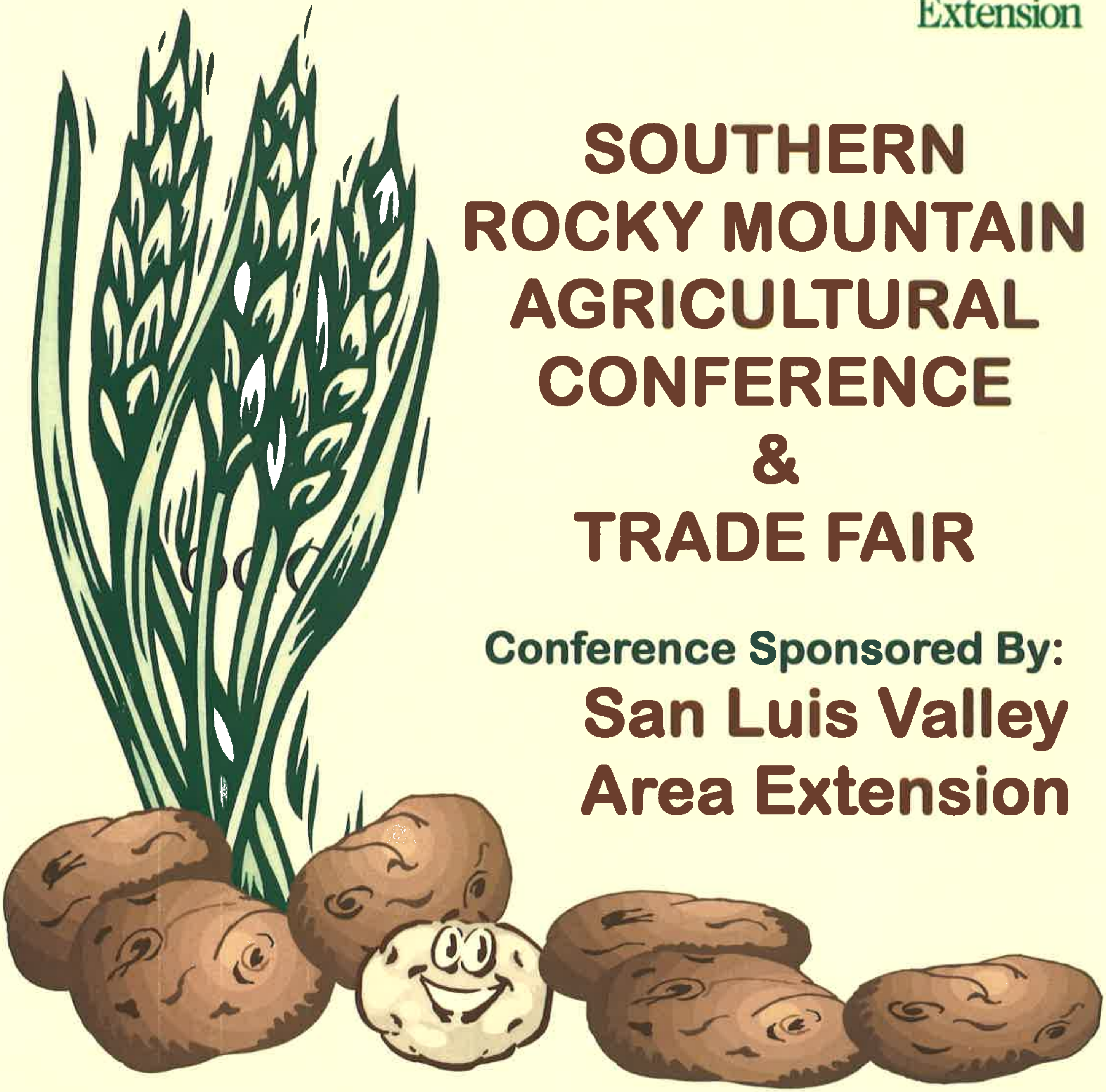
2007 PROCEEDINGS

Colorado State University Cooperative Extension



SOUTHERN ROCKY MOUNTAIN AGRICULTURAL CONFERENCE & TRADE FAIR

Conference Sponsored By:

San Luis Valley Area Extension

Trade Fair Sponsored By:

Monte Vista Chamber of Commerce

24th Annual

Southern Rocky Mountain Agricultural Conference And Trade Fair

January 30 - February 2, 2007
Ski-Hi Park
Monte Vista, Colorado

CONFERENCE PROCEEDINGS

Conference Planning:
Merlin Dillon, Area Extension Agent, Agronomy
Rob Davidson, Extension Seed Potato Specialist

Conference Sponsored By:
Colorado State University
Cooperative Extension

Proceedings Developed By:
Colorado State University
Cooperative Extension

POTATO DAY
Tuesday, January 30

7:00 BREAKFAST
Sponsored by: **Monte Vista CO-OP**

GRAIN DAY
Wednesday, January 31

7:00 BREAKFAST

Sponsored by: **SLV Rural Electric CO-OP**

Small Grain Management Seminar **Proceedings Page No.**

8:00 Organic Durum Extraordinary Market Opportunities, ***Kathryn Begeal, Ceres Organic Harvest, Boulder, CO.***

8:50 New Herbicides for Wheat and Barley, ***Phil Westra & Brien Larsen, CSU Weed Specialist & Research Associate, Colorado State University, Ft. Collins, CO.***

9:40 Enhancing Grain Protein in Wheat and Barley, ***Merlin Dillon, Area Extension Agronomist, SLV Research Center, Center, CO..Page 23***

10:00 Refreshment Break (Trade Fair)

10:20 Growing and Marketing Malt Barleys, ***Ray Pinney, Grain Mgr., M.V. CO-OP, Monte Vista.***

10:40 Growing and Marketing Pristine HWS Wheat, ***Dan Biggerstaff & Kevin Hodges, Westbred, LLC, Montana & Idaho.***

11:30 SLV Area Noxious Weed Update, ***Darrell Plane, Rio Grande County Weed Supervisor.***

11:45 SLV Area Power Update, ***John Villyard, CEO, SLV Rural Electric Co-op., Monte Vista, CO.***

12:00 LUNCH And VISIT TRADE FAIR

Sponsored by: **First Southwest Bank**

1:30 KEYNOTE SPEAKER: Jay Lehr,

Economist and Futurist

Sponsored by:

Farm Credit of Southern Colorado

2:30 Refreshment Break (Trade Fair)

2:45 Limited Irrigation Sunflower for Biodiesel Production. ***Ben Doon, Costilla County Biodiesel and San Juan Biodiesel, San Luis, CO.***

3:30 Understanding Ultra-low Sulfur Diesel, ***Rob Bond, Alta Fuels, Alamosa, CO.***

Producing Canola Biodiesel in the SLV, ***Dan Mortensen, CEO, Alta Fuels, Alamosa. CO.***

4:30 SOCIAL HOUR (Growers & Speakers)

Sponsored by: **A & L Coors, Alamosa, CO.**

5:30 CPAC (Area II) Annual Meeting in Extension Meeting Room, Ski Hi Park.

FORAGE DAY
Thursday, February 1

7:00 BREAKFAST

Sponsored by: **Sunflower Bank**

Alfalfa Management Seminar **Proceedings Page No.**

8:00 Understanding Alfalfa Winterkill,
***Dan Undersander, University of Wisconsin Extension Forage Specialist, Madison, WI*..Page 25**

8:50 Using Roundup Ready Technology to Produce Higher Quality Alfalfa, ***Phil Westra & Brien Larson, CSU Weed Specialist & Research Associate, Colorado State University, Ft. Collins, CO.***

9:40 Refreshment Break (Trade Fair)

10:20 Reseeding Old Stands, ***Dan Undersander, Univ. Wisconsin Extension Forage Specialist, Madison, WI*..Page 31**

11:10 Managing Alfalfa To Reduce Winterkill,
***Richard Sparks, NRCS Regional Agronomist, Center*..Page 35**

12:00 LUNCH and VISIT TRADE FAIR
Sponsored by: ***Community Banks of the Rockies***

1:30 Using Bio-fertility and bio-pesticides in Production Agriculture , ***Michael Holmes, Holmes Enviro LLC, Corvallis, OR*..Page 38**

Organic Production Seminar

2:20 Experiences of A Local Organic Producer,
Amy Kunugi, Southern Colo. Farms, Center, CO.

3:10 Refreshment Break (Trade Fair)

3:30 Organic Fertility Management, ***Adriane Elliott, Research Associate, Colorado State University, Ft. Collins, CO.***

4:20 Organic Crop Production, ***Patrick O'Neill, Agronomist, Agro Engineering, Alamosa, CO.***

5:00 SOCIAL HOUR (Growers & Speakers)
Sponsored by: **A & L Coors, Alamosa, CO.**

Continuing Education Credits are available for Certified Crop Advisors (CCA) and Commercial Applicators (CEC).

WATER/LIVESTOCK DAY
Friday, February 2

7:00 BREAKFAST
Sponsored by: **San Luis Valley Federal Bank**

Water Management Seminar **Proceedings Page No.**

8:00 Choice: Saving Water or Saving Soil,
Richard Sparks, NRCS Regional Agronomist , Center,CO....................................Page 41

8:50 Water Metering Concerns. ***Corey DeAngeles, Colorado Div. Water Resources, Alamosa, CO***

9:40 Refreshment Break (Trade Fair)

10:30 Water: Where We're At, Where We're Going, ***Mike Sullivan, Division Engineer, Division of Water Resources, Alamosa, CO.***

11:10 Sub-District No.1 Update, ***Board Members and Steve Vandiver, Director, Rio Grande Water Conservation District, Alamosa, CO.***

12:0O LUNCH and VISIT TRADE FAIR
Sponsored by: ***Mountain View Restaurant***

Livestock Production Seminar

1:00 Late Pregnancy Abortions and Stillbirths in Beef Herds– What's Abnormal? ***Roger Ellis, CSU Extension Veterinarian, Ft. Collins, CO.***

2:00 Investigation of Abortions in Beef Cattle, ***John Andrews, Director, CSU Western Slope Diagnostic Lab, Grand Junction, CO.***

2:45 Refreshment Break

3:00 Weak Calves at Birth – What's Abnormal? ***Roger Ellis, CSU Extension Veterinarian.***

3:45 Investigation of Weak Calves, ***John Andrews, Western Slope Diagnostic Lab, Grand Junction, CO.***

4:30 Question and Answer Panel , ***Speakers and local veterinarians.***

5:00 SOCIAL HOUR (Growers & Speakers)
Sponsored by: **A & L Coors, Alamosa, CO.**

In's & Out's of DMN

Sastry Jayanty, Postharvest Physiologist, San Luis Valley Research Center,
Department of Horticulture & LA, Center CO 81125

Sprouting and disease management are two major and very important issues in maintaining potato quality in storage. If proper sprout control is not maintained, significant detrimental impacts on tuber quality and storability will result. Sprouting causes weight loss and impedes airflow in storage causing disease.

This presentation will emphasize the important options that need to be considered before applying sprout suppressants. The data I am describing here is a summary of research articles published in different scientific journals.

The primary method to control sprouting in storage is use of chlorpropham (CIPC). CIPC inhibits sprouting by interfering with cell division and must be applied after the wound-healing. This is irreversible sprout inhibitor mostly used on tubers intended for fresh market and processing industry.

Relatively new sprout inhibitor, ethyl substituted naphthalenes are naturally occurring in potato tubers, contribute to flavor in baked potatoes (Buttery et al 1970 and Coleman et al 1981). These compounds showed sprout suppressant activity on a short-term basis approximately 30 days. Mode of action of these compounds for sprout suppression is by regulating phyto-hormones (Meigh et al 1973, Kleinkopf et al 2003). The differences in mode of action are exploited by potato storage industry by alternating with popular sprout suppressant, CIPC for long term storage needs. The synergistic mode of action between these two compounds for sprout suppression was reported by Beaver et al (2003). This approach led to reducing the required concentration of CIPC to achieve effective sprout suppression in potato storage.

The short-term nature of sprout suppressant activity of 1, 4-DMN allowed a very high potential use in the seed industry. 1, 4-DMN is marketed specifically to control sprouting of seed during storage and transit. Beveridge et al (1981a) was the fist to suggest that 1, 4-DMN has an effect on tuber size distribution and showed its concentration dependence. To understand the effect of 1, 4-DMN on stem number and tuber size, a three year study was conducted by Dr. Rick Knowels and his colleagues at University of Idaho on the effect of 1, 4-DMN with three russet cultivars (Russet Burbank, Ranger Russet and Umatilla Russet). Seed was treated thrice with 1, 4-DMN during storage period after wound healing.

The results of this study shows seed treated with 1, 4-DMN affects size distribution in all three russet cultivars studied. 1, 4-DMN has no effect on above ground stem number in case of Ranger Russet but there is decline by 10% in US No.1 tuber yields and 12% increase in the tuber number there by reducing average tuber size by 18%. 1, 4-DMN has similar effect on Russet Burbank but response is less compared with Ranger Russet in terms of tuber size and US No.1 yields. Umatilla Russet showed more sensitivity to the application of 1, 4 DMN on its seed. Treated Umatilla Russet seed produced 21% more undersize tubers and also overall yield reduction (Knowles et al 2005).

The delay in plant emergence in 1, 4-DMN treated seed has no effect on overall plant stand (Beveridge et al 1981b). The increase in stem number across the cultivars tested (Ranger Russet 0.0, Umatilla Russet 0.3 and Russet Burbank 0.4) was not uniform to affect source sink relationships causing change in the tuber number and size distribution (Knowles et al 2005).

Multiple applications of 1, 4-DMN are required to suppress the sprouting in seed tubers stored at higher temperatures. 1, 4-DMN can be used to shift tuber size distribution to yield smaller size tubers if there are economic incentives in certain specialty varieties. Fresh market and processing industries, particularly canning industry, are more interested in smaller size potatoes. There is difference in responses in potato cultivars for 1, 4 DMN treatments on seed. Care has to be taken to get detailed information on specific cultivar response to 1, 4 DMN treatment before application.

