetation treatments. Include areas where contour felling has occurred on steep slopes. Trials should include both seeding and transplanting of plant materials. Successful establishment of plantings involves managing sustainable moisture. If the roots of the plants or seedlings dry out, the plants will die. Any soil treatment that enhances moisture retention and reduces surface evaporation would be desirable (i.e. mulching after seeding or planting).

Seeding trials should be practical for the steep slopes that dominate the area and may include:

- Aerial seeding
- Hydro-seeding
- Hand broadcasting
- Hand held mechanical broadcaster
- Different types of tractor-mounted seeding equipment where practical
- Mulch treatments (for example, different depths of wood chips and hay mulch)
- Time of seeding (spring, summer, or fall)
- Diversity of native species

Transplanting trials should also be initiated. Because local plant materials are currently not available, we recommend planting commercially available plant materials from New Mexico or southern Colorado that are adapted to the same elevations of the canyon. The LLPMC can provide assistance locating adapted plant materials. Transplanting trials should include several species, containers of various depths (which determines rooting length), and time of planting (spring, fall, and winter). Generally, in the Southwest the very best performing treatments will be those that most efficiently utilize the limited water between rainfall events. Successful transplanting methodologies are generally very expensive, and are often used to establish seed source islands to improve diversity of an ecosystem. We have had great field transplanting success (80% or higher) by sub-irrigating shrubs grown in tall pots (30” deep containers) twice in the spring with a hydrated starch polymer. An example planting of this can be seen on a 6-mile highway

median planting of 2,000 plants on NM Highway 285 between Interstate 25 and the Lamy turnoff (Figure 2). The planting is in its 14th year.

Figure 2: This established shrub planting by the 12th year only received two irrigation treatment in the village of Eldorado, NM

MiSHS-Term Activities Continue Focus on Stabilization

- Initiate successful revegetation treatments from the trials beginning in the upper watershed where vegetation densities need to be improved to help armor the site enhancing slope stability.
- Continue the application of proven vegetation treatments focusing on north and east facing slopes that traditionally respond better to revegetation treatments because they receive less sunlight which reduces moisture stress. Also, focus on flat areas with shallow topsoil to protect it because these areas have a good chance of successful establishment as long as the topsoil remains in place.

Late Term Activities After Sufficient Stabilization Has Been Achieved

- Apply vegetation treatments to canyon floor including in the riparian zone
- Consider using water weirs at appropriate locations on inside turns (composed of rock or logs used to reduce velocity of flow) to encourage sedimentation to reduce bank erosion.
- Consider using long-stem narrow leaf cottonwoods, willows, alders, redosier dogwood, birch and other species to rebuild the riparian ecosystem.

Figure 3: Plants established using long-stem technology without irrigation and Rock Weirs* on the Rio Grande in Bernalillo, NM six years after planting (2012) .

*Rock Weirs installed by the Bureau of Reclamation, Albuquerque District Office

‘Windbreaker’ Big Sacaton Windstrip Project Estancia, New Mexico

The Natural Resources Conservation Service (NRCS) Los Lunas Plant Materials Center (LLPMC) was contacted by Lisa Dennisson, Soil Conservation Technician at the NRCS Estancia Field Office. A cooperator in their service area has been trying to solve the soil erosion conditions at his ranch by installing cross fencing and permanent water facilities as part of the conservation management system plan developed in cooperation with the NRCS and the East Torrance Soil and Water Conservation District (SWCD). To help prevent soil erosion during the windy season, the Estancia Field Office suggested installing a vegetative windbreak consisting of ‘Windbreaker’ big sacaton which can become established fairly quickly. ‘Windbreaker’ big sacaton is a variety adapted to many ecological types of locations in New Mexico and Arizona, and it has proven to be an excellent species for windbreaks.

The cooperator, Deveral Walters, owns a small ranch which is used to raise and train horses and is located just north of Estancia. This area of New Mexico is subject to high winds, especially during the windy season (March-June). Establishing a vegetative windbreak is part of the cooperators overall conservation management system plan which qualified this project for funding from the *Environmental Quality Incentives Program*.

The NRCS LLPMC agreed to grow the big sacaton transplants, and they were started from seed in March 2013 in the LLPMC greenhouse. They were ready for transplanting by the end of May, and on June 12, 2013 the NRCS LLPMC delivered 200 ‘Windbreaker’ big sacaton transplants to the cooperator. The transplants were installed within two days of delivery, and the planting consisted of two, 500-foot rows of transplants placed on 5-foot centers. The planting is being irrigated from an established drip system to provide adequate moisture to the transplants for optimum establishment and growth.

This planting will be monitored for growth and survival by the NRCS Estancia Field Office throughout the 2013 growing season.

Deveral Walters’ Ranch in Estancia, NM. A drip system was installed prior to the installation of the ‘Windbreaker’ big sacaton transplants on 6-12-2013

Deveral Walters' Ranch in Estancia, NM – July 2013 'Windbreaker' big sacaton transplants

Deveral Walters' Ranch in Estancia, NM-July 2013 'Windbreaker' big sacaton windstrip planting

Grand Canyon National Park

Introduction

In July 1990, the U.S. National Park Service (NPS) made an agreement with the USDA-NRCS Los Lunas Plant Materials Center (LLPMC) to collect, propagate, and increase native grasses, forbs, shrubs, and trees. This agreement states that the LLPMC will produce the plant materials for the purpose of revegetating disturbed areas and native landscaping projects in the Grand Canyon National Park (GCNP) which includes both the north and south rim areas of the park.

Accomplishments

In 2013 the LLPMC accomplished the following activities:

- Muttongrass – Grew plug transplants from the seed harvested at the LLPMC. These transplants were used to establish an additional 1.00 acre muttongrass production field.

  To improve the seed production of muttongrass, a split application of 100 lbs/acre of gypsum ($CaSO_4$) was applied in 2013. Calcium deficiency can suppress seed development, and the application of $CaSO_4$ may provide an increased harvest of muttongrass.

- Needleandthread – Grew plug transplants from the seed harvested at the LLPMC. These transplants were used to establish an additional 0.26 acre seed production field which increased the acreage from 0.33 acres to 0.59 acres.

- Indian ricegrass –Harvested seed from the 0.14 acre Indian ricegrass production field that was established in January 2012.

- Spike muhly – Grew plug transplants from the seed harvested from the seed production field at the LLPMC. These transplants were used to establish an additional 0.30 acre spike muhly seed production field which increased the acreage from 0.70 acres to 1.0 acres.