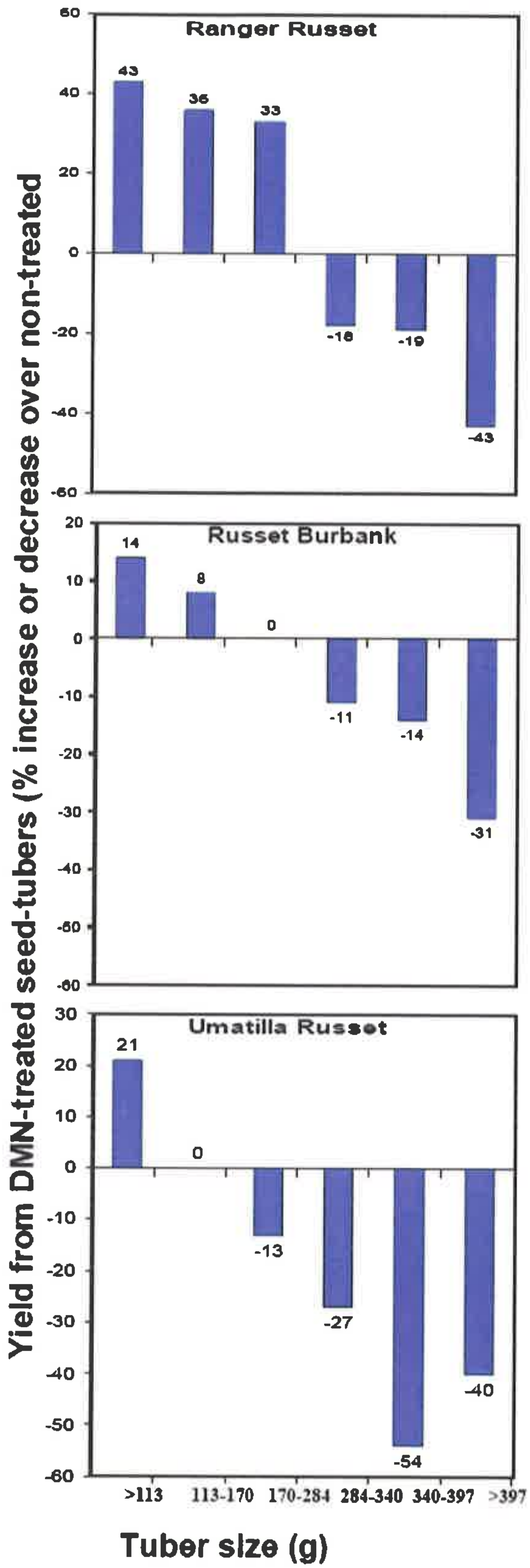


Figure: 1, 4 DMN –induced changes in the size distribution of tubers produced in 3 cultivars. Yields of each tuber size class are expressed as a percent increase or decrease over non-1,4-DMN-treated seed. Data are averaged over three years (Knowles et al 2005).

Literature cited:

Buttery RG, Seifert RM, and Ling LC 1970 Characterization of some volatile potato compounds. J Agr Food Chem 18(3):538-539.

Coleman EC, Ho CT, Chang SS. 1981. Isolation and identification of volatile compounds from baked potatoes. J Agric Food Chem 29:42-48.

Meigh, DF, AAE Filmer, and R Self. 1973. Growth-inhibitory volatile aromatic compounds produced by Solanum luberosum tubers. Phytochemistry 12:987-993.

Kleinkopf GE, NA Oberg, and NL Olsen. 2003. Sprout inhibition in storage: current status, new chemistries and natural compounds. Amer J Potato Res 80:317-327

Beveridge JL, J Dalziel, and HJ Duncan. 1981a. The assessment of some volatile organic compounds as sprout suppressants for ware and seed potatoes. Potato Res 24:61-76.

Beveridge JL, J Dalziel, and HJ Duncan. 1981b. Dimethylnaphthalene as a sprout suppressant for seed and ware potatoes. Potato Res 24:77-88.

Knowles, N Richard, Knowles, Lisa O, Haines, Margo M 2005.1,4-Dimethylnaphthalene Treatment of Seed Potatoes Affects Tuber Size Distribution Amer Journal of Potato Research 82:170-190

TRENDS IN POTATO STORAGE

By Michael D. Lewis Ph.D., Technical Consultant
Cerexagri/Decco, Inc, Fruitland, Idaho

Physiological Disorders

It seems that every year more and more reports surface regarding a physiological potato defect known as internal sprouts. Research has had a challenge with reproducing this ghostly phenomenon. Some theories have been written that try to explain why the disorder occurs but none have been proven. It is an extremely important problem, for when internal sprouting occurs, the malady can render a stored potato crop unmarketable.

It is the purpose of this presentation to provide you with a logical explanation of why internal sprouts occur, describe possible physical and chemical interactions, and discuss some possible solutions.

THE CAUSE:

There are two basic phases of potato crop production that need to be explained independently of each other – the Physical Phase and the Chemical Phase.

First, everyone should understand sprout development. When a tuber breaks dormancy, a bud forms in the eye of the potato; under proper storage conditions, the bud will elongate forming a sprout. Potato sprouts that grow internally in a tuber or into another potato are called 'internal sprouts' (***Figure* 0042**). A section entitled "Physiological Disorders", published in *Potato Production Systems,* written by Dr. Nora Olsen, et al. from the University of Idaho, suggested that the phenomenon can be caused by physical and chemical inhibition. The authors further described the physical cause of the disorder as pressure or contact by other tubers, debris, or storage walls against a sprouting eye, thus restricting the outward growth and forcing the sprout to grow inward. In addition, the sprout inhibitor, Chlorpropham (CIPC) was linked as another possible cause of the problem. This was an excellent condensed explanation of the disorder but fell short of explaining the cause of the problem or possible preventions.

Fig. 0042

It is pretty well understood that internal sprouts occur in stored potatoes that are flaccid or soft; the **physical phase**. Potato growers go to great extremes to insure their crop is irrigated properly and that the harvested potatoes received plenty of humidity when they were placed in storage, so how could they be soft? This loss of turgidity can occur in several places from harvesting to storage. It is important to understand where the moisture losses occur so you have a better chance of reducing the incidences of Internal Sprouts.

Two main areas of tuber water loss can be readily identified. The first area starts in late summer as the potato plant matures and the foliage starts to die. Growers often allow the vines to die naturally or chemically desiccate their potato foliage in an effort to harden-off the tubers and set the skin for the coming harvest. During this period, the soil moisture can be reduced. It is important to note that even though the soil moisture is reduced, the humidity around the tubers is probably very high with one exception. Those tubers in the top of the hill can undergo moisture stress and have the potential to suffer internal moisture loss especially if the crop is kept in this environment for an extended period of time (two weeks or more). A short irrigation or two before harvest not only softens the soil for harvest, it provides moisture to the potatoes and help elevate tuber moisture loss. Yet, those tubers close to the soil surface have a propensity to dehydrate from the time of the last irrigation until harvest, especially in a usually warm season.

Fall temperatures in the SLV on the average can be cool but in the last decade they seem to have been higher than normal. If the day temperatures are high; the night temperatures can also be high, thus not allowing the soil or the tubers to cool. Under these conditions, tuber pulp temperatures can be quite warm before and at harvest; the higher tuber pulp temperature, the higher the respiration rate which also increases tuber moisture loss. All potatoes respire. Stressed potatoes (heat, water, etc. stress) that are harvested and placed into storage will have a higher respiration rate than non-stressed. Again, the higher the respiration rate, the more tuber moisture loss. Keep in mind that tuber moisture loss is continuous and occurs in storage even when potatoes are harvested in optimum conditions, but at a slower rate. These two areas of pre- and post-harvest excess tuber moisture loss are two pieces of the puzzle; the stage is now set for internal sprouts to occur in storage.

As harvest starts, potatoes hot or cold are placed into storage. Excessive water loss from the tubers will also occur if the storage humidity system is not adequate (not able to supply 95+% RH to the pile) from a poor design or if the system is just worn out or if the humidity system is mismanaged. This is especially true during the first week or so of storage; an extremely critical time for moisture loss especially if the pulp temperatures are hot or if the potatoes have been field-stressed. The storage environment has now become a big part of the internal sprout puzzle.

If you add all the areas of potential tuber moisture loss, you now can see why some tubers after only a month in storage have the potential to be soft. The degree of softness may not be able to be determined by touch while others in the same pile feel spongy. When these soft tubers are placed under tons of pressure from those tubers piled on top of them, they will flatten at the tuber to tuber, tuber to wall, tuber to floor contact points especially those at the middle and downward to the bottom of the pile. These contact points are often referred to as pressure flattening or pressure bruise if internal sprouts have not developed.

Another piece of the internal sprout puzzle is the **chemical phase** and its interaction with tubers in storage, especially soft potatoes. Over the years, CIPC or low concentrations of the product has been suggested by many authors and researchers as one of the main causes of internal sprouts. At this point, it is important to continue the discussion of the process of storing potatoes as it relates to the chemical interaction. After the tubers are wound-healed, the storage temperature is gradually lowered in an effort to reduce the tuber pulp temperatures thus slowing the respiration rate and water loss. Potatoes that are labeled for long-term storage will receive a sprout inhibitor, normally Chlorpropham (CIPC) or one of the labeled alternative sprout inhibitor products. Normally, sprout inhibitors are applied once or twice as an aerosol fog to tubers in storage. This process can take place from late October to as late as May.

Now it is time to discuss the interaction between the flaccid tubers (discussed earlier) and CIPC. As soon as the potatoes are placed into storage, the tubers will lose moisture. The pile will shrink (the magnitude will depend on the humidity system, the condition of the tubers, the variety and the storage management practices) compressing the potatoes against each other. Sprout inhibitors are applied as early as October in an effort to get a more uniform application before the pile settles. The problem is stressed potatoes (the one or two tubers that were slightly dehydrated in the top of the hill before harvest) that comprise 10 to 20% of the pile have already soften, thus pressure flatting of those tubers has already taken place. Because of this pressure flatting, any eye that is within that flattened area is protected from the CIPC or any other applied sprout inhibitor. CIPC, for example, when applied in a storage environment as a thermal aerosol, turns into a crystal as the fog cools and is distributed throughout the pile. Although, the crystals are of micron size, penetration into the compressed area to the protected buds is limited (Figure 3). The CIPC will stop all exposed buds from sprouting, but the untreated bud under the compressed area of the tuber can grow with vigor (**Figure 0013**). Because the potatoes are so tightly compressed together, the sprout that is untreated and growing has no place to elongate except into the adjoining tuber or grow internally.

Internal sprouting normally is observed late in the season (approximately, April until the end of the season) when the potatoes are removed from storage or sample loads are taken out. CIPC residues concentrations can be quite low, especially in areas of the pile that are settled or where the CIPC distribution was limited due to dirt, rot or debris. It is understandable why CIPC due to low concentration levels, got the blame for causing internal sprouting.

Fig. 0013.

PREVENTION:

The physical phase causing internal sprouting is the most challenging to handle especially the in-field stresses; those that occur in the late-season; right before or after the potato foliage has been remove. It is important to keep the soil moist but not wet; especially the top four to six inches where the top two or three tubers are located. It is easy to say ‘keep the top layer of the soil moisture moist’, but in doing so, you run the risk of adding too moisture. Too much moisture can produce disease, enlarged lenticels, etc. These are challenges that only the experienced grower can manage or ‘try to manage’. After the foliage has removed especially in hot, dry late summer conditions, light frequent irrigations can keep the soil pliable for harvesting (amounts vary depending on your soil type and texture) and hopefully maintain humidity levels around the tubers to a point where very little dehydration takes place. This is one of those gray areas where here is no exact answer. Experience is the best teacher; knowledge of the soil, the irrigation system and the variety all add to management success.

The second physical stress that can dehydrate tubers comes post-harvest – in the early stages of storage. As the potatoes are loaded into storage many managerial processes must take place in order to minimize the internal sprout potential. All pre-storage maintenance must be complete and the facility is ready; the floors are damp and the ventilation/refrigeration system has been test-run. It is important to understand, the storage season begins as soon as the first tuber hits the storage floor. When the tubers cover the first or second duct, it is time to start the ventilation system. Caution: before the system is started, you must first be sure that enough duct gates are open to keep from building excessive pressure inside the plenum and fan-house. Secondly, it is important that your airflow to the open ducts be adjusted properly (the speed will vary per storage) so as not to ring moisture out of the air and to maintain the correct air distribution in the open ducts. Variable Frequency Drives (VFDs) can be very valuable with this task. Remember as the storage continues to be filled, more gates will have to be opened and you will have to readjust the air into the ducts. Your ventilation service provider can supply you with the number of ducts that should be open and how to calibrate the duct air flows.

Supplying air and humidity to the pile during the early phase of storage can be challenging to managers due to limited outside cooling air. It is important that when you have run-time, the system should be operating. An evaporative pad humidification system and refrigeration can be very beneficial during this particular storage phase. It is important that the refrigeration system be capable of removing heat not just maintaining temperature. A refrigeration system removes humidity from the air so watch your humidity in the plenum closely when the system is running.

Tuber heat (also called field-heat) is an issue that must be dealt with as the potatoes are placed into storage. As mentioned earlier, the warmer the tubers are coming into storage, the higher the respiration rate. High respiration equals high water loss, but the problem is, there is little you can do about this with the exception of – while maintaining a maximum of a 2 degree differential between the top and bottom of the pile, cool the pile as fast as possible (the rate depends on the end-use, i.e. processing, fresh-pack or seed) and maintain as high humidity as possible without free-water. Maintaining a maximum of 2 degrees differential between the top and bottom of the pile is critical; the greater the differential the more tuber dehydration will occur. At this early phase of storage (curing period and the early cool-down), supplying too much air probably is not possible. The method of lowering pile temperatures (fast or slow) is not super critical with regards to internal sprouts as long as the method fits the end-use of the potatoes and you don't dehydrate the tubers. The areas that are critical are the humidity and the temperature differential!

The following will deal with specifics that a storage manager can control. Tuber water loss can be quite dramatic the first few weeks or more of storage. On a per month basis, this period will experience the highest percent tuber moisture loss. H. Waelti, 1989, showed that 2% loss or more the first month of storage is possible with an inadequate humidity system. Your humidity system will make or break you during this time period especially with regards to internal sprouts. At this point in this discussion, it is important you have general understanding of Relative Humidity (RH) and what happens with humidity in the plenum, in the pile and above the pile.

Relative humidity is defined as the ratio of amount of moisture in the air compared to the maximum amount of moisture that the air can hold at a given temperature. It has been demonstrated time and time again, in order to minimize tuber dehydration you must maintain 95% + RH in the plenum not on top of the pile or in the return air – in the plenum. Humidity systems are designed to maintain a level of humidity at a specified temperature. During the early stages of storage (filling/loading), usually maximum outside air is taken in if cooling (ambient air is lower than the set-point) is available. High velocity, warm outside air with low moisture content is challenging to humidify to 95 +%. Most storages especially the older ones, have humidity systems that can maintain adequate humidity when the tuber pulp temperatures come close to the holding temperature, but until those temperatures are approached, the tubers are subjected to high vapor pressure deficit (lower humidity outside the tuber than inside), thus causing high tuber moisture loss. Those growers that have an evaporative cooling pad system have a larger advantage, but even evaporative cooling pads in some cases can not maintain this high level of RH and require supplemental humidity if the fans are running full speed and the outside air is quite warm with low humidity. It all depends on the system and how it was designed. Some of the older storages will have one or two centrifugal humidifiers. These systems really have a challenge maintaining adequate humidity. You should now be starting to develop a mental picture of why tubers dehydrate during this first month of storage and why internal sprout can occur.

Maintaining adequate relative humidity in storage can be a storage manager's nightmare, especially if rot is present. Managing elevated percentages of rot in storage at the beginning of the storage phase and/or during the storage season is a presentation within itself and will not be discussed.

It is not purpose of this presentation to compare ventilation systems but only to suggest the level of humidity you need. You or your ventilation representative will have to determine the efficiency of your system under your conditions. RH should be taken in two or more places in your storage plenum. In addition, it is critical that the humidity sensors that are or will be installed in your storage plenum be capable of measuring RH to 95+% -- not all humidity sensors have that capacity. Whether you have a modern evaporative pad cooling system, a high-pressure system, an air-washer, or a centrifugal system, once you have determined the capacity of your humidity system in your storage under these challenging conditions, you can add portable centrifugal systems to your humidification system as long they are suspended off the floor.

In Summary: Internal sprouts occur due to a number of interactions in the field and in the storage environment. Buds that are protected from a sprout inhibitor treatment due to pressure flattening of the tubers have the potential of developing into internal sprouts. Working to eliminate in-field stresses, using the most efficient storage humidification equipment and applying proper storage management procedures will reduce if not eliminate internal sprouts.

Potato Sprout Inhibitors/Suppressants

One of the most important tools for managing potato quality in storage is an effective sprout inhibitor/suppressant. Sprouting in storage causes increased weight loss, reduced tuber quality, removal challenges and can limit air flow. Without a sprout inhibitor, long-term storage is a challenge if not almost impossible.

Over the past 50 years, CIPC (Chlorpropham) has been the #1 sprout inhibitor in the US, Canada and many potato producing areas of the world. It is by definition a true sprout inhibitor. When properly applied and according to the label, CIPC will *inhibit* sprout growth. The mode of action of the compound that causes sprout inhibition is by interfering with cell division (interrupts the spindle formation during active mitosis) BUT some cell enlargement in the bud *still* takes place. This enlargement causes the buds to swell or peep. This growth (peeping) is often mistaken for sprout growth. These peepers must form in order to absorb the CIPC. Again, if CIPC is applied correctly and at label rates, sprout growth or elongation will not continue. It important to understand that several factors affect the performance of CIPC, such as the storage environment, application technology and rate, cultivar (variety), etc.

When CIPC under went re-registration in the early 90s, there were rumors that the industry may lose the use of the compound on potatoes. In the mid-90s, the EPA (Environmental Protection Agency) required the CIPC tolerance levels on fresh potatoes to be lowered from 50 to 30 ppm which further increase the industries' anxiety regarding the possible loss of the product.

Alternative sprout inhibitors to CIPC started to be evaluated in many parts of the world; products like plant extracts [i.e. volatile oils also called essentials oils like caraway, peppermint, spearmint and clove or their components (s-carvone, eugenol)] and hydrogen peroxide-based compounds. These products physically damage or kill the developing the developing sprout often turning the bud/sprout brown or black. Several of these products have proven to be quite effective, but some are not without challenges that have limited their acceptance by the industry. S-carvone, extracted from caraway oil is currently being marketed (Talent™) in several European Countries.

Clove Oil (a.i. eugenol) is one of the naturally occurring compounds that have shown sprout suppression activity in the US as well as in Europe. It has gained acceptance especially among the fresh pack and organic industries because of its ability when applied properly and at the correct rate to kill peeping buds and turn them black. Clove Oil is applied as a thermal fog and can be applied shortly after the tubers are placed into storage. It has shown no negative effects on wound healing. Current research (University of Idaho @ Kimberly) shows that it is most effective after the peepers have formed on the tubers. Sprout suppression from the aerosol application of Clove Oil has lasted up to 60 days or longer depending on the storage temperature and variety. The Clove Oil damages/kills most exposed buds and when combined with CIPC and storage temperatures, the auxiliary sprouts are slow to re-appear.

Substituted naphthalenes are another group of compounds that has shown success at suppressing sprout development in potatoes. Several groups in Europe in the 1980s evaluated many naphthalene isomers with some success. Lewis, et al. from 1992 through 1997 (when the information was published) also evaluated several isomers. The mode of action of naphthalenes is thought to impact the hormonal process of sprouting unlike the cell division inhibitor, CIPC. Since that initial research, two products have been registered in the industry for potato sprout control; 1,4Sight™ (1,4-dimethylnaphthalene) and Amplify™ (2,6-diisopropylnaphthalene). Long-term storage using only naphthalene compounds require multiple applications to achieve similar control as CIPC. Amplify ™ is to be applied in combination with CIPC, but can only be applied one time during the storage season. Research data have shown mixed results when the products are compared to the label rate of CIPC. Additional research needs to be conducted on both these products.

Hydrogen Peroxide-based materials have been evaluated in the US and in Israel for potato sprout suppression. Some of the products have demonstrated sprout suppression by seemly physically damaging the meristematic tissue in the developing sprouts/buds. Repeated applications of the materials are a necessary to achieve long-term sprout suppressant.

The newest alternative sprout inhibitor/suppressant is an experimental product evaluated and patented by Dr. Rick Knowles of Washington State University (WSU). Dr. Knowles and his associates evaluated Aliphatic Aldehydes and Ketones which are classes of natural products produced by the potato that has shown good promise as a long-term sprout inhibitor. Dr. Knowles selected a couple of compounds that have shown in several small scale research projects, sprout suppression for 12 months with two aerosol applications when the potatoes were stored at 48°F. In addition, the compound when applied as an aerosol at specific rates has shown physical damage to the buds turning them black. The marketing license was picked up by AmVac. The research is on- going at WSU and additional work is taking place at the University of Idaho @ Kimberly Research Facility.

Other products that have been evaluated for potato sprout inhibition/suppression but have yet to be adopted in the industry includes: ethylene, Jasmonates and irradiation.

In Summary: CIPC has been a stable, dependable product for close to fifty years. When applied correctly by a licensed applicator and at the established label rates to healthy potatoes under proper storage conditions, CIPC will keep potatoes sprout-free for 12 months or longer. The future of CIPC is unknown so continuing research for an alternative product to CIPC is necessary. Until CIPC is replaced, it is a necessity to learn and understand how CIPC works. It is also important to understand how all alternative products are applied and how they work, so they will provide you with tools to maintain raw product quality in storage.

NOTES:

Using Green Manures To Enhance Potato Production: I, Effect on Columbia Root-knot Nematodes.

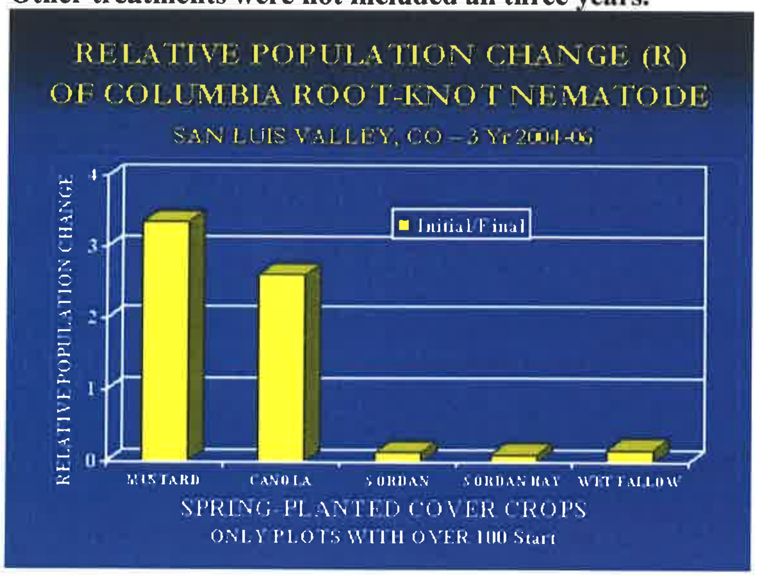
Merlin A. Dillon, Area Extension Agronomist, San Luis Valley Research Center.

CPAC Area II has funded this project since about 2001. Green manure crops are planted instead of grain in a potato/grain rotation. Green manure crops are planted to reduce water use, reduce Columbia Root-knot nematodes (CRKN) levels, and improve soil health. CRKN are sampled four times in the two years. First, a survey of the prospective field determines whether high levels of CRKN are present. Second, established plots are sampled to determine the starting CRKN level. Green manure crops are then grown for about 60 days and then chopped and soil incorporated with a chisel or disk. The third nematode sample is in late October each year (a mid-rotation nematode level). The final CRKN level is in May (potato planting) the following year. The starting CRKN level is compared to final CRKN level.

Several green manure crops have drastically reduced nematode levels as measured at potato planting and as shown in Figure 1 below. Mustard and canola were not so effective on CRKN as Sordan 79 sorghum-sudan, Sordan 79 harvested for hay or wet fallow.

Oilseed radish was used in the trial for two years. It was not extremely effective on CRKN; however, it has been reported effective on stubby root nematode. Honeysweet variety sorghum-sudan has been used in the trial for one and part of the second year. It too is not as effective as Sordan 79 for CRKN; however, it may have other benefits other than nematode reduction

Fig. 1. Change in CRKN levels at potato planting, 3 year average.
Other treatments were not included all three years.



Benefits: One of the best uses of Sordan 79 is for commercial potato growers to use this green manure as a way to postpone or prevent the need to control nematodes. Using Telone or Vydate is expensive. Sordan 79 green manure not only reduces CRKN, it helps build soil health, save water and boost potato yield and quality (see article by Delgado). Conversely, a potato/Sordan rotation can greatly increase wind erosion, especially in the months of April and May prior to planting Sordan. A winter cover crop of wheat or rye can reduce this wind erosion without using very much water. Saving soil is just as important as saving groundwater.

Using Green Manures To Enhance Potato Production: II, Other Benefits - Effects on Nutrient Cycling, Tuber Yield and Quality

Jorge A. Delgado[1], Samuel Y.C. Essah[2], Merlin A. Dillon[2] Russel Ingham[3], Daniel Manter[1], Alan Stuebe[4] and Richard T. Sparks[5]

[1]USDA-ARS Soil Plant Nutrient Research Unit, Fort Collins, CO; [2]CSU, SLVRC, Center, CO; [3]OSU, SLVRC, Center, CO; [4]USDA-NRCS, Alamosa, CO; [5]USDA-NRCS Center, CO

INTRODUCTION: Colorado's San Luis Valley (SLV) is one of the leading producing areas of fresh market potatoes in the U.S.A. and produces over ninety percent of the state's potatoes. In this region, potatoes are grown under center-pivot irrigated sandy soils that have low soil organic matter and micronutrient content. Micro-nutrients can be a problem in this region of high pH sandy soils for crops that are susceptible to Fe, Mn, and Zn deficiencies.

Another concern for this region is the drought that reduced the recharge of underground water resources. Due to the recent drought, it has been recommended to cut back on the amount of irrigated acreage. It is important to develop irrigation alternatives so limited irrigation can be viable for farmers and contribute to sustainable systems across region (Hu et al. 2005). Additionally, irrigated sandy soils are susceptible to nitrate leaching.

Nutrient management, especially nitrogen (N), affects tuber yield and quality (Essah and Delgado, 2007). For cover crops such as winter wheat or barley with high carbon (C) to nitrogen ratios (C/N of about 100), the cycling of N to the following potato crop was reported to be about 8 to 10% (Delgado et al. 2004). Cover crops such as mustard that have lower C/N ratios (close to 30) cycled higher N to the following potato crop (about 30%; Collins et al. 2007). This green manure fertilization by the mustard contributed 30 to 40 kg N ha^{-1} to the potato crop (Collins et al. 2007). Cover crops reduce erosion (Delgado et al. 1999), minimize nitrate leaching (Delgado 1998, Delgado et al. 2001a), improve soil quality (Al-Sheikh et al. 2005) and can be used for biocontrol (Dabney et al. 2001). Rotations with large productions of crop residue, such as small grains and winter cover crops contribute to; maintaining soil organic matter levels in the SLV, reducing erosion of fine particles; maintaining macro and micro nutrient levels and scavenging soil NO_3-N from deep in the soil profile (down to 3 to 5 feet) (Delgado, 1998, Delgado et al. 1999; Al-Sheikh et al. 2005).

Cover crop studies have been conducted in the SLV since the early 1990's in cooperation between the USDA-ARS-Soil Plant Nutrient Research Unit, Colorado State University San Luis Valley Research Center and USDA Natural Resource Conservation Service (Delgado et al. 1996; 1999; Delgado, 1998). These studies have also been conducted in cooperation with consultants and under commercial farm operations bringing together resources from the USDA, CSU, OSU, consultants and private farmers (Delgado et al. 2001b).

We need to continue to look for potato cropping systems that will reduce disease problems, increase water use efficiencies, increase nutrient use efficiencies and minimize NO_3-N leaching. SLV farmers are already taking advantage of winter cover crops such as winter rye and winter wheat in vegetable and potato rotations. There is the need for additional studies to evaluate alternative summer green manure cover crop dry matter production and nutrient cycling and their effects on tuber yield and quality.