The following tables list the species currently established at the LLPMC, the amount of seed produced in 2013, and the amount of pure live seed (PLS) on inventory for the GCNP:

2013 Grand Canyon National Park Seed Production Fields			
Common Name	Scientific Name	**Agreement Acreage**	**2013 Acreage**
blue grama	*Bouteloua gracilis*	2.00	2.60
bottlebrush squirreltail	*Elymus elymoides*	0.50	0.00*
Indian ricegrass	*Achnatherum hymenoides*	0.50	0.14
muttongrass	*Poa fendleriana*	1.00	2.13
needleandthread	*Hesperostipa comata*	0.50	0.59
sideoats grama	*Bouteloua curtipendula*	0.50	0.00*
spike muhly	*Muhlenbergia wrightii*	0.50	1.00

* The bottlebrush squirreltail and sideoats grama fields were removed prior to 2011 as per agreement with GCNP.

2013 Amount of Seed Produced for the Grand Canyon National Park		
Common Name	**Scientific Name**	**Pounds Cleaned (Bulk)**
blue grama	*Bouteloua gracilis*	50.7
Indian ricegrass	*Achnatherum hymenoides*	0.88
muttongrass	*Poa fendleriana*	9.2
needleandthread	*Hesperostipa comata*	9.0
spike muhly	*Muhlenbergia wrightii*	2.1

Grand Canyon National Park Pure Live Seed (PLS) on Inventory in 2013				
Common Name	**Scientific Name**	**Accession**	**PLS (lbs.)**	**Test Date**
blue grama	*Bouteloua gracilis*	9062875	2.07 14.96 4.23 28.93	11/17/2009 12/6/2010 11/17/2011 2/13/2013
blue grama	*Bouteloua gracilis*	9066803	8.43 4.38 23.66	1/28/2011 12/15/2011 2/13/2013
muttongrass	*Poa fendleriana*	9062861	2.00 0.14 74.71	9/17/2010 3/13/2012 12/20/2012
needleandthread	*Hesperostipa comata*	9066655	3.97	3/28/2013
sideoats grama	*Bouteloua curtipendula*	9066732	0.50	12/04/09
Spike muhly	*Muhlenbergia wrightii*	9066802	9.31 12.29 0.40	1/25/2011 1/24/2012 1/29/2013

Technology Development

Indian ricegrass – Due to the high rate of dormant seed commonly associated with Indian ricegrass, especially in the first year after harvest, and the limited amount of the seed the LLPMC received from GCNP, plant establishment in the Indian ricegrass field was very low. This required an increase in maintenance for this seed production field since seeding occurred in 2012 (see the following photograph). The low stand percentage in the production field meant extra herbicide applications and increased weeding throughout the growing season. Spot spraying of herbicide and hand weeding and cultivation was needed, on average, every two weeks during the 2013 growing season. The treatments for this field were possibly close to twice as much as needed for a normal, fully-established seed production field at the LLPMC.

Grand Canyon National Park Indian ricegrass seed production field 14

Muttongrass – As previously stated in prior Grand Canyon National Park reports, the LLPMC has evaluated new techniques to increase seed production for muttongrass. Increased irrigation and the addition of gypsum fertilizer to the muttongrass field did increase the seed production, but it has also increased the cost of growing this species. The muttongrass from GCNP does not perform well on the soils at the LLPMC, and the life span for seed production is, at best, three years. After that, seed production decreases dramatically and the mortality rate is very high. This requires continued evaluation of the need to re-establish new fields of the muttongrass to meet the acreage stated in the GCNP agreement. This also increases the cost for production of this species.

Grand Canyon National Park muttongrass seed production field 33N

Grand Canyon National Park muttongrass newly established 1.0 acre seed production field 37S

Grand Canyon National Park needleandthread seed production field 24N

Grand Canyon National Park spike muhly seed production field 21S

Grand Canyon National Park spike muhly newly-established seed production field 21S

Zion National Park

Introduction

In June 2009, an agreement was made between the USDA-NRCS Los Lunas Plant Materials Center (LLPMC) and Zion National Park (ZNP) to propagate 800 pure live seed (PLS) pounds of bottlebrush squirreltail (*Elymus elymoides*) and 200 PLS/lbs. of Indian ricegrass (*Achnatherum hymenoides*).

The agreement states that ZNP will use this seed to revegetate disturbed areas in the park. The seed of these two species was collected by the park staff and sent to the LLPMC for conditioning. After conditioning, the seed was used to establish seed production fields according to the agreement.

Accomplishments

We used a new technique to harvest the ZNP bottlebrush squirreltail in 2013; a Trac-Vac harvester was modified so it could be attached to a tractor (see the following photograph). This allowed us to harvest a greater amount of seed from the production field than in previous years. By using the Trac-Vac harvester, the amount of bulk material harvested doubled, and the amount of cleaned seed weight almost tripled compared to using a flail-vac harvester or combine harvesting methods in 2012.

Harvesting ZNP bottlebrush squirreltail with a Trac-Vac harvester attached to a tractor

See the following tables for the established species at the LLPMC, the amount of seed produced in 2013, and the amount of pure live seed on inventory for ZNP:

2013 Zion National Park Seed Production Fields			
Common Name	**Scientific Name**	**Agreement Acreage**	**2013Acreage**
bottlebrush squirreltail	*Elymus elymoides*	1.50	1.00
Indian ricegrass	*Achnatherum hymenoides*	0.50	0.42*

* Only 0.42 acres of Indian ricegrass was established due to the amount of seed originally received from ZNP.

2013 Amount of Seed Produced for Zion National Park		
Common name	**Scientific name**	**Pounds Cleaned (Bulk)**
bottlebrush squirreltail	*Elymus elymoides*	210.00
Indian ricegrass	*Achnatherum hymenoides*	32.5

Zion National Park Pure Live Seed (PLS) on Inventory in 2013				
Common Name	**Scientific name**	**Accession**	**Pure Live Seed on Inventory (lbs)**	**Test Date**
bottlebrush squirreltail	*Elymus elymoides*	9066532	2.65 13.74 0.47 14.35 12.54 13.83 45.90	8/20/09 9/17/10 8/27/07 8/06/05 8//08/11 8/08/11 1/17/13
cane bluestem	*Bothriochloa barbinodis*	9066543	0.60 (bulk) 1.36 2.19 1.58 0.20 (bulk)	No test[2] 1/21/05 1/17/06 3/09/07 No test[4]
galleta	*Pleuraphis jamesii*	9066586	1.51 0.58 (bulk) 0.46 (bulk)	1/08/07 No test[4] No test[4]
Indian ricegrass	*Achnatherum hymenoides*	9066528	15.48 44.12 26.57 33.06 22.74 27.87 49.97	10/16/06 4/28/08 10/31/08 11/11/09 12/14/10 11/30/11 2/19/13
muttongrass	*Poa fendleriana*	9066531	4.55 0.70 1.84 (bulk)	5/30/08 11/20/08 No test[4]

[2] Seed was not sent for testing due to an insufficient amount of seed or seed was from the collections made at the ZNP.