MATERIALS AND METHODS: Cover crop dry biomass production and nutrient uptake studies were conducted from 2003 to 2006 (**Fig. 1**). Two years studies have been conducted to monitor the effect of the cover crops on the following potato crop. The experimental design was a completely randomized block with 5 replications. Cover crop treatments included; wet fallow, mustard, oilseed radish, canola, sorghum-sudan and sorghum-sudan hay in small plots (12' x 35'). Permanent markers were located at the site and GPS coordinates enabled tracing the treatment effects over a two year study. Soil samples were collected initially for nutrient analysis. After cover crop harvest, but before incorporation, the soil was sampled again to monitor nutrients (**Fig. 2**.). After the cover crops biomass samples were collected for yield and nutrient analysis -- the cover crops are incorporated (**Fig. 3**). For the hay treatment, the aboveground biomass is removed from the plot area.

Soil samples were collected again before potato planting. Potatoes were planted and monitored. Tubers were harvested and graded for marketable yield and tuber quality. The cover crop biomass production, dry matter, C, N and nutrient uptake and cycling impacts on tuber yield were assessed. Soil samples were collected with a Giddings truck to trace NO_3-N transport. Macro and micro nutrient uptake by cover crops and potato were measured with an Atomic Absorption Analysis method. Tuber yield, quality and nutrient uptake data were subjected to analysis of variance and mean separation was tested with LSD ($P<0.10$).

RESULTS AND DISCUSSION: The sorghum-sudan, mustard, radish, and canola average dry matter production with limited irrigation was 3000, 4300, 4500, and 6261 lbs per acre, respectively. These cover crops were produced with an average of 17 cm of irrigation, 25 to 30 cm (10 to 12 inches) less than for a barley or potato crop. The farmer will have the option to grow the cover crop with limited irrigation and have the alternative of using the aboveground biomass for hay (sorghum-sudan) or incorporating it as a green manure crop.

Mustard, radish, and canola had higher Ca content than the sorghum-sudan. Sorghum-sudan extracted twice the amount of Cu and Mn than radish, canola, or mustard. Additionally, sorghum-sudan Zn content was higher than that of the mustard and canola. Cover crops can be used as green manures to cycle nutrients to other important crops.

Under commercial farm operations, the total marketable tuber yield was increased by 12 to 30% when potatoes followed a sorghum-sudan green manure instead of wet fallow plots. For the potatoes following sorghum-sudan, there was superior tuber quality, with 40% higher production, for tubers greater than 8 ounces when compared to tuber quality and production rates that followed a wet fallow plot.

Additionally sorghum-sudan hay also increased tuber yield and tuber quality. These preliminary results conducted under commercial field studies show that there is potential to generate additional income ($60.00 to $400.00 dollars per acre), which would more than offset the cost and management of the cover crop. The farmer will have the option of harvesting the sorghum-sudan or incorporate the sorghum-sudan as a green manure.

Sorghum-sudan increased the macro and micro nutrient uptake of potato tubers. The Cu, Mn, and Zn use efficiencies of the sorghum-sudan cover crop was 4, 19, and 4%, respectively. The K, Ca, and Mg sorghum-sudan cover crop nutrient use efficiencies were 3, 22, and 40%, respectively.

For these field studies the best yield and tuber quality response came from the sorghum-sudan green manure crop prior to potatoes. Ingham et al (2007) reported the highest control of nematodes for the sorghum-sudan, however the wet fallow plots also had similar low levels of nematodes. The Mn ($r^2=0.43$) and Zn ($r^2=0.48$) cover crop aboveground biomass uptake was correlated with tuber yield ($P<0.05$). This data suggest that the cover crops are correcting micro-nutrients deficiencies for these high pH sandy soils with low organic matter content.

One negative effect was found with the canola plots. In two years of trial, the potato yields and tuber quality was reduced when potatoes followed canola compared to wet fallow plots and sorghum-sudan. The marketable production of tubers in the canola plots was much less than after wet fallow, and the tubers were smaller. The preliminary response in these two field studies suggest that canola green manure may have an allelopathic effect, which reduces the yields and quality of potatoes.

SUMMARY: These studies show that green manure crops can provide farmers with a viable alternative to ensure sustainability of water resources, conservation of soil, increase in yields, and even increase in tuber quality. One particular green manure cover crop that is proving a viable economical alternative is sorghum-sudan. We suggest that users could add winter cover rye after the potato crop to minimize erosion prior to planting sorghum-sudan.

REFERENCES:

Al-Sheikh, A., J.A. Delgado, K. Barbarick, R. Sparks, M. Dillon, Y. Qian and G. Cardon. 2005. Effects of Potato-Grain Rotations on Soil Erosion, Carbon Dynamics and Properties of Rangeland Sandy Soils. J. Soil Tillage Res. 81:227-238.

Collins H.P., J.A. Delgado, A. Alva and R.F. Follett. 2006. Use of ^{15}N Isotopic Techniques to Assess the Potential of a Mustard Cover Crop to Cycle N to Potatoes. Agonomy Journal (*In print*)

Dabney, S.M., J.A. Delgado, and D.W. Reeves. 2001. Using winter cover crops to improve soil and water quality. J. Comm. Soil Sci. Plant Anal. 32:1221-1250.

Delgado, J.A. 1998. Sequential NLEAP simulations to examine effect of early and late planted winter cover crops on nitrogen dynamics. J. Soil Water Conserv. 53:241-244.

Delgado, J.A., M.A. Dillon, R.T. Sparks, and R.F. Follett. 2004. Tracing the fate of ^{15}N in a small-grain potato rotation to improve accountability of N budgets. J. Soil Water Conserv. 59:271-276.

Delgado, J.A., R.F. Follett, J.L. Sharkoff, R.R. Riggenbach, and R.T. Sparks. 1996. Preliminary assessment of N-uptake and NO_3-N accumulation of winter cover crops and their effect on soil and water quality in the San Luis Valley of Colorado. Proc. 13th Annual Potato/Grain Conference. pp 5-6.

Delgado, J.A., R.J. Ristau, M.A. Dillon, H.R. Duke, A. Stuebe, R.F. Follett, M.J. Shaffer, R.R. Riggenbach, R.T. Sparks, A. Thompson, L.M. Kawanabe, A. Kunugi, and K. Thompson. 2001b. Use of innovative tools to increase nitrogen use efficiency and protect environmental quality in crop rotations. J. Comm. Soil Sci. Plant Anal. 32:1321-1354.

Delgado, J.A., R.R. Riggenbach, R.T. Sparks, M.A. Dillon, L.M. Kawanabe, and R.J. Ristau. 2001a. Evaluation of nitrate-nitrogen transport in a potato-barley rotation. Soil Sci. Soc. Am. J. 65:878-883.

Delgado, J.A., R.T. Sparks, R.F. Follett, J.L. Sharkoff, and R.R. Riggenbach. 1999. Use of winter cover crops to conserve water and water quality in the San Luis Valley of south central Colorado. P. 125-142. *In* R. Lal (ed.). Soil Quality and Soil Erosion. CRC Press, Boca Raton, FL.

Essah, S.Y.C. and J.A. Delgado. 2007. Nitrogen management for maximizing potato yield, tuber quality, and environmental conservation. Procedings First International Conference on Environmental Research, Technology and Policy. Building Tools and Capacities for Sustainable Production. July 16 - 19, 2007, Accra Ghana, (*In print*)

Hu, C., J.A. Delgado, X. Zhang, and L. Ma. 2005. Assessment of Groundwater Use by Wheat (*Triticum aestivum* L.) in the Luancheng Xian Region and Potential Implications for Water Conservation in the Northwestern North China Plain. J. Soil Water Conserv. 60:80-88.

Fig 1a.

Fig 1b.

Figure 1. USDA-ARS, CSU, USDA-NRCS, consultants, and commercial farmers cooperate in the mid 1990's on winter cover crops, winter rye and winter wheat studies in the San Luis Valley. From 2001 to 2006 the team studied green manure cover crops; canola, sorghum-sudan, sorghum-sudan hay and white mustard on above ground biomass production and cover crop effects on nutrient cycling **(Fig 1a.)**. Samuel Essah, Horticulturist, CSU; left), Jorge Delgado (Soil Scientist, USDA-ARS; Center) and Merlin Dillon (Agronomist, CSU; right) inspect cover crops **(Fig 1b.)**.

Fig 2a.

Fig 2b.

Fig 2c.

Figure 2. A Giddings truck mount was used for collection of soil samples to assess the potential for cover crops to scavenge, recover and cycle soil nitrogen (nitrate-nitrogen, NO_3-N) and other nutrients. The truck is set up in the middle of the plot after the cover crop aboveground sample have been collected (Fig. 2a), the probe is inserted to 5 feet (Fig 2b) and the soil sample is separated in bags and put in coolers for laboratory analysis (Fig 2c).

Figure 3. After collection of aboveground cover crop biomass and soil samples the cover crops are incorporated **(Fig 3a).** Crop residue cover range on average from sorghum-sudan > canola and white mustard > sorghum-sudan hay plots > fallow plots. **(Fig 3b).**

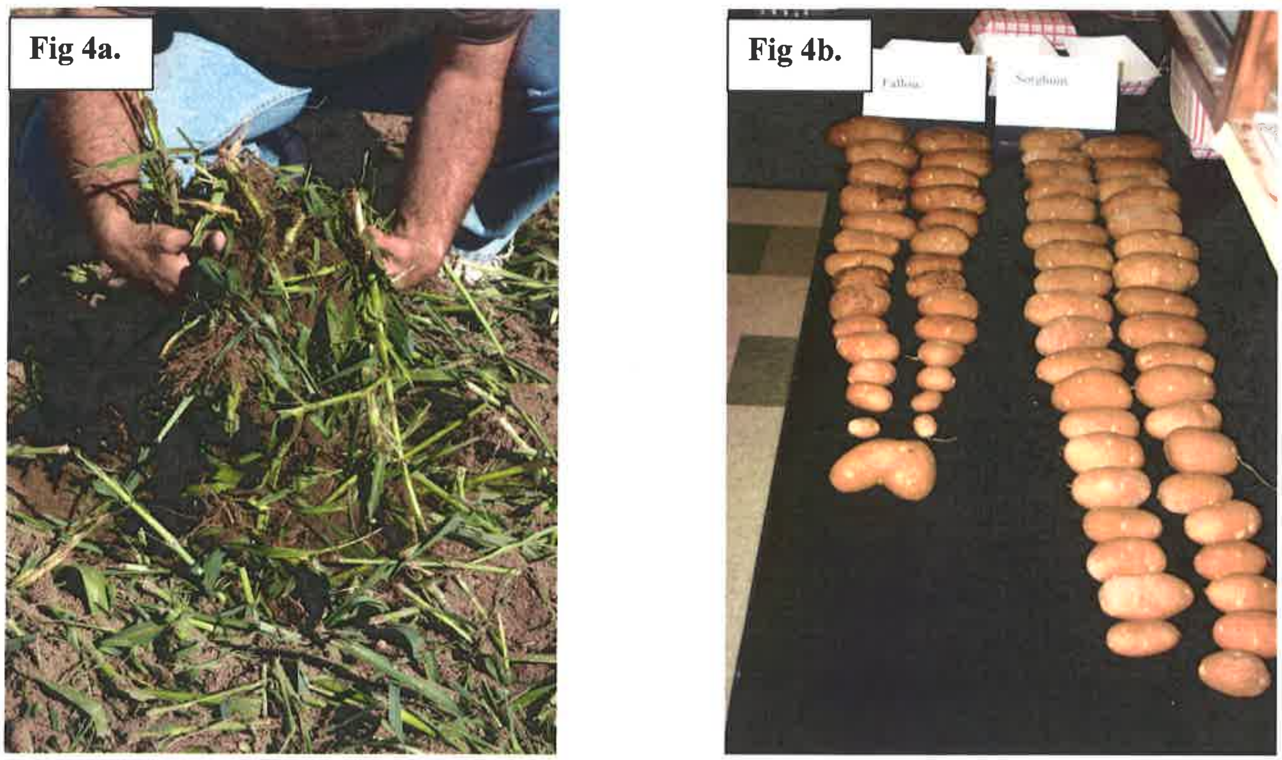


Figure 4. A large amount of fresh crop biomass is incorporated below the soil surface **(Fig 4a).** Sorghum-sudan significantly increased potato production and tuber quality on two different commercial fields **(Fig 4b).** The tuber production yield and quality for the potato following sorghum-sudan plots were significantly higher **(tubers on the right side Fig 4b)** than the production following a wet fallow plot **(tubers on the left side Fig 4a).**

Using Green Manure To Enhance Potato Production: IV, Effect of Green Manure Cover Crops on Soil Fungal Diversity and Biomass

Dan Manter[1], Jorge Delgado[1], Merlin Dillon[2], Samuel Essah[2]

[1]USDA-ARS, Soil-Plant-Nutrient Research Unit, Fort Collins, CO
[2]Colorado State University, SLVRC, Center, CO

Abstract

The effects of various green manure cover crops (sorghum-sudan (sordan 79), mustard, canola, Honeysweet sorghum-sudan, and wet wet fallow) to influence soil fungal biomass and diversity were tested in a potato field in the San Luis Valley, Colorado. Soil samples (0-5 cm depth) were randomly selected from each cover crop plot and soil fungal communities were analyzed based on fungal DNA profiles. All cover crops increased the soil fungal biomass as compared to the wet fallow treatment, with the greatest fungal biomass in the sordan 79 plots. On average, 13 different fungal species were identified in each of the various cover crops. Of these species, three are known potato pathogens (*Fusarium equiseti*, *Verticillium* sp., and *Alternaria solani*). Cover crops differed in their ability to suppress, or reduce biomass, of these pathogenic species. For example, the mustard cover crop significantly reduced the biomass of all three species; whereas, sordan 79 significantly reduced both *Verticillium* sp. and *Alternaria solani*. Sordan 79 appears to be a beneficial cover crop in potato rotations since it promotes total soil fungal biomass and diversity and presumably a healthier soil, and at the same time can limit the proliferation and abundance of some potato pathogens in the soil.

Introduction

Through various processes such as root exudation and changes in soil properties, different plant species affect the soil microbial population around them. As a result, various cover crops or crop rotations can change the soil microbial community in agricultural systems influencing the vigor and yield of crop plants as beneficial microbes (i.e., those involved in nutrient cycling, etc.) proliferate and/or pathogenic species are suppressed. As part of a larger project to study the influence of cover crops on potatoes in the San Luis Valley, this study examined the effect cover crops on soil fungal community biomass, diversity and abundance.

Methods

Plots: The experimental design consisted of a randomized complete block design with six treatments and five replications. All plots were 12 ft x 35 ft. Treatments consisted of one of five cover crops (sordan 79, sordan 79 hay, mustard, canola, honeysweet) or wet wet fallow, which were planted in the spring of 2005 after incorporation of a winter rye cover crop. The following year all plots were planted to potato. Fungal community dynamics were analyzed on three soil samples (0-5 cm depth) collected from each plot on May 17 2005 (pre-cover crop), September 27 2005 (post-cover crop), and March 27 2006 (pre-potato).

Fungal Communities: Changes in fungal biomass were analyzed by monitoring changes in the soil community profile of rRNA gene fragments. Briefly, DNA isolated from the soil samples were amplified by qPCR with conserved fungal primers (ITS1-F and ITS4), and the number and abundance of various DNA fragments was separated and quantified by capillary electrophoresis. This combination of molecular techniques allows for a direct estimate of total fungal biomass (i.e., total amount of amplified

DNA) and an index of soil fungi diversity (i.e., number of DNA fragments of varying lengths). DNA mutation results in varying rRNA gene fragment lengths that often vary between fungal species and/or individual and can be used as a marker of known or unknown species without the need to culture and grow the fungi in the laboratory. As a result, changes in the total number of rRNA fragments are related to soil fungal community diversity, and changes in the abundance of any one fragment is related to biomass changes in only the fungal species of the same rRNA gene fragment length.

Results

Total soil fungal biomass changed over time in all cover crop treatments (Fig. 1). In all treatments, a seasonal pattern was observed such that fungal biomass was highest during the summer and lowest in the spring and fall. Within sample dates, fungal biomass differed significantly between cover crops and was highest in the sordan 79 plots and lowest in the wet fallow plots.

Species diversity was not influenced by cover crop treatment with all plots containing an average of 13 different fungal species. Of these species, three are known potato pathogens (*Fusarium equiseti*, *Verticillium* sp., and *Alternaria solani*). Cover crops differed in their ability to suppress, or reduce biomass, of these pathogenic species (Fig. 2). For example, *F. equiseti* biomass was lowest under the mustard and highest under the sordan 79 cover crops. Both the mustard and sordan 79 cover crops significantly reduced the presence of *Verticillium* sp. and sordan 79 resulted in the best control of *Alternaria solani*. Sordan 79 appears to be a beneficial cover crop in potato rotations since it promotes total soil fungal biomass and diversity and presumably a healthier soil, and at the same time can limit the proliferation and abundance of some potato pathogens in the soil.

Figure 1. Total fungal biomass estimated from qPCR using conserved rRNA fungal primers.

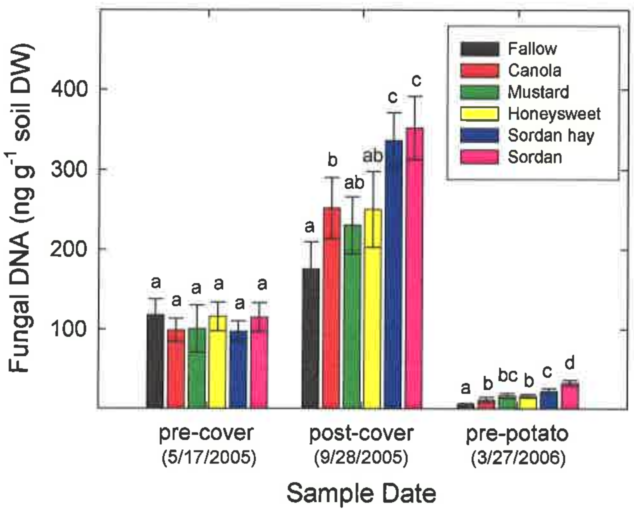
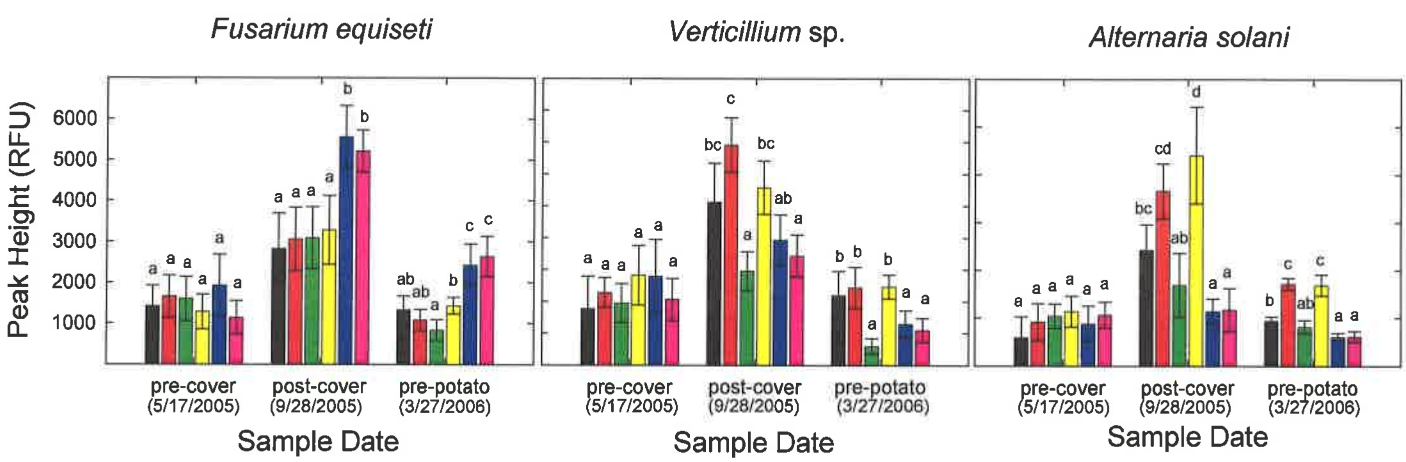


Figure 2. Biomass of individual pathogenic species estimated from rRNA gene fragment abundance.



Enhancing Grain Protein in Wheat and Barley

Merlin A. Dillon, Area Extension Agronomist, San Luis Valley Research Center.

Three separate small plot, replicated trials were conducted at SLVRC last summer. All plots were treated exactly the same except for nitrogen applied at heading. Routine nitrogen applications in May; at-heading applications were 0, 30, 45 or 60 lbs per acre applied on June 24-27. Yields were determined by measuring plot length of each plot, combine harvest, weighing grain harvested, correcting grain yield for 12% moisture. Protein content was determined by the Wheat Breeding Project at CSU-Ft. Collins. Results are shown in Tables 1-3. Yields were less than expected, especially for some trials. Even though yields were below average, applying nitrogen at heading consistently increased grain protein. One might expect a better response when yields were high with fairly low protein.

Table 1. Effect of Heading Application Nitrogen on Grain Protein, Dr. Jorge Delgado N^{15} potato nitrogen recovery trial.

This trial was designed as cooperation with Dr. Delgado, ARS-Ft. Collins. N^{15} was applied at heading to a 2'x 2' area. Dry urea was applied at heading (June 26) in the remainder of the plot. Heading applications for this series of trials were all applied within a few days. Early nitrogen application
was 100 lbs/acre plus fertigation of 30 lbs/acre plus the variable rates at heading.

Crop residues were moved after Hege combine harvest and uptake will be measured in the following potato crop. Nitrogen uptake at heading application will be determined.

Yields were poor in this area; however, nitrogen application increased grain protein. Protein differences were statistically significant. Nitrogen applications did not increase grain yield.

Nitrogen Treatment	Grain Yield	Grain Protein
	Bu/acre	%
Jerome, HRS Wheat		
0	98.7	11.2
0	87.2	11.3
30	106.0	12.0
60	109.3	12.9
Average	100.3	11.9
Snowcrest, HWS Wheat		
0	70.6	13.2
0	68.3	12.6
30	83.0	13.8
60	75.2	14.1
Average	74.3	13.4
Test Average	**87.3**	**12.6**
LSD, 10%	**11.8**	**0.73**

Table 2. Effect of Heading Application Nitrogen on Grain Protein on Nora, Hard Red Spring Wheat. Located beside the Hard Wheat Variety Trial.

This trial was Results are very similar to the previous trial. Heading nitrogen application increased the grain protein. Each 30 pound increment increased grain protein a little less than one percent, about 0.8%. Yield was not increased; however, grain protein was increased statistically significant.

Nitrogen Treatment	Grain Yield	Grain Protein
	Bu/acre	%
Nora, Hard Red Spring Wheat		
0	97.1	10.8 b
30	96.7	11.5 ab
60	104.1	12.3 a
Average	**99.3**	**11.5**
LSD, 10%	**NS**	**0.92**

Table 3. Effect of Heading Nitrogen on Grain Protein, Nora HRS spring wheat and WB881 durum wheat. Trial located beside the Jorge Trial.

Another trial, this one with two wheat cultivars. Yield was not affected by at-heading nitrogen application. Grain protein was increased and was statistically significant. In this trial, grain protein was increased more than one percent for each 30 pound/acre application.

Nitrogen Treatment	Grain Yield	Grain Protein
	Bu/acre	%
Nora, Hard Red Spring Wheat		
0	118.4	11.2
30	113.0	11.8
60	115.4	13.2
Average	**115.6**	**12.1**
LSD, 10%	**NS**	**0.40**
WB881, Durum Wheat		
0	95.6	11.8
30	81.9	13.1
60	86.4	14.1
Average	**88.0**	**13.0**
LSD, 10%	**NS**	**0.34**

Summary:

In each trial, grain protein was statistically improved by heading application of nitrogen. Heading applications of nitrogen will not always improve grain protein. Excess nitrogen that is still available after heading will limit the protein response.

Similar trials will be conducted with malting barley next year. Sticking my neck out, I say that malt barley will respond similarly; and heading nitrogen applications would improve grain protein when it might be too low for the premium offered. Of course, heading applications could increase barley grain protein to a level too high for the premium.

Notes:

Understanding Alfalfa Winterkill

Dr. Dan Undersander
Extension Forage Specialist, University of Wisconsin, Madison

Alfalfa is a significant economic crop in much of the United States. Severe winter kill can affect millions of acres. Perhaps more importantly, winterkill can devastate localities when high percentages of acreage are affected within a region. Global climate change modeling suggests increased frequency and severity of alfalfa winter kill and injury in future years because of less reliable autumn hardening conditions coupled with reduced snow cover; both key factors in alfalfa winter hardiness (Bélanger et al., 2002). As a result, understanding the physiological and morphological basis of alfalfa winter hardiness and freezing tolerance and the environmental factors that affect these traits are key to successful future production.

Physiological Basis of Winter Survival

Alfalfa winterhardiness is determined to a large extent by its freezing tolerance. Current thinking is that the plasma membrane (around the perimeter of the cell, just inside the sell wall) is the primary site of freezing injury and maintenance of the semi-permeability of cell membranes after a freeze-thaw cycle is needed for plant survival.

Since freezing within cells is lethal, cold-adapted plants have evolved mechanisms to allow either supercooling of the cell solution (cooling below 32°F without freezing) or to initiate ice formation in extracellular (outside the cell) spaces rather than inside the cell. It is thought that freezing damage is largely a result of extracellular freezing that dehydrates unfrozen cells and ultimately kills them (Pearce, 2004). It is estimated that at -1.5°F, which cold-acclimated alfalfa can tolerate for short period of time, about 90% of cell water has been lost with a corresponding reduction in cell volume (Pearce, 1988). The similarity of responses to freezing and desiccation is supported by observations that limited desiccation can increase freezing tolerance of plants.

In some cases, damage may occur when extracellular ice grows and crushes tissues causing damage.

Both dehydration or cell rupture from crushing can cause membrane breakdown during the thawing process which releases toxic compounds from the vacuole (storage organ of cell) which kills the tissue. This is why plants often look healthy until spring greenup.

Theories relating winter injuries to the dehydration of the plasma membrane or the damaging effects of the concentration of intracellular solutes in the unfrozen cell solution are still being debated. Regardless of the exact mechanism, it is known that cold-induced desiccation will affect the functioning of macromolecules (enzymes) and will solidify membranes. Consequently, superior cold tolerance of alfalfa relates to factors controlling the location, the growth rate and the propagation of ice within the plants and among molecular changes that will help stabilize membranes and proteins in the dehydrated state.

Low temperature-induced accumulation of soluble sugars increases cold tolerance in plants. Root and crown starches breakdown to produce sugars which reduce winter injury (Cunningham et al., 2001). Sugars, such as sucrose, reduce the amount of water lost during extracellular freezing and may help stabilize larger molecules and membranes within the cell. Raffinose-based polysaccharides may protect cells by creating of a glassy state that helps protect macromolecular structures in desiccated cells and they may help stabilize membranes by directly interacting with phospholipids of the membrane.

While higher levels of sugars and polysaccharides increase winter survival of fall defoliated plants, this is likely only one of several winter survival mechanisms since selection for greater winter hardiness does not always result in accumulation of sugars, proteins, and amino acids in all genetic backgrounds (Weishaar et al., 2005).

Free amino acids also accumulate in taproots and crowns during cold acclimation of alfalfa (Hendershot and Volenec, 1993). The amino acid, Proline, has been shown to accumulate but whether it confers stress tolerance or is a consequence of stress is being debated. Proline has been reported to mediate osmotic adjustment, scavenge free radicals, stabilize macromolecular structure stabilizer, buffer redox potential and serve as a nitrogen source in stressed cells. Concentrations of the amino acids, Arginine and Histidine, also increase in alfalfa taproots during cold acclimation in autumn.

The hardening process of alfalfa (described later) will result in increased lipids. These lipids are primarily polyunsaturated linoleic and linolenic acids, which have a lower melting point that saturated fatty acids. Phospholipids (constituents of membranes) also increase. Increased unsaturated phospholipids reduce the temperature at which the cell membrane will solidify. When the membrane turns solid it loses integrity and leaks cell compounds. Cells with solidified membranes will usually die.

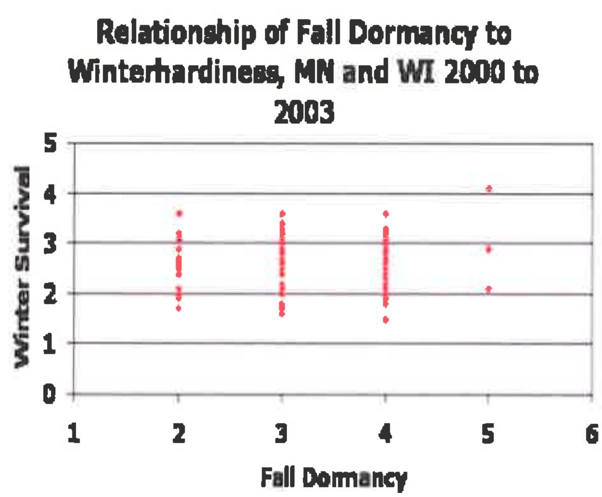
Cold acclimation increases also promotes resistance to low-temperature pathogens (Griffith and Yaish, 2004).