Zion National Park Pure Live Seed (PLS) on Inventory in 2013				
Common Name	**Scientific name**	**Accession**	**Pure Live Seed on Inventory (lbs)**	**Test Date**
sand bluestem	*Andropogon halii*	9066529	2.73 (bulk)	No test[4]
			2.80	3/20/06
			8.89	3/21/07
			3.26	6/14/10
			9.84	7/07/10
			19.48	4/19/10

Zion National Park bottlebrush squirreltail seed production field 19

This agreement expired in 2013. The LLPMC has removed the seed production fields of bottlebrush squirreltail and Indian ricegrass. The ZNP seed (see the previous table) will be stored at the LLPMC until the Park submits a request for seed.

Carlsbad Caverns National Park

Introduction

On August 23, 2004, an agreement was made between the USDA-NRCS Los Lunas Plant Materials Center (LLPMC) and the Carlsbad Caverns National Park (CCNP) for the collection, propagation, and the increase of native grass species. A new agreement began in 2010 that provides for the propagation of transplants and seed increase by the LLPMC for CCNP native grass species.

Accomplishments

The following table lists the CCNP pure live seed (PLS) on inventory at the LLPMC:

Carlsbad Caverns National Park PLS on Inventory in 2013				
Common Name	**Scientific Name**	**Accession**	**Pure Live Seed on Inventory (lbs.)**	**Test Date**
blue grama	*Bouteloua gracilis*	9066604	13.85	1/24/07
			8.12	1/09/08
			2.79	6/17/10
			2.59	12/01/09
			8.60	12/15/11
green sprangletop	*Leptochloa dubia*	9066658	27.40	1/25/11
			14.38	12/07/11
plains bristlegrass	*Setaria vulpiseta*	9066606	17.37	5/15/08
			71.99	7/13/10
			24.04	2/12/10
			14.53	12/08/10
			46.03	1/03/12
purple threeawn	*Aristida purpurea*	9066607	7.90	4/23/08
			3.04	6/11/10
			0.54	5/18/10
			3.36	1/06/12
sideoats grama	*Bouteloua curtipendula*	9066605	41.29	1/19/06
			36.34	1/23/07
			17.14	3/10/08
			40.08	6/29/10
			13.54	12/23/09
			9.72	1/25/11
			0.74	1/03/12
			3.00 (bulk)	No test[3]
			1.02 (bulk)	No test[5]
			0.40 (bulk)	No test[5]

This agreement expired in 2012. Any CCNP seed (see the previous table) will be stored at the LLPMC until the Park submits a request for the seed.

[3] Seed not sent for testing due to an insufficient amount of seed or seed was from the collections made at the CCNP.

Glen Canyon National Recreation Area

Introduction

In 2013, an agreement was made between the US Department of Interior National Park Service (NPS) Glen Canyon National Recreation Area (GCNRA) and the USDA-NRCS Los Lunas Plant Materials Center (LLPMC) for the collection of native seed, the propagation of those seeds, and the increase of native grass, shrub and tree species at the LLPMC.

The agreement states that NPS will use the seed and transplants produced by the LLPMC for identified project areas at GCNRA. Populations of native grass, shrub and tree species will be identified by the park staff, and seed of the identified species will then be sent to the LLPMC. These collections will then be conditioned and used by the LLPMC in seed increase plantings or transplant production.

The following tables list the species specified in this agreement and the amount of seed received by the LLPMC from the GCNRA in 2012:

Glen Canyon National Recreation Area Accessions and Amount of Seed Received at the LLPMC				
Common Name	**Scientific Name**	**Plant Symbol**	**Accession Number**	**Amount Received**
Grasses				
purple threeawn	*Aristida purpurea*	ARPU9	9067016	4.86 grams
Shrubs and Trees				
arrowweed	*Pluchea sericea*	PLSE	9067027	18.2 grams
broom snakeweed	*Gutierrezia sarothrae*	GUSA2	9067023	16.8 grams
buckwheat	*Eriogonum corymbosum*	ERCO14	9067021	17.6 grams
fourwing saltbush	*Artiplex canescens*	ATCA2	9067020	96.3 grams
Fremont cottonwood	*Populus fremonti*	POFR2	9067025	not weighed
Goodding's willow	*Salix gooddingii*	SAGO	9067026	not weighed
Rabbitbrush *	*Ericameria spp.*	ER spp.	9067024	16.4 grams
seepwillow	*Baccharis spp.*	BA spp.	9067022	5.18 grams
shadscale	*Atriplex confertifolia*	ATCO	9067019	274 grams

* The rabbitbrush seed appeared to contain four different species. One of the species appeared to be *ericameria nauseousa* and another one appeared to be *Isocoma*. The other two species could not be identified by seed alone.

The following table lists the amount of seed sent to the LLPMC for *cleaning purposes* only:

Glen Canyon National Recreation Area Seed Received (*for cleaning and storage purposes only*)			
Common Name	**Scientific Name**	**Plant Symbol**	**Amount Received for Cleaning & Storage**
Grasses			
galleta	*Pleuraphis jamesii*	PLJA	0.76 grams
Trees, Shrubs, Forbs			
wirelettuce (A) small seed	*Stephanomeria spp.*	ST spp.	17.1 grams
wirelettuce (B) large seed	*Stephanomeria spp.*	ST spp.	3.8 grams

Accomplishments

The following tables list the GCNRA agreement acreage, the amount of the currently established seed production fields, and the amount of seed produced in 2013:

2013 GCNRA Seed Production Fields			
Common Name	**Agreement Acreage**	**2013 Acreage**	**Pounds Cleaned (Bulk)**
purple threeawn	0.25	0.10	0.96

Transplant Production

- Goodding's willow (*Salix gooddingii*) and seepwillow (*Baccharis spp)* – It is anticipated that cuttings can be made from LLPMC stock during the winter to produce the 40 plants needed to meet the amount stated in the agreement.
- Purple threeawn – Plug transplants were grown from the seed received from GCNRA. These transplants were used to establish a 0.10 acre seed production field at the LLPMC. In 2013, seed was harvested from the purple threeawn production field. The seed produced in 2013 will be used to increase the production field acreage in 2014.
- Rabbitbrush – The rabbitbrush seed appeared to contain at least four different species. One appeared to be *Ericameria nauseousa* and another appeared to be *Isocoma*. The other two species could not be identified from the seed alone.
- Shadscale – All of the seed was planted in spring of 2013 at a rate of ½ cup of seed per plug tray. Under greenhouse conditions, the seed did not germinate. As a result, the plug trays were placed in cold stratification for 12 weeks to help induce germination. A small amount of plants did germinate (10 plants per tray) after the cold stratification. Rodent predation was noticed in the germinated plants, and as a result, the plug trays were covered. However, there was not any new germination after the rodent damage. This seedlot appeared to have low viability, and because of this, additional collections may be required to meet the amount specified in the agreement.