Morphological Basis of Winter Survival

Deeper-set crowns of fall-dormant alfalfa cultivars, when compared to the shallow-set crowns of non-dormant cultivars, is thought to be a key morphological trait preventing exposure of overwintering tissues to sublethal temperatures (Smith, 1952). While differences do exist, this is seldom quantified and largely unknown from most commercially available varieties.

Winterkill can also result from heaving where repeated soil freezing and thawing, usually during the spring, can cause crowns and the upper portion of the taproot to be pushed out of the soil. This results in tissue exposure to air temperatures with little or no insulating from the soil. It may also cause the taproot to break off if heaving is over 1 inch. Heaving is caused by ice crystals forming in the soil of shrinking and swelling clays. This repeated expansion and contraction of the soil push the crowns (and fence posts and other things) out of the soil. Heaving is more likely to occur where the soil is more exposed to daily temperature variation, so residue can reduce heaving. Fibrous roots crops (grasses) mixed with the alfalfa will also reduce heaving. Since the taproot nature of alfalfa makes it more susceptible to heaving, factors such as branch rooting, smaller plant size (worse for large crowns), and resistance to *Aphamomyces euteiches* Drechs (which prunes branch roots) can reduce heaving.

Fall dormancy is the morphological trait most associated with alfalfa adaptation in northern latitudes. Non fall-dormant cultivars grow tall in the fall, while more fall dormant varieties remain shorter. In fact, the test for fall dormancy is to cut the alfalfa in early September, to measure plant height 25 to 30 days later and then to rate dormancy from 1 to 11 based on regrowth height relative to a series of checks. However, both shoot growth rate after cutting and yield are higher in less dormant varieties, so we want the least dormancy we need to survive the winter. For this reason plant breeders have been striving to break the relationship between fall dormancy and winterhardiness. Correlations between winter hardiness and fall growth span from none to strong. The results of experiments such as that of Schwab et al. (1996), in which cultivars from throughout the spectrum of winter hardiness were



evaluated, show that a negative phenotypic correlation between autumn plant height and winter injury is evident. Our data suggests that over the narrow range of fall dormancy 2 to 4, which we are likely to plant, there is currently little relationship between fall dormancy and winter survival (graph above).

However we know little about the mechanism of fall dormancy. We do know that dormant cultivars harden up to 3 times faster than non-dormant cultivars (Kanneganti et al., 1998a, b). We know that hardening initiates at crown temperatures of 60°F, with maximum hardening rate occurring between 40 and 50°F. Hardening is enhanced by fluctuating temperatures with highs around 50°F and low temperatures near freezing. De-hardening occurs at temperatures greater than 60°F and when soil temperature at 2 to 4 inches is above 40°F.

It is also important to realize how much the plant hardens for winter varies from year to year because hardening is a function of both the plant's genetic potential for hardening and whether or not proper weather conditions occurred for optimum hardening. So, in some winters, plants may be more or less hardened than other years depending on the fall weather.

In addition we should recognize that buds for growth the next spring are formed in the fall. If many of these are killed, the plant may live but need to form new buds. The need to start over delays spring growth and total season yield. The table shows that, when fall cutting was taken, yield of the cutting next spring was reduced. Winter injury resulting in killed buds can usually be diagnosed by two heights of growth: A few stems will come out early (from buds that survived the winter) and many stems will come later being about 3 to 4 inches shorter than the early stems. If you often see two heights of stems in the spring, consider more winterhardy varieties.

Table 1. Effect of fall cutting on yield next spring, Arlington, WI

Year	Fall Cut Date	Yield		
		Fall	Spring	Difference
		----------tons/acre----------		
1986-87	Sept 30	0.72	2.23	0.78
	Oct 15	0.71	2.45	0.56
	Oct 30	0.55	2.59	0.55
	None	----	3.01	----
1987-88	Sept 30	1.04	2.17	0.31
	Oct 15	0.88	2.36	0.12
	Oct 30	0.85	2.44	0.04
	None	----	2.48	----

*difference from spring yield of fields uncut in fall (3.01 or 2.48 t/a, respectively)

Data from R. Walgengach, USDA-ARS

Environmental Factors affecting Alfalfa Winter Survival

Temperature changes appear to be the primary factor leading to the development and maintenance of alfalfa cold hardiness. Cold temperatures increase the respiration of taproots. Cold acclimation begins in autumn when the mean air temperature approaches 50°F and the accumulation of freezing tolerance accelerates as temperatures approach 40°F.

However, the greatest winterhardiness occurs when cool temperatures are accompanied by short photoperiods (daylength). Both decreasing photoperiod and declining air temperatures lead to fall dormancy and increased winterhardiness. Rapid changes in photoperiod that occur in very Northern latitudes like Alaska are not recognized properly by cultivars adapted to regions located in the continental U.S., and these plants do not cold acclimate or survive winter even though other conditions (temperature) are appropriate. Thus, rate of photoperiod change appears to be more important than length of photoperiod in initiating cold acclimation.

Diseases can reduce alfalfa winterhardiness and survival, though the mechanisms are poorly understood. Bacterial Wilt, Fusarium, Brown Root Rot, and Verticillium have all been reported to interact with winter to reduce stands. We often see alfalfa get infected with a disease over summer and then die from winterkill due to the plant's weakened state. In addition, certain diseases, such as Brown Root Rot, are particularly injurious in cold weather.

Poor drainage is known to reduce alfalfa persistence (Benoit et al., 1967). As tile line spacing decreased from none to 61 m to 31 m, winter kill concomitantly declined from 87 to 62 to 44%. Poor drainage results in wetter soils that are colder and more conducive to disease growth.

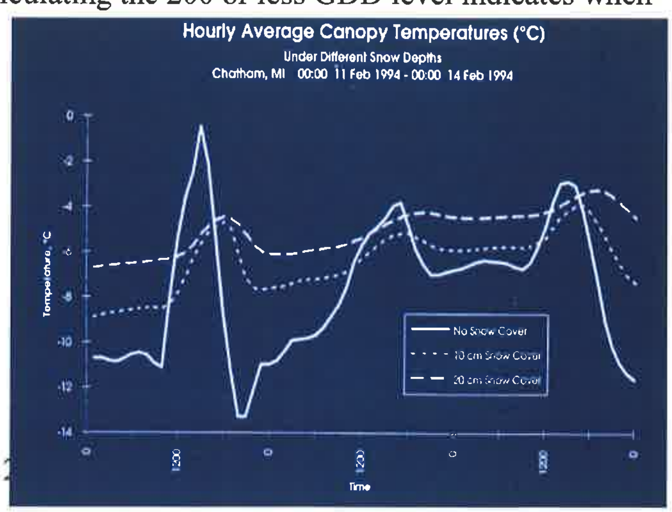
Poor drainage on the soil surface forming ice sheets can quickly result in alfalfa death in winter. Encasing alfalfa in ice for 20 to 50 days or more can completely kill the plants. Injury is caused by accumulation of CO_2 and limitation of O_2. Ice sheets are barriers to CO_2 diffusion, permitting this gas to accumulate to levels that are toxic to alfalfa. Fall dormant cultivars were found to be more tolerant of ice encasement than were non-dormant cultivars. This differential survival may be due to higher rates of respiration in non-dormant causing injurious levels of CO_2 to be reached sooner than in fall dormant cultivars.

Soil pH and plant nutrition, and especially potassium application, is one management factor that improves alfalfa winter hardiness. Plants with adequate nutrition grow better and have greater levels of root reserves. Some have reported low taproot protein concentrations were associated with high winter killing under low pH conditions. Potassium may also be involved in the protection of plant proteins.

Autumn cutting strategies impact alfalfa winter survival. Willard (1930) was among the first to propose that a period of uninterrupted growth in autumn was necessary for winter survival in Ohio so taproot reserves could accumulate prior to the onset of winter. Other work has shown that plants cut in September had fewer crown buds, fewer stems and lower yield the next spring than plants left uncut or those cut in October.

Total nonstructural carbohydrates in the roots have long been associated with alfalfa winter survival. However the data supporting this is sparse. While recent work confirms that root total nonstructural carbohydrate (TNC) concentration is not a good indicator of the genetic potential for freezing tolerance, other taproot constituents, including individual soluble sugars that comprise the root TNC pool and several N pools, are better related to freezing tolerance (Castonguay et al., 1995; Cunningham, 2001). Therefore, alfalfa winter hardiness and freezing tolerance may be more related to components of TNC rather than total TNC.

With regard to this we need to allow the growth cycle to build root reserves. These reserves are high at cutting and then decline until the alfalfa has reached a regrowth height of 6 to 8 inches. Alfalfa must either be cut early enough in the fall to regrow and replenish root carbohydrates and proteins or so late that the alfalfa does not regrow or use any root carbohydrates, if we want good winter survival. This has resulted in the recommendation of a 'no-cut' window from about Sept 1 to killing frost. In this regard, Dhont et al. (2003) have suggested that growing degree days of less than 200 or more than 500 are optimal for winter survival. The concept being that that alfalfa needs 500 growing degree days (GDD, base 41°F accumulated until a killing frost of 25°F) after the last cutting to regrow sufficiently for good winter survival and yield the next year. This means we can cut in the fall as late as 500 GDD will still accumulate without hurting the winter survival. Calculating the 200 or less GDD level indicates when insufficient fall alfalfa regrowth has occurred to use up root carbohydrates. These plants would also have good winter survival. We have been testing this in Wisconsin and find that it works well.



In addition, a relatively small amount of snow can provide good insulation as shown in the graph at the right. This snow will keep the soil warmer than daily low air temperatures. It will also keep the soil from warming up as rapidly so that dormancy is not lost during a short warm spell over winter. Value of snow in alfalfa winter survival is the reason we often have more winterkill when winters are 'mild' and less snow occurs.

In summary, alfalfa winterhardiness, ice sheeting, and diseases can all kill alfalfa during the winter. Genetic differences exist for differing levels of winterhardiness. Some management will reduce winter injury or kill. The attached score sheet will allow us to score our risk of winter injury and kill. However, we must remember that these factors are only beneficial over the middle range of winters and some winters will be so severe that alfalfa dies no matter what is done.

References

Bélanger, G., P. Rochette, Y. Castonguay, A. Bootsma, D. Mongrain, and D. A. J. Ryan., 2002. Climate change and winter survival of perennial forage crops in Eastern Canada. Agron. J. 94:1120-1130.

Benoit, G. R., K. D. Fisher, and J. Bornstein. 1967. Alfalfa survival-indicator of sloping land drainage effectiveness. Agron. J. 59:444-447.

Castonguay, Y., P. Nadeau, P. Lechasseur, and L. Chouinard. 1995. Differential accumulation of carbohydrates in alfalfa cultivars of contrasting winter hardiness. Crop Sci. 35:509-516.

Cunningham, S. M., J. A. Gana, J. J. Volenec, and L. R. Teuber. 2001. Winter hardiness, root physiology, and gene expression in successive fall dormancy selections from "Mesilla" and "CUF 101" alfalfa. Crop Sci. 41:1091-1098.

Dhont, C., Y. Castonguay, P. Nadeau, G. Bélanger, and F. Chalifour. 2003. Alfalfa root nitrogen reserves and regrowth potential in response to fall harvests. Crop Sci. 43:181-194.

Griffith, M., and M. F. W. Yaish. 2004. Antifreeze proteins in overwintering plants: a tale of two activities. Trends Plant Sci. 9:399-405.

Hendershot, K. L., and J. J. Volenec. 1993. Taproot nitrogen accumulation and use in overwintering alfalfa. J. Plant. Physiol. 141:68-74.

Kanneganti, V. R., C. A. Rotz, and R. P. Walgenbach. 1998a. Modeling freezing injury in alfalfa to calculate forage yield: I. Model development and sensitivity analysis. Agron. J. 90:687-697.

Kanneganti, V. R., W. L. Bland, and D. J. Undersander. 1998b. Modeling freezing injury in alfalfa to calculate forage yield: II. Model validation and example simulations. Agron. J. 90:698-704.

Pearce, R. S. 1988. Extracellular ice and cell shape in frost-stressed cereal leaves: A low temperature scanning electron microscopy study. Planta 175:313-324.

Pearce, R. S. 2004. Adaptation of higher plants to freezing. pp 171-203 *In* B. J. Fuller, N. Lane and E. E. Benson, eds. Life in the frozen state. CRC Press, Boca Raton, USA.

Schwab, P. M., D. K. Barnes, and C. C. Sheaffer. 1996. The relationship between field winter injury and fall growth score for 251 alfalfa cultivars. Crop Sci. 36: 418-426.

Sprague, M. A., and L. F Graber. 1943. Ice sheet injury to alfalfa. Agron. J. 35:881-894.

Weishaar, M. A., E. C. Brummer, J. J. Volenec, K. J. Moore, and S. M. Cunningham. 2005. Improving winterhardiness in nondormant alfalfa germplasm. Crop Sci. 45:60-65.

Willard, C. J. 1930. Root reserves of alfalfa with special reference to time of cutting and yield. Agron. J. 22, 595-602.