The following table lists the GCNRA amount of transplant production in 2013:

2013 Amount of Transplants Produced for GCNRA			
Common Name	**Scientific Name**	**Agreement Request**	**Number of Transplants**
arrowweed*	*Pluchea sericea*	0	130
buckwheat	*Eriogonum corymbosum*	750	800
fourwing saltbush	*Atriplex canescens*	1,000	1,750
Fremont cottonwood	*Populus fremonti*	50	45
Goodding's willow	*Salix gooddingii*	100	60
rabbitbrush	*Ericameria spp.*	750	1,150
seepwillow	*Baccharis spp.*	50	230
snakeweed	*Gutierrezia sarothrea*	500	1,050

* The arroweed (*Pluchea sericea)* was started in the spring of 2013 due to the uncertainty of being able to meet the *salix* and *populus* agreement amounts.

Glen Canyon National Recreation Area purple threeawn seed production field 21S

Southeast Utah Group
Arches and Canyonlands National Parks

On, August 27, 2010, an agreement was made between the US Department of Interior National Park Service (NPS) Southeast Utah Group (Arches and Canyonlands National Parks) and the USDA-NRCS Los Lunas Plant Materials Center (LLPMC) for the collection of native seed, the propagation of those seeds, and the increase of native grass species at the LLPMC.

The agreement states that NPS will use the seed produced by the LLPMC for identified project areas in the two national parks. Populations of Indian ricegrass (*Achnatherum hymenoides*) were identified and collected by the Park staff and sent to the LLPMC for conditioning and for future seed production. The following tables show a complete list of the accessions specified in this agreement and the seed received by the LLPMC:

Southeast Utah Accessions Grown at the LLPMC				
Common Name	**Park Location**	**Scientific Name**	**Plant Symbol**	**Accession Number**
Arches National Park Accessions				
Indian ricegrass		*Achnatherum hymenoides*	ACHY	9066888
Canyonlands National Park Accessions				
Common Name	**Park Location**	**Scientific Name**	**Plant Symbol**	**Accession Number**
Indian ricegrass	Island in the Sky	*Achnatherum hymenoides*	ACHY	9066907
Indian ricegrass	Needles	*Achnatherum hymenoides*	ACHY	9066908
Indian ricegrass	Island in the Sky and Needles mix	*Achnatherum hymenoides*	ACHY	9066887

Accomplishments

The following table lists the amount of acreage specified in the agreement, the amount of acreage in 2013, and the amount of seed produced in 2013:

2013 Southeast Utah Seed Production Fields				
Arches National Park				
Common Name	**Park Location**	**Scientific Name**	**Agreement Acreage**	**2013 Acreage**
Indian ricegrass		*Achnatherum hymenoides*	1.00	0.50
Canyonlands National Park				
Common Name	**Park Location**	**Scientific Name**	**Agreement Acreage**	**2013 Acreage**
Indian ricegrass	Island in the Sky	*Achnatherum hymenoides*	0.50	0.26
Indian ricegrass	Needles	*Achnatherum hymenoides*	0.50	0.09

2013 Seed Received from Southeast Utah				
Arches National Park				
Common Name	**Park Location**	**Scientific Name**	**Harvest Year**	**Pounds Cleaned (Bulk)**
Indian ricegrass		*Achnatherum hymenoides*	2010	0.20
Indian ricegrass		*Achnatherum hymenoides*	2013	1.28
Canyonlands National Park				
Indian ricegrass	Island in the Sky	*Achnatherum hymenoides*	2013	0.90
Indian ricegrass	Needles	*Achnatherum hymenoides*	2010	0.10
Indian ricegrass	Needles	*Achnatherum hymenoides*	2012	0.38

Indian ricegrass	Needles	*Achnatherum hymenoides*	2013	0.30
2013 Southeast Utah Seed Production				
Arches National Park				
Common Name	**Park Location**	**Scientific Name**	**Pounds Cleaned (bulk)**	
Indian ricegrass		*Achnatherum hymenoides*	No harvest	
Canyonlands National Park				
Common Name	**Park Location**	**Scientific Name**	**Pounds Cleaned (bulk)**	
Indian ricegrass	Island in the Sky	*Achnatherum hymenoides*	10.4	
Indian ricegrass	Needles	*Achnatherum hymenoides*	3.9	

As a result of a discussion with the Southeast Utah Group in 2013, 0.50 acres of the Arches National Park Indian ricegrass in field 26N at the LLPMC was removed. This field was destroyed after the presence of an unknown Indian ricegrass established itself in the seed production field. The seed harvested in 2013 from Field 27N and 26N were harvested together causing all seed to be contaminated from Arches National Park.

Due to the high amount of dormant seed (commonly associated with Indian ricegrass, especially in the first year after harvest and the limited amount of the seed received from Arches and Canyonlands) plant establishment in the Indian ricegrass fields was low. This caused an increase in maintenance of the seed production fields, especially during the growing season.

The LLPMC will have germination tests done in 2014 on the Indian ricegrass seed received in 2013 from both parks and from the seeded harvested at the LLPMC. Depending upon the results of the germination tests, the LLPMC will decide how to increase the remaining acreage state in the agreement for both parks, either by producing transplants or by direct seeding.

The low percentage of stand in the production fields required extra herbicide applications and increased weeding throughout the growing season. Spot spraying with herbicide, hanSHS-weeding, and cultivation was performed on an average of every two weeks in 2013. The extra treatments for these fields required approximately two times the amount needed for a normal, fully-established seed production field. Low percentages of germination and small amounts of seed from the wild collections can lead to extra resources to produce the amount of seed needed to fulfill agreement requirements.

In 2014, the LLPMC will have germination tests performed on the Indian ricegrass seed that was received in 2013 from Arches and Canyonlands along with the seed harvested at the LLPMC in 2013. Depending on the results of the germination tests, the LLPMC will decide how to establish the remaining acreage of the Indian ricegrass field, either by growing transplants in the greenhouse or by direct seeding.

Canyonlands National Park 'Island in the Sky' Indian ricegrass seed production field 24N

Canyonlands National Park 'Needles' Indian ricegrass seed production field F33N

Arches National Park Indian ricegrass seed production field F27N

Active Field Studies

Propagation of Autumn Amber

Study Number: NMPMC-P-9803-UR

Evaluation of propagation techniques will be performed in 2013 as required.

2013 Treatment and Harvest

Action - Field 26S	2013 Date
Irrigation 3" application	3/26, 6/13

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated for optimum growth in 2014.

Hope Desert Willow Stock Plant Production

Study Number: NMPMC-P-0102-UR

2013 Treatment and Harvest

Action - Field 26S	2013 Date
Irrigation 3" application	3/21, 4/9, 5/2, 5/23, 6/11, 8/27, 10/23

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated for optimum growth in 2014.

Regal Desert Willow Stock Plant Production

Study Number: NMPMC-P-0101-UR

2013 Treatment and Harvest

Action - Field 26S	2013 Date
Irrigation 3" application	3/21, 4/9, 5/2, 5/23, 6/11, 8/27, 10/23

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated and fertilized in 2014 for optimum growth of planting.

Species from Four Corners Region

Study Number: NMPMC-P-9505-CR

The plantings of different shrub species collected in the Four Corners region of New Mexico continue to be grown for possible plant material release in the future. The desert needlegrass and bluebunch wheatgrass collections that were part of these original collections have been placed into seed increase for a possible plant release in cooperation with the Bureau of Land Management. Evaluations will be completed as needed on the remaining collections of this study.

2013 Treatment and Harvest

Action - Field 35N	2013 Date
Irrigation 3" application	3/27, 4/19, 6/4, 8/15, 11/12, 11/19

Weed control was performed throughout the growing season to keep the fields clean and promote vigorous growth of the plantings. Field will be irrigated and fertilized in 2014 for optimum growth.

Mexican Whitesage

Study Number: NMPMC-9801-WL

This Mexican Whitesage collection is being evaluated for its potential as a conservation plant release. No evaluations were completed in 2013.

2013Treatment and Harvest

Action - Field 26N	2013 Date
Irrigation 3" application	None

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. No seed was harvested in 2013. Seed harvest will be attempted in 2014. The field will be irrigated and fertilized in 2014 for optimum growth of planting.

Single Leaf Ash and Fragrant Ash

Study Number: NMPMC-P-9804-UR

Evaluation of these accessions of ash will continue in 2014 for possible conservation plant materials release.

2013 Treatment and Harvest

Action - Field 26S	2013 Date
Irrigation 3" application	3/21, 4/9, 5/2, 5/23, 6/11, 8/27, 10/23

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated and fertilized in 2013 for optimum growth of the planting.

Mesa Dropseed Initial Evaluation Planting

Study Number: NMPMC-P-0702-RA

In 2006, 18 collections of the warm-season, native bunchgrass mesa dropseed, (*Sporobolus flexuosus*), were made in the LLPMC service area for inclusion into an initial evaluation study. These collections will start the evaluation process to produce a conservation plant release of mesa dropseed.

In 2007, seed from each of these collections was used to start transplants in the greenhouse. The transplants were planted into replicated plots in field 31S on 8/21/2008. The replicated initial evaluation planting will be evaluated annually to provide data for a possible conservation plant material release from the LLPMC of mesa dropseed.

2013 Treatment and Harvest

Action - Field 31S	2013 Date
Irrigation 3" application	3/15, 5/3, 5/29, 6/19, 8/8, 9/5
Herbicide	3/12

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. Field will be irrigated and fertilized in 2014 for optimum growth of planting.

CSU-10/Paloma Indian Ricegrass Comparison Trial

Study Number: NMPMC-P-0903-RA

On 10/27/2009 transplants of two accessions of Indian ricegrass, 9065428 (CSU-10) and 'Paloma' were transplanted into Field 23N. The planting consists of two 38-inch spaced rows with groups of 10 plants of the 'Paloma' and 'CSU-10,' randomly located in the rows. The 10 plants in each group are spaced at one-foot interval with a two-foot spacing between each group.

We will be evaluating the forage and seed production of 'CSU-10' against 'Paloma' to determine the possibility of a future plant material release of CSU-10.

2013 Treatment and Harvest

Action - Field 31S	2013 Date
Irrigation 3" application	3/11, 4/9, 4/26, 5/21, 6/13, 8/26, 10/21
Herbicide	3/12
Fertilization	
40 lbs. Nitrogen	5/13, 9/24
40 lbs. Phosphorous	5/13, 9/24
Herbicide application	3/7

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated and fertilized in 2014 for optimum growth of planting.

BLM Seed Increase Production Fields

Study Number: NMPMC-S-1101-RA

In 2013, seed of certain native species was collected from the Colorado Plateau and sent to the LLPMC for processing and planting in seed increase production fields.

2013 Treatment and Harvest

Action – Field 23N- Smallflower globemallow	2013 Date
Irrigation 3" application	3/11, 4/9, 4/26, 5/21, 6/13, 8/26, 10/21
Fertilization	
40 lbs. Nitrogen	5/13, 9/24
40 lbs. Phosphorous	5/13, 9/24
Herbicide application	3/7

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated and fertilized in 2014 for optimum growth of planting.

Big Sacaton (*Sporobolus wrightii*)

Study Number: NMPMC-P-8401-CP

Big sacaton is a native, robust, perennial warm-season bunchgrass. It is found throughout the southwestern United States, usually occurring on low alluvial flats and flood plains. It is useful forage for livestock and wildlife. Under irrigation, big sacaton may reach heights exceeding 3 m. The mature plants range in height from 1–4 m. Based upon its density and height, it has the potential as a windbreak plant for irrigated cropland.

Seed collections of big sacaton were taken from 37 locations throughout New Mexico. These collections were used to establish non-replicated, accession rows that consisted of 520 plants in a field at the Los Lunas Plant Materials Center. Based on a visual evaluation of vigor and height, ten superior plants were selected. Each selected superior plant came from a separate accession to maintain a diverse population. From these ten plants, one super selection was made. A hybrid, cross-planting was established as an attempt to improve the height of the progeny.

In 1992, colonal shoots of each selected plant were planted into a hybrid, seeSHS-production block with the super plant as the male pollinator. In 1995, seed was hanSHS-harvested from each female parent. In 1996, this seed was used to establish an evaluation planting that contained both parents and progeny. The progeny were derived from seed, and the parents were vegetatively propagated. Both sets of plants were grown in 6-inch square pots for eight months in an attempt to equalize carbohydrate reserves in the seed derived plants and the clones. The planting design was an 8-replicated, split-plot, randomized block design. Each replication consists of 20 plants spaced on 10-ft. centers. A plot consists of a parent and the progeny plant.

The planting is mowed in the winter to remove plant liter from the previous year. By the end of the third growing season, the leaf blades of most plants had approached 3 m in height. When the plants are flowering they may approach 4 m.