Table 13. Calculating Your Risks of Injury (Following Page)

Table 13 Calculate Your Risk of Winter Injury

1. What is your stand age?			
> 3 years		4	
2 to 3 years		2	
≤ 1 year		1	0
2. Describe your alfalfa variety:			
A. What is the winterhardiness?			
Moderately winterhardy (ws score 4)		3	
Winterhardy (ws score 3)		2	
Very Winterhardy (ws score 2)		1	0
B. What is the disease resistance?			
Moderate resistance to only bacterial wilt		4	
Moderate resistance to Bacterial wilt plus either Anthracnose, Fusarium wilt, phytophthora root rot, or Verticillium wilt		3	
Moderate resistance to all above mentioned diseases		1	0
Alfalfa variety total score (multiply two)			0
3. What is your soil pH?			
≤ 6.0		4	
6.1 TO 6.5		2	
≥ 6.6		0	0
4. What is your soil exchangeable K Level?			
Low (≤ 80 ppm)		4	
Medium (80 to 120 ppm)		3	
Optimum (120 to 160 ppm)		1	
High (≥ 161 ppm)		0	0
5. What is your soil drainage?			
Poor (somewhat poorly drained)		3	
Medium (well to moderately drained)		2	
Excellent (sandy soils)		1	0
6. What is you soil moisture during fall/winter?			
Wet		5	
Medium to dry		0	0
7. Describe your harvest frequency:			
Cut interval	**Last Harvest**		
< 30 days	Sept. 1 to Oct. 15	5	
	After Oct. 15	4	
	Before Sept. 1	3	
30 to 35 days	Sept. 1 to Oct. 15	4	
	After Oct. 15	2	
	Before Sept. 1	0	
> 30 days	Sept. 1 to Oct. 15	2	
	After Oct. 15	0	
	Before Sept. 1	0	0
8. For a mid to late October cut, do you leave more than 6 inches of stubble?			
Yes		0	
No		1	0
Determine your total score (sum of points from questions 1 to 8)			0

Fall cutting Risk	
If you score:	**Your risk is:**
3 to 7	low
8 to 16	moderate
17 to 27	high
28 or more	very high

Reseeding Old Alfalfa Stands to Reduce Winterkill Losses

Dr. Dan Undersander, Extension Forage Specialist, University of Wisconsin

The major problem when alfalfa is winterkilled is the issue of alfalfa autotoxicity. Many truths and half-truths exist about the autotoxicity of alfalfa. Autotoxicity is the production of compounds(s) by existing plants that reduce seed germination or forage productivity. Autotoxicity may occur either when alfalfa is seeded into an existing stand to thicken it or into a field previously seeded to alfalfa. We will discuss autotoxicity first than consider some planting options.

The reason this trait originated in alfalfa is thought to be a result of environmental selection. Alfalfa originated around the northern coast of the Mediterranean which was a hot, dry desert when perennial alfalfas were evolving. Development of the autotoxic trait may have reduced competition from nearby new seedlings for scarce soil moisture.

While the chemical(s) responsible for autotoxicity are not conclusively identified, we know the autotoxic compound has the following characteristics:

1. It is extractable from fresh alfalfa herbage and not a product of microbial action,
2. It is water-soluble,
3. It is more concentrated in alfalfa herbage than in roots,
4. It delays germination,
5. It inhibits of alfalfa root growth causing swelling, curling, and discoloration of the root, and lack of root hairs,
6. It reduces alfalfa root growth more than it reduces seed germination.

The best evidence suggests that the chemical, medicarpin, may be a primary cause. However some of the characteristics observed for autotoxicity do not seem to be associated with medicarpin.

It is well recognized that autoxicity causes stand failure when alfalfa is planted too soon after old alfalfa. Often, autotoxicity is mistakenly not considered to be a problem if the new alfalfa stand becomes well established but does not yield or persist well. These growers fail to recognize these factors also may be the result of autotoxicity. Research suggests that the negative effects of autotoxicity may linger, causing unnoticed long-term reductions in plant stands and yield.

We also know that soil texture plays a significant role in autotoxicity. Extracts made from alfalfa topgrowth containing the autotoxic chemical passed more rapidly through leaching columns of sandy soil than through columns containing silty clay loam. Fractions of the leachate that passed through the columns were collected and added to petri dishes containing alfalfa seeds. Approximately fifty percent more water was required to move the extracts through the silty clay loam compared to the sandy soil. The autotoxic effect on root growth was stronger (reduced root growth more) in the sandy soil, but persisted longer for the silty clay loam.

This suggests that in the short term autotoxicity may be more severe in sandy soils. However, with irrigation the autotoxic factor may be leached out of the root zone more easily in sandy soils than in soils of heavier texture. This practice has been used successfully in Kansas and Nebraska where sandy fields are irrigated heavily after killing the old alfalfa, but before planting the new stand. Further research is needed to determine the amount of rainfall or irrigation needed for different soil textures to allow shortened rotation intervals.

Work in New Hampshire and in Michigan showed that alfalfa could be successfully established after alfalfa by killing the old stand with herbicide and planting after a two or three week interval.

Autotoxic effects were observed in both studies if alfalfa was seeded less than two weeks after killing the old stand.

In Wisconsin, it was observed that when the old alfalfa stand was plowed in the fall and reseeded the following spring, plant density of the new stand was acceptable, but dry matter yield was poor compared to alfalfa planted after a rotation with corn.

By contrast, research in Illinois and Wisconsin showed that a one year rotation with corn gave the best stands and yields of alfalfa following alfalfa compared to reseeding after shorter intervals.

In Missouri, alfalfa seeded after old alfalfa using rotation intervals of 2 weeks, 3 weeks, 6 months, 12 months, and 18 months produced the highest plant stands and dry matter yields for 12- and 18-month rotations. Plant density of the 2-week and 3-week rotations were 13-20% lower compared to the 18-month treatment and yields were up to 8% lower. A yield reduction of 8% over the life of an alfalfa stand can be quite significant. The 6-month treatment had stands near equal to the 12-and 18-month treatments, but had low yield, similar to the results of the Wisconsin study. Plants dug from the 2- and 3-week rotation plots had extensively branched roots with little taproot development. Plants from the 12- and 18-month plots had prominent taproots typical of normal alfalfa plants. Exposure to the autotoxic chemical may have inhibited taproot growth, but plants survived by producing branch roots. The ranking for plant density and yield during the seeding year remained for the following 3 years. The longest rotations had the greatest plant stand and the shortest rotations had the lowest plant stand. Plant density declined in all the rotation treatments at the same basic rate, however the ranking remained the same for three years.

There is some evidence that the yield penalties to alfalfa performance planted after alfalfa may not be as great in these areas as in other regions. In a replicated study at Davis, CA, no differences in stand or yield was found when alfalfa was replanted 2 or 4 weeks after the incorporation of a 4-year alfalfa stand into a clay-loam soil, compared with fallow controls. A reduction in stand was observed when alfalfa was replanted immediately or 1 week past plowdown. No significant yield reduction was observed during the first four harvests with any alfalfa-alfalfa treatment compared with fallow-alfalfa controls. This occurred both in spring (April) and fall (September) plantings, and it should be noted that date of seeding had a much greater effect on stand establishment and yield than did presence or absence of the previous alfalfa crop

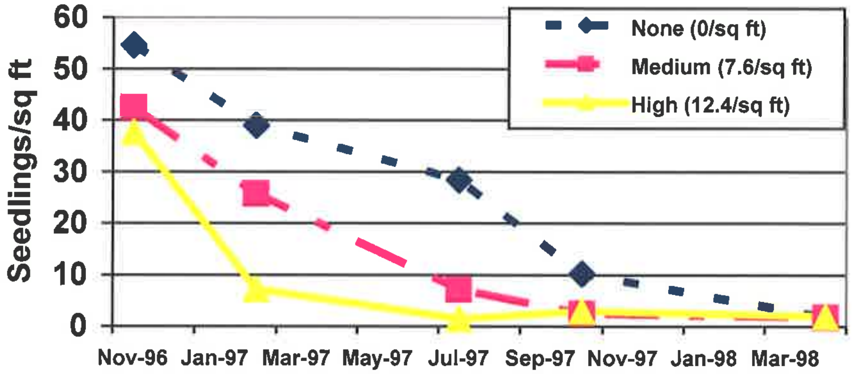
In western Nebraska under center pivot irrigation on sandy soils, growers similarly are interested in returning a field quickly to alfalfa production. In those areas, where soil erosion is a significant factor, an effective back-to-back alfalfa system is to destroy old alfalfa in late spring (often after first cutting) with tillage or preferably herbicide, seed foxtail millet for a quick hay crop, and then no-till alfalfa into the millet stubble in mid- to late August. On non-irrigated soils, 30 days completely out of alfalfa usually is sufficient, but at least half a growing season is preferred. Growers can destroy the old alfalfa crop in early spring for an August seeding or destroy in fall for a spring seeding.

Reseeding into alfalfa to thicken it has been reported. Some popular press recommendations from Kansas have been to apply high rates of seed-treatment fungicides. Frequent irrigation of the new alfalfa on sandy soils may have contributed more to the successful interseeding than did the fungicide, since later research studies in Kansas and in Iowa failed to support this recommendation.

These studies indicate that seedling disease may not be the primary cause of stand failure when attempting to thicken old alfalfa stands. In previous research we observed that old alfalfa plants appear to develop a zone of influence around them in which establishment and growth of new seedlings are inhibited. If the effect and size of this autotoxic zone could be determined then thickening old stands might be possible when old plant density declines below a critical level.

Typical results of overseeding alfalfa into existing alfalfa stands are shown in Figure 1 conducted on a grower's field near Sacramento, CA on a loamy clay soil. Alfalfa was seeded into spots of varying existing alfalfa stand densities (0, 7.6 and 12.4 plants per square foot) in four replications. Stand counts in November showed a very high initial success rate of 38 to 55 new seedlings per square foot, depending on the existing stand density. In the first production year (1997), it appeared as if the seedlings in open areas had survived, and were helping to 'fill in' the bare areas of the field. However, upon closer scrutiny, the growth of the overseeded plants was minimal and they did not contribute much to the overall forage production. In late summer, there was a precipitous drop in population of the new seedlings, especially in the previously 'open' areas. A year after the overseeding attempt, there was very little impact of the overseeded plants on stand and likely not on yield. These results are typical of those observed in the eastern United States as well.

Fig 1. Seedling counts in 2 yr old alfalfa of varying densities, Sacramento, CA



Experiments to determine the size of the autotoxic zone around and alfalfa plant have shown that seedling density and yield of alfalfa was strongly inhibited within an 8-inch (20-cm) radius of the old alfalfa plant. A zone of this size would mean that the old stand would have to have a plant density of less than 0.8 plants per square foot before new plants could establish between the zones successfully. New seedlings emerging within the autotoxic zone of the old plant still would not likely contribute to yield.

Considering the above, management strategies that eliminate existing alfalfa plants and residue can improve establishment of new alfalfa. The time required for breakdown of alfalfa residue in soil and subsequent removal of the autotoxic chemical from the root zone may vary with soil type and management. It appears that with irrigation and light soils, we may be able to reseed in 4 to 5 months. On heavier soils seeding sooner than a year will result in reduced alfalfa yield for the life of the stand.

Therefore, the best management is to remove all alfalfa reside, to till, and to plant an annual for the summer growing season. The choices are limited but a few exist:

1. Plant a summer small grain (perhaps hard red spring wheat or spring barley) and have it custom harvested. This will provide some cash income and allow transport to where a market exists. Be sure that a market exists before planting this.
2. Since the region is based on forage, it seems reasonable to consider alternative forages:
    a. Oats or triticale with small grains. Seed at 1 to 2 bushels of the small grain and about 50 lb of the peas. This crop grows fast and will produce 2 to 4 tons of high quality dry matter. It should be harvested at the boot stage of the oats for dairy and at soft dough for beef and dairy heifers. This is a common dairy feed in the Midwest and some dairies might be willing to substitute for alfalfa (check first)
    b. Italian ryegrass at seeded at 20 lbs/acre will produce high quality forage for the dairy or horse industry.

c. Italian ryegrass seeded with crimson or red clover. Seed at 12 lbs ryegrass and 6 lb clover. It will produce a high quality dairy feed with some legume that dairymen are familiar with. This would also be excellent for the horse industry.

d. Foxtail millet or sudangrass seeded at 20 lb/acre, can produce a good high quality dairy feed, though most dairymen would resist feeding it to the milking cows.

Notes:

(This space left blank for your notes)

Alfalfa Management to Prevent Winterkill

Richard Sparks, NRCS Agronomist, CCA 13131
January 2007

Alfalfa stands tend to decline over time. This decline is normally gradual; the number of plants decreases each year due to various causes. One of the most common causes of stand deterioration is crown and root diseases. As alfalfa plants with poor pathogen resistance die out, yields temporarily remain high due to increased numbers of tillers on the remaining plants. Eventually, however, thin stands yield significantly less and are invaded by more and more competitive weeds, such as dandelions, shepherds purse, foxtail and quack grass.

Management to extend the life of alfalfa stands include planting more resistant varieties, maintaining soil fertility, insect and weed control, and slowing pivots down to apply heavier less frequent irrigations.

Winter kill strikes San Luis Valley alfalfa

BY RUTH HEIDE
For some, it is total loss........
Pueblo Chieftan, May 6, 2006

Winter kill, in contrast to normal stand deterioration, is the sudden death of relatively healthy alfalfa plants due to freezing of crown tissue that has not gone into full dormancy.

This occurs in the San Luis Valley of Colorado when warm temperatures permit alfalfa to continue to try to grow late into November & December, followed by a sudden drop in temperatures when no protective snow cover is present.

The winter kill in 2006 is a tragic example. Almost 90% of alfalfa stands lost their first set of tillers when air temperatures plunged to 10 – 15 below zero in January. A few stands survived to produce fair second cuttings; however, most stands were irreversibly damaged and will need re-establishing. All new seedling stands were killed. Observations of alfalfa stands and individual plants that survived can guide us into management techniques that may prevent winterkill.

Management techniques can be categorized as follows:

Managing Alfalfa Dormancy

:

1. **Planting more dormant alfalfa varieties**: While greater dormancy helps, using dormancy 2 costs some yield in three cutting systems. Dormancy 2 varieties such as Vernal stop growing in September. In 2006, this made little difference due to the severity of winter kill. However, alfalfa with a fall dormancy of 1, such as *Spredor 3*, did show a significant improvement in survival yet still lost much of the first cutting.

> ***Recommendation 1: Plant more dormant alfalfa varieties (a dormancy rating of 3 or less).***

2. **Hardening off alfalfa stands prior to winter**: Warmer fall and early winter temperatures and more frequent irrigations result in continued fall growth and delayed dormancy. This reduces winter "hardening" or "acclimation" of the alfalfa plants essential for winter survival. Hardening prepares the plants to withstand freezing injury by decreasing water content, increasing root carbohydrate and protein, and converting starch to sugar.[1] More dormant varieties do decrease their freezable water content and accumulate more solutes (especially potassium) in the cell sap as they harden off in the fall.[2] This natural "antifreeze" prevents ice crystals from forming and destroying the crown cells

One interesting observation in the spring of 2006 was alfalfa stands that had been drought stressed in 2005, and were not irrigated at all prior to going into the winter **did not winterkill**. They were not still trying to grow in December prior to the sudden drop to below zero temperatures and they did NOT suffer the severity of winterkill. This was especially noticeable in alfalfa stands where nozzles were plugged, or pattern overlap was inadequate, and in the end gun areas.