In August 2002, the planting was evaluated for leaf height, basal width, and appearance. A separate, paired, T-test statistical analysis was performed on each replication comparing the height of each parent to its progeny. The progeny and parent plants were not significantly different in height (alpha .05). However, there appears to be a difference in leaf blade width, color, and uprightness between the parents and progeny plants. The cloned parent plants remain identical to their source where the progeny plants seem to have random variation.

The August 2002 colonal big sacaton planting was removed in 2009. See previous *LLPMC Annual Technical Reports* for information on study NMPMC-P-8401-CP.

2013 Treatment and Harvest

Action – Field 13N – Parent Lines	Field 26N Parent Lines	Date
No Action	Irrigation – 3” Application	5/3

Weed control was performed throughout the growing season. These fields will be irrigated in 2014. These fields will be fertilized and irrigated for optimum growth of planting in 2014.

Little Bluestem Polycross Increase Block and Advanced Evaluation

Study Number: NMPMC-P-0604-RA

Little bluestem is a native, warm-season bunch grass and is recognized as an important species for revegetation seeding in its area of adaptation. The LLPMC has released the variety 'Pastura' little bluestem, and it has been used extensively in revegetation efforts throughout the LLPMC service area. There are several little bluestem varieties that have been developed by the Natural Resources Conservation Service (NRCS) Plant Materials Program that are currently available through commercial seed sources.

Background

1990 –1991 – A re-collection of little bluestem accessions from the LLPMC service was completed in an attempt to find an improved selection of little bluestem that may out-perform 'Pastura.' These accessions were grown in the LLPMC greenhouse and transplanted to an initial evaluation planting in 1991. After extensive evaluation of these accessions by the LLPMC, five collections were identified that appeared to have better attributes when compared to the 'Pastura' release.

2006 – On March 8, 2006, culms of these five accessions were dug from the parent plants and placed into containers to produce new transplant material. All transplants were then planted into a replicated, polycross block in Field 28S on August 2, 2006. Several of these transplants did not survive the initial container planting, and new plants were grown in 2007 to complete the polycross block.

2007 – On May 1, 2007 additional culms were taken of the five accessions and placed into transplant containers. On August 22, 2007, these transplants were planted into the polycross block in Field 28S. All the transplants did not survive until the August date, and additional transplants were produced in to complete the polycross planting.

2008 – On April 25, 2008 more culms of the five accessions of little bluestem were dug from the initial evaluation planting in Field 6 and placed into transplant containers. On August 7, 2008 these transplants were then planted into the crossing block in Field 28S. All of the transplants of 2008 survived completing the planting of the little bluestem polycross block.

2013 – We will continue to harvest seed from the polycross block, and we will continue to develop a plant release for this species.

2013 Treatment and Harvest

Action – Field 28S	2013 Date
Fertilizer	
40 pounds Nitrogen	63, 7/23
40 pounds Phosphorous	2/7, 5/6, 6/3
Irrigation 3" application	3/13, 5/7, 6/4, 6/21, 7/10
Herbicide application	3/7, 5/7, 5/30
Insecticide application	7/16, 8/5, 8/30
Harvest seed	No harvest in 2013

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting. The field will be irrigated and fertilized for optimum growth in 2014.

Tobosa Polycross Increase Block

Study Number: NMPMC-P-0602-RA

Tobosagrass (*Pleuraphis mutica* Buckley) is an important, warm-season, bunchgrass that grows in the Los Lunas Plant Materials Center's (LLPMC) service area. There has been a high-priority need to develop an improved selection of tobosagrass, and to provide this selection to commercial seed sources. Since the initial evaluation collections were done in the late 1970s, the LLPMC has been in the process of selecting a plant material release of this species. This species of bunchgrass is in high-demand for seeding efforts in the low rainfall, southern desert areas of the LLPMC service area.

2006 – In 2006, culms were taken from six accessions in the initial evaluation planting (IEP) in Field 6 at the LLPMC, which were identified as having the potential for a plant material release. The vegetative material was used to start transplants for inclusion in a polycross block to be established in Field 28S at the LLPMC.

The transplants of the six accessions were planted into Field 28S on August 2, 2006. Several of the transplants from the six accessions had died prior to the August planting, and this required new plants to be harvested in 2007 to complete the polycross block.

2007 – On May 1, 2007, culms were taken again from the IEP in Field 6 and potted in containers to grow transplants for the polycross block in Field 28S. On August 22, 2007, the transplants were planted in the polycross block in Field 28S. Several transplants had died prior to this planting, and as a result, new culms had to be dug and transplanted in 2008 to complete the polycross block.

2008 – On April 25, 2008, culms were taken again from the IEP in Field 6 and potted in containers to grow transplants for the polycross block in Field 28S. On August 8, 2008, the transplants were planted in the polycross block in Field 28S. All of the transplants survived, and the tobosograss polycross block was complete.

2013 – We will continue to harvest seed from the polycross block, and we will continue to develop a plant release for this species.

2013 Treatment and Harvest

Action – Field 28S	2012 Date
Fertilizer 40 pounds Nitrogen 40 pounds Phosphorous	 6/3, 7/23 2/7, 5/6, 6/3
Irrigation 3" application	3/13, 5/7, 6/4, 6/21, 7/10
Herbicide	3/7, 5/7, 5/30
Pesticide application	7/16, 8/5, 8/30
Harvest seed	No harvest in 2013

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

2013 Annual Seed Production Report

Project Number/Name	Field #	Acres	Planting Date	Fertilizer Applications	Irrigation Dates (3" Application)	Harvest Date	Harvest (Cleaned Wt. lbs.)
NMPMC-S-1101-RA BLM Seed for Success Project coneflower	8 23S	0.50 0.30	9/26/2011 2010	40 lbs/ac N 3/22, 5/13, 7/23, 11/18 40 lbs/ac P 3/22, 5/13, 7/23 40 lbs/ac N 3/22, 5/13 40 lbs/ac P 3/22, 513	3/27, 4/22, 5/17, 6/13, 7/3 3/26, 4/18, 5/6, 5/23, 6/13, 7/8, 8/16, 9/4	10/23 10/21	135.00 24.40
NMPMC-S-0901-CP Windbreaker SPWR seed Increase	8 14	0.85 0.40	8/2009	40lbs/ac N 6/3, 11/18 40 lbs/ac P 5/6, 6/3 40 lbs/ac N 5/7, 6/3, 11/18 40 lbs/ac P 6/3	3/27, 5/9, 6/5, 6/25 3/18, 5/10, 6/5, 6/25, 10/10	9/24 9/24	
NMPMC-S-0302-RA **Salado** alkali sacaton Foundation seed field	11	1.0	2003	40 lbs/ac N 5/22 40 lbs/ac P 5/22	4/22, 5/23, 6/18, 9/5	8/1	4.6
NMPMC-S-0402-RI **Westwater germplasm**a Alkali muhly Foundation seed field	11	1.0	2004	40 lbs/ac N 5/22 40 lbs/ac P 5/22	3/29, 5/10, 6/4, 6/28, 7/3		
NMPMC-00701-OT 906609 Boulder County, CO little bluestem seed production	14	0.48	8/16/2011	40 lbs/ac N 5/7, 6/3, 10/18 40 lbs/ac P 6/3, 10/18	3/13, 5/9, 5/29, 6/24, 7/10, 9/18, 10/3	9/17	0.88
NMPMC-0701-OT 9066910 Boulder County, CO prairie dropseed seed production	14	0.48	8/17/2011	40 lbs/ac N 5/22, 7/23, 10/18 40 lbs/ac P 5/22, 7/23, 10/18	3/12, 4/30, 5/22, 6/13, 7/3, 9/5, 9/17, 9/30, 10/8	8/19	2.4
NMPMC-S-0703-PA **Grenville** switchgrass seed production	14	0.14	2007	40 lbs/ac N 5/7, 6/3, 11/18 40 lbs/ac P 6/3	3/18, 5/10, 6/5, 6/25, 10/10		
NMPMC-S-0503-RI 9066589 Composite vine mesquite seed increase field	14	1.0	2005	40 lbs/ac N 11/18	5/3, 6/11, 10/16		
NMPMC-S-7801-RA **Hachita** blue grama	16	2.0	1978	40 lbs/ac N 5/22	5/2, 5/25, 6/25	10/15	27.5

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Foundation seed field							
NMPMC-S-0801-PA **Jose** tall wheatgrass foundation seed production	18	1.0	2008	40 lbs/ac N 3/22, 4/23, 5/22, 11/18 40 lbs/ac P 3/22, 4/23, 5/13, 5/22	3/28, 4/26, 5/23, 6/17, 10/10		
NMPMC-S-0402-RA **Vaughn** sideoats grama Foundation seed field	19	1.20	7/22-28/2004	40 lbs/ac N 6/5, 11/18	3/29, 5/2, 6/7, 7/3	9/9	
NMPMC-S-0401-RA **Pastura** little bluestem Foundation seed field	19	0.86	2004	40 lbs/ac N 5/7, 6/5, 11/18	3/29, 5/10, 6/11, 7/10		
NMPMC-S-0301-RA **Viva** galleta Foundation seed field	19	2.4	2003	40 lbs/ac N 6/5, 11/18	4/4, 6/7, 6/26	8/9	8.4
NMPMC-S-1001-WO 9062861 Grand Canyon NP muttongrass seed production	28S	1.00	2010	40 lbs/ac N 2/7, 3/20 40 lbs/ac P 2/7, 3/20 50 lbs/ac GYP 4/4	3/6, 3/21, 4/9, 4/26		
	35S	0.50	2010	40 lbs/ac N 2/7, 5/13 40 lbs/ac P 5/13 40 lbs/ac GYP 1/10, 4/4, 5/13	3/11, 4/9, 4/26, 5/22, 6/13, 6/24, 7/1	6/9	
	33N	0.50	2011	40 lbs/ac N 2/7, 3/20, 5/13, 9/24 40 lbs/ac P 3/20, 5/13, 9/24 50 lbs/ac GYP 1/10, 3/13, 4/4, 9/24 40 lbs/ac N 5/13, 7/23, 9/24 40 lbs/ac P 5/13, 7/23, 9/24 50 lbs/ac GYP 5/13	1/8, 3/4, 3/21, 4/9, 4/26, /5/17, 5/29, 6/11, 6/24, 7/10, 7/31, 8/15, 8/30, 9/4, 10/3 1/7, 3/1, 3/20, 4/4, 4/26, 5/13, 5/29, 6/11, 6/24, 7/8, 8/15, 8/30, 9/4, 10/3, 10/23	5/9	9.2
	21S	0.12	2012		1/17, 3/1, 3/20, 4/9, 4/26, 5/17, 5/30, 6/11, 6/24, 7/10, 8/15, 8/30, 9/4, 10/3, 11/12		

Project Number/Name	Field #	Acres	Planting Date	Fertilizer Applications	Irrigation Dates (3" Application)	Harvest Date	Harvest (Cleaned Wt. lbs.)
	24S 37S	0.50 1.00	2012 2013	40 lbs/ac N 5/13, 7/23, 9/24 40 lbs/ac P 5/13, 7/23, 9/24 50 lbs/ac GYP 4/4, 9/24 40 lbs/ac N 11/18	9/25, 9/30, 10/3, 10/10, 10/21, 11/12		
NMPMC-S-1101-RA 9062875 Grand Canyon NP blue grama seed production	20N 28S 18	0.76 0.50 0.75	2011 2006 2010	40 lbs/ac N 6/3, 10/17 40 lbs/ac P 5/6, 6/3, 10/17 40 lbs/ac GYP 6/3, 10/17 40 lbs/ac N 6/3, 7/23,10/17 40 lbs/ac P 2/7, 5/6, 6/3, 10/17 40 lbs/ac GYP 6/3, 10/17 40 lbs/ac N 5/7, 6/3, 10/18 40 lbs/ac P 6/3, 10/18 40 lbs/ac GYP 1/10, 6/3, 10/21	3/15, 5/9, 6/4, 6/21, 7/11 3/12, 5/9, 6/4, 6/21, 7/8, 9/5 3/27, 5/9, 6/4, 6/28, 9/9	10/1 9/27 9/26	46.9
NMPMC-S-0901-WO 9066802 Grand Canyon NP spike muhly seed production	20S	0.70	2009 2013	40 lbs/ac N 4/23, 10/21 40 lbs/ac P 2/7, 10/21 40 lbs/ac GYP 10/21 40 lbs/ac N 9/24, 10/21 40 lbs/ac P 9/24, 10/21	3/20, 4/4, 4/26, 5/21, 6/6, 6/19, 7/10, 9/4, 10/31 7/18, 7/23, 7/31, 8/9, 8/27, 9/4, 10/3, 10/21	10/18	2.1
NMPMC-S-9701-RA **Nogal** black grama Foundation seed field	21N	1.3	1997	40 lbs/ac N 6/3, 10/17 40 lbs/ac P 6/3, 10/17	5/7, 6/4, 6/27	10/9	8.7
NMPMC-S-0904-RA 9066803 Grand Canyon NP Blue grama seed production	21S	0.60	2009	40 lbs/ac N 6/3, 10/17 40 lbs/ac P 5/6, 6/3, 10/17 40 lbs/ac GYP 6/3, 10/21	3/11, 5/7, 6/4, 6/19, 7/12	10/7	3.8

Project Number/Name	Field #	Acres	Planting Date	Fertilizer Applications	Irrigation Dates (3" Application)	Harvest Date	Harvest (Cleaned Wt. lbs.)
Glen Canyon NRA 9067016 threeawn seed production	21S	0.10	2013	40 lbs/ac N 7/23, 9/24 40 lbs/ac P 9/24 50 lbs/ac GYP 9/24	5/28, 5/30, 6/4, 6/7, 6/11, 6/17, 6/21, 6/27, 7/8, 7/23, 8/9, 8/30, 10/23	10/2	5.0
NMPMC-S-1101-RA 9066885 BLM "Seeds for Success" species seed increase globemallow	23N 34S	0.06 0.54	2011 2012	 40 lbs/ac N 3/20, 9/24 40 lbs/ac P 9/24	3/15, 4/17, 5/6, 5/23, 6/13, 7/10 1/8, 3/4, 3/22, 4/22, 5/13, 5/29, 6/11, 6/24, 7/8, 8/26, 9/9, 10/8, 10/31	 6/20, 8/16, 10/28	 39.0
NMPMC-S-1101-RA 9066884 BLM Seeds for Success species seed increase primrose	34S	0.	2012	40 lbs/ac N 3/20, 9/24 40 lbs/ac P 9/24	1/8, 3/4, 3/22, 4/22, 5/13, 5/29, 6/11, 6/24, 7/8, 8/26, 9/9, 10/8, 10/31	8/21	4.5
NMPMC-S-0802-RA 9066330 Desert needlegrass seed production	23N	0.45	2008	40 lbs/ac N 5/13, 9/24 40 lbs/ac P 5/13, 9/24	3/11, 4/9, 4/26, 5/21, 6/13, 8/26, 10/21	5/28, 6/11	
NMPMC-S-1301-WO 9066888 Arches National Park Indian ricegrass seed production	26N 27N	0.45 0.50	2012 2012	40 lbs/ac N 4/23, 6/5 50 lbs/ac GYP 6/5 40 lbs/ac N 4/23, 6/5, 7/23 40 lbs/ac P 9/28 50 lbs/ac GYP 6/5, 9/24	3/6, 4/4, 4/23, 5/17, 6/5, 7/2, 8/27 3/13, 4/9, 5/2, 5/17, 6/5, 7/10, 8/27, 10/22	5/21, 6/11, 6/14 5/21, 5/29, 6/11, 6/14	No harvest
NMPMC-S-1301-WO 9066907 Canyonlands National Park Indian ricegrass seed production	24N	0.26	2012	40 lbs/ac N 3/20, 4/23, 9/24 40 lbs/ac P 3/20, 9/24 50 lbs/ac GYP 9/24	3/4, 3/21, 4/9, 4/23, 5/17, 5/30, 6/11, 6/24, 7/10, 8/15, 8/30, 9/4, 10/3, 11/12	5/21, 6/11, 6/14	6.5
NMPMC-S-1301-WO 9066904 Grand Canyon National Park Indian ricegrass seed production	14	0.14	2012	40 lbs/ac N 7/23, 10/18 40 lbs/ac P 7/23, 10/18 40 lbs/ac GYP 1/10	1/29, 3/21, 4/18, 5/17, 6/17, 7/10, 8/27	5/22, 5/30, 6/11, 6/14	0.88
NMPMC-S-1301-WO 9066908 Canyonlands National Park Indian	33N	0.09	2012	40 lbs/ac N 2/7, 4/23, 5/13, 9/24 40 lbs/ac P 5/13, 9/24	3/6, 3/12, 4/9, 4/26, 5/17, 5/23, 6/19, 7/10, 8/15, 9/4, 10/22	5/22, 5/28, 6/14	3.9

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ricegrass seed production				40 lbs/ac GYP 1/10, 9/24			
NMPMC-S-9401-RA **Paloma** Indian ricegrass foundation seed field	20N 20N	0.37 0.52	2009 2011, 2012	40 lbs/ac N 4/23, 6/5, 9/24, 11/18 40 lbs/ac P 9/24	3/15, 3/20, 4/23, 4/26, 6/6, 7/8, 10/3	5/23, 5/30, 6/11	181.0
NMPMC-S-1301-R **Niner** sideoats grama	25S 35N	0.90 0.20	2012 2012	40 lbs/ac N 5/13, 7/23, 9/24 40 lbs/ac P 5/13, 7/23, 9/24	1/7, 3/1, 3/25, 4/17, 5/3, 5/17, 5/29, 6/12, 6/24, 8/16, 9/4	8/20, 10/29	
NMPMC-S-1102-WO 9066797 Grand Canyon Needleandthread seed production	28S 24N 24N	0.09 0.24 0.26	2011 2012 2013	40 lbs/ac N 2/7, 3/22 40 lbs/ac P 2/7, 3/22 50 lbs/ac GYP 4/4 40 lbs/ac N 3/20, 10/17 40 lbs/ac P 3/20, 10/17 50 lbs/ac GYP 10/21	3/6, 3/22, 4/9, 5/10, 5/30, 6/11, 6/24, 7/8, 9/5, 10/31 1/8, 3/4, 3/21, 4/9, 4/26, 5/17, 5/29, 6/11, 7/10, 9/5, 10/31 7/19, 7/23, 7/31, 8/8, 8/20, 9/5, 10/31	6/21 6/21	9.0
NMPMC-S-0301-WO 9066532 Zion NP bottlebrush squirreltail seed production	19	1.00	2010, 2011	40 lbs/ac N 3/22 40 lbs/ac P 3/22 40 lbs/ac GYP 1/22	1/19, 3/1, 3/27, 4/19, 5/3, 5/23, 6/28	6/6, 6/7, 6/13, 6/17, 6/24	210.0
NMPMC-S-0801-RA 9066431 bluebunch wheatgrass seed production	35N 18	0.30 0.65	2008 2010	40 lbs/ac N 2/7, 5/13, 9/24 40 lbs/ac P 9/24 40 lbs/ac GYP 1/10 40 lbs/ac N 3/22, 4/23, 10/18 40 lbs/ac P 3/22, 4/23, 10/18	3/15, 4/9, 5/2, 5/23, 6/17, 8/15, 10/31 3/27, 4/23, 6/18, 7/10, 10/10	6/19 6/18	3.4
NMPMC-S-0301-WO 9066528 Zion NP Indian ricegrass seed production	35N	0.50	2004 2005	40 lbs/ac N 2/7, 4/23, 6/5 40 lbs/ac GYP 1/10, 6/5	3/15, 3/21, 4/26, 6/5, 7/3	5/23, 5/29, 6/12	32.5

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