This leads me to my second management recommendation: Fall irrigation should be delayed until temperatures are cold enough that dormant or semi-dormant alfalfa will not resume growth (a mean daily temperature of around 40 degrees F).

Recommendation 2:
Avoid continuing irrigations on alfalfa stands in October following the third cutting. Allow alfalfa to gradually withdraw soil moisture as it goes into dormancy.

Managing Severity of Freezing:

The severity of freezing can be mitigated, however, by the timing of a final irrigation in November. Growers that applied ½ inch of irrigation water in the latter part of November in 2005 prevented winterkill the following January 2006. This was likely due to moisture in the soil freezing, rather than the water in the alfalfa crowns freezing. It became a "shock absorber" as temperatures plunged suddenly.

Recommendation 3:
Apply at least ½ inch irrigation water on dormant alfalfa in November, especially on coarser textured, loams and loamy sand soils.

The insulating effect of snow will prevent winterkill but this is obviously beyond the control of the grower The insulating effect of air in the soil surface also reduces the depth of severe freezing. "Ice sheeting"[1] (the melting of snow and refreezing on the surface) eliminates the insulating effect of the air that otherwise would be present in the soil surface in the northern states, and results in winter killed alfalfa. Ice does not have sufficient air to insulate the alfalfa crowns. To avoid the same problem in the San Luis Valley, the last irrigation in November or

December must be during warm periods and on unfrozen soils to ensure sufficient time for gravitational water to move through the soil profile before freezing.

Recommendation 4:
Avoid irrigations that pond water on the soil surface when soils are frozen. This is especially critical when irrigating alfalfa on heavier textured clay loam soils.

The condition of the field in the fall of the year also has a significant effect of reducing winterkill. Soils compacted during harvest operations will freeze deeper. Compaction reduces the air present in the soil surface, and allows the depth of freezing temperatures to penetrate deeper into the soil.

Fields that have adequate stubble height tend to insulate alfalfa crowns and have the added benefit of keeping snowfall in place rather than drifting and exposing bare areas. Grazing alfalfa in the fall should be carefully monitored to avoid too much removal of the stubble. Compaction from grazing can also be reduced by making sure soil surface is dry when being grazed.

Recommendation 5:
Minimize compaction from windrowing, baling and hauling hay when soil is too wet.

Recommendation 6:
Avoid grazing alfalfa stubble when soils are too wet.
Avoid removal of too much alfalfa stubble by grazing.

Depth of dry, uncompacted soil cover over the crowns mitigates the severity of freezing. Crowns and crown buds that were deeper than 1.5 to 2 inches generally did not freeze. One grower had broadcast sand and gravel in deep wheel tracks. Spillage of this material onto adjacent alfalfa plants prevented winterkill. Also, deeper crowns are better protected from freezing. I would like to suggest drilling alfalfa at ½ inch deep in the bottom of 2 inch deep drill furrows. Deep furrow drills are not typically available in SLV, but would offer potential for more soil cover over the crowns. Depth of crown set may also be genetic, and warrant research into varieties that set crowns deeper.

Recommendation 7:
Research is needed into alfalfa seeding techniques and varieties that will lead to deeper crowns.

References

[1] Joel Bagg - Forage Specialist/OMAF, Ministry of Agriculture, Food and Rural Affairs, Ontario, Canada

[2] Darrin Haagenson, Graduate Research Assistant
Department of Agronomy, Purdue University

Biofertility and Biopesticides for Improving Crop Quality

Michael T. Holmes[1], Brett Leyshon[2], Lance Funk[2] and Ernie Myers[3*]

1 Holmes ENVIRO, LLC, 2876 West Hills Rd., Philomath, OR 97370. (541) 760-1161
2 NuEarth, LLC, 2965 Fairground Rd., American Falls, ID 83211. (208) 226-5551
3 Mountain Valley Seed, 3501 County Rd. 53, Center, CO 81125. (719) 754-2139

Summary

One future direction of production agriculture may be to include microbial inoculants that stimulate specific plant growth responses and disease reduction. In this study, the inoculants were considered to be biofertility agents or biopesticides. Using an Open Source Management approach, biofertility and biopesticides were combined with conventional practices in field trials throughout the Pacific Northwest. General trends in plant growth, yield and crop quality were determined after treatments with microbial inoculants. Limitations of biopesticides for fungal disease suppression were noted to avoid unwarranted risk to growers.

Introduction

The benefits of soil organisms have been well studied and many groups that benefit plant growth have been isolated over the past 30 years. The importance of a specific group of microbes referred to as Plant Growth-Promoting Rhizobacteria (PGPR) have been the focus of researchers worldwide. The PGPRs may colonized the surface and intercellular regions of plant roots, then stimulate hormones (IAA) for root production or induce systemic resistance (ISR) to biotic and abiotic stress.

More recently, PGPRs and selective fungi are being investigated as biopesticides or biocontrol agents of crop diseases. Antibiotic production is one mechanism inwhich PGPRs like *Pseudomonas fluorescens* can reduce soil borne disease. Another mechanism that fungi like *Trichoderma atroviride* can reduce root rot disease is by direct parasitism and chitinase production. When plants are under attack by disease (biotic) or drought (abiotic) stresses, some PGPRs can stimulate ISR pathways thereby helping the plant to protect itself.

With the combining of new genetic techniques and standard microbiological methods, we can identify the PGPRs that provide the highest benefits to plant growth and their activity in the root zone. After a biological inoculant is added to the soil or plant roots, localization studies indicate that the primary zone of colonization is near the root tips. Other studies indicate that PGPRs can also invade the cortex regions of plant roots and provide benefits such as nitrogen fixation for non-leguminous crops. In addition, the benefits of PGPRs to legumes has been greater nodulation and increased root biomass.

We have begun to establish the economic benefits that PGPRs to production agriculture. The ability of these specific organisms to improve crop yields is well described in the scientific literature but there are few studies that have evaluated the benefits of PGPRs on split field applications and the grade quality of crops. After critical evaluation by academic and industry researchers, there are clear trends that PGPRs may improve the yield and quality of crop.

Methods and applications

A combinations of microbial inoculants and organic extracts were used for root-based and foliar-spray formulations. Pure isolates of PGPRs were grown using standard microbiological methods. The concentrations of bacterial and fungal inoculants were determined by direct microscopy. Combinations of organic extracts such as worm casting and humates were added to each formulation as biostimulants of the microbial inoculants and plant growth.

Applications methods are considered an open-source management because the standard practices remain unaltered and additional costs were avoided. For example, applications of the root treatments may include in-furrow during planting, side-dress, chemigation or drench applied. Successful results have been obtained by mixing the root treatment with some fertilizers and fungicides. If chemical products were considered toxic to the microbial inoculants, application of the inoculant was delayed by 10-14 days. Application methods of the foliar-spray treatments included aerial and sprinklers. The PGPRs appeared to be unaffected by the standard fertility being applied throughout the crop season such as urea or 10-34 fertilizer.

Selective data from the university field tests are presented to better understand some tends and potential benefits of biofertility and biopesticides. Additional field trials were conducted by independent research services. All products were submitted to the researcher and applied based on the manufacturer suggestions. All labels and information regarding the bioproducts can be reviewed at www.nuearthllc.com.

Results and discussion

The benefits of PGPRs to plant growth have been described for more than 20 years in the scientific literature. In most studies a single bacterial species were added to plants and the difference in crop yields determined at the end. Our approach to the commercial development of bioproducts has been to add several of the best PGPRs and organic extracts to field crops, then determine yield, quality and gross returns. We have measured major improvements in early plant growth and the crop quality at harvest.

We present these field test data as the general trends that were observed for potato production during the past three years in the Pacific Northwest. Additional trials in 2004 on 22 potato fields resulted in an average yield increase of 14%. This continues to be the average yield increase for potatoes throughout the United States including Colorado and Michigan to date (data not shown).

In 2004, potato trials at the University of Idaho resulted in an increase of $489/acre based on the contract price of process potatoes (Table 1). These results along with other independent field trials indicate that the primary benefit of PGPRs was an increase of US #1s from 6-10 oz.

Table1: Comparison of Russet Burbank Potato trials using the grower standard program to the biofertility program in which three applications of bioproducts were added.

Treatment & Season	US #1's %	Gross return US $/acre	Increase US $/acre
Grower Std 2004	59.3	1,414	
Biofertility 2004	65.6	1,903	489
Grower Std 2005	76	2,902	
Biofertility 2005	86.4	3,303	401
Grower Std 2006	68.9	2,106	
Biofertility 2006	74.5	2,577	471

In 2005, similar trends of increased of US #1 potatoes and gross returns were measured in the university and independent field trails (Table 1). We also began to observe that the biopesticide components (*Trichoderma atroviride* and *Bacillus subtilis*) alone were not sufficient to control fungal diseases like Early Blight. Additional field trails at Washington State University indicated that the microbial inoculants were not sufficient at controlling potato diseases such as Pink Rot. However, the marketable yield value was increases by the biofertility program when the diseased portion was subtracted from the total crop yield.

In 2006, the biofertility program increased to gross return on potatoes over a standard nutritional program for Idaho (Table 1). In addition, we began to demonstrate the PGPRs could be applied to repair crops after environmental stress like hail damage and drought. In Colorado, many fields treated with the root and foliar formulations continued to grow after sever hail damage.

The response of alfalfa to PGPRs has also been consistent in field trials during the past 5 years. Our applications of the inoculants ranged from seeding of new fields to rejuvenation of established stands in the spring. A larger leaf-size of alfalfa treated with PGPRs can result in higher Relative Feed Values (Table 2). The benefit of PGPRs is most notable for meeting dairy requirements during the mid to late season when the plants become fibrous with more stems.

Table 2. Relative Feed Values of Alfalfa treated with biofertility/PGPRs in Idaho, 2004.

Treatment	1st cut	2nd cut	3rd cut
Untreated-Check	147	172	173
Biofertility	151	184	198

The benefits of PGPRs to corn production have been well described from research and field trials. Selective bacteria such as *Azospirillum* sp. were isolated from sugar cane and continue to perform great when inoculated onto other grass crops. In addition to a significant increase in root biomass, the development of subterminal ears can result in 10 – 14% yield increase on Sweet Corn. The yield increases were is more variable on Field Corn varieties (Table 3) but similar trends in root mass and ear development were observed.

Table 3: Results of Sweet Corn and Field Corn trials in the Pacific Northwest

Field Trial	% Yield increase	comments
Sweet Corn, 2002	13% and 19%	reduce *Fusarium* root rot
Sweet Corn, 2003	10%, 14% and 18%	establish crop in poor soils
Field Corn, 2004	10% and 42%	higher crude protein
Field Corn, 2005	7%	19% moisture

Selective PGPRs have also shown positive results on various other crops including wheat, green beans, peas, small fruits and vegetable seed crops. One mechanism that has been suggested for crop improvements is the ability of PGPRs to influence plant hormone production. The PGPRs can associate with some essential microbes like rhizobia and mycorrhiza thereby improving their synergistic effect. The evidence of their potential for crop improvement is available from studies worldwide.

Finally, we offer many words of caution to growers trying to apply PGPRs and other soil organisms to control plant diseases. Although there is good evidence that PGPRs can reduce plant disease under controlled conditions such as greenhouses and incubators, we have not achieved sufficient disease suppression without including conventional pesticides. The future direction may be to integrate the biofertility and biopesticides with conventional pesticides to obtain maximum benefits.

References

Literature on PGPRs and biopesticides is available online through searches at:
1. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi
2. http://agricola.nal.usda.gov
3. More field test results are available from authors

Choice: Save Water or Save Soil

Richard Sparks, NRCS 2007, NRCS Agronomist, CCA 13131
January 2007

Depending on how you define saving water, there are several options:
IRRIGATION PUMPING: You can reduce the amount of water you pump, if you improve the efficiency of your irrigation system. A pivot that applies water at a uniformity of 95% will require 10% less pumping than a pivot that applies at a uniformity of 85.

REDUCING EVAPORATIVE LOSSES: To save water by reducing evaporation you have several options:

1. Slow the pivot down and wet your soil surface and canopy less frequently. Allow the soil surface to dry out a little better between irrigations. This savings is fairly minor, but does reduce evaporation. You can only slow down to the point that the amount of water being applied is equal to around half of the available water holding capacity of your soil to the crop growth stage rooting depth.
2. Change your nozzle package to apply larger droplets of water closer to the soil surface to reduce evaporation of the water before it hits the crop canopy or the soil surface. This works only where surface movement of water is not made worse by the impacts of large droplets on the soil surface. If the water you apply will not stay where it hits the soil, then the crop yield and crop quality suffers.

CONSUMPTIVE USE: If your definition of water savings is the reduction of crop consumptive use, you really have only one choice. You have got to adjust the crop rotation to include crops that have a lower consumptive use requirement for the entire rotation. **This presentation focuses on that definition of water savings**.

SAVE WATER – POTATO BARLEY ROTATIONS

The long term average yearly consumptive use will be **16.6 inches** after subtracting effective rainfall. Compare a Potato - Sordan rotation. Substituting a Sordan set aside crop that you will apply only 10 inches will reduce the rotation average to **13.3 inches.**

Consumptive use reduced 20% over the two year rotation.

SOIL LOSSES

A Potato - Barley rotation with a good mulch tillage system loses around 19.1 tons per acre per year on a loamy sand soil, and 7.4 tons per acre per year on a gravelly sandy loam soil.

Compare a Potato – Sordan rotation. Substituting the Sordan crop for the barley crop will increase the average annual erosion on the loamy sand soil to 39.4 tons per acre per year, and 16.6 tons per acre soil loss on the gravelly sandy loam soil. That is an increase in erosion of 100%.

You've doubled your soil losses by decreasing the water used by 20%.

Must we really pay this price to save water?

OPTIONS EXIST FOR POTATO ROTATIONS:

If potato pathogens are a problem, and you need to use a warm season crop like Sordan to reduce the pesticide applications necessary to grow a marketable crop, consider the following:

Option 1: Use a fall planted Winter Rye cover crop following potatoes to save soil during the spring months of April and May prior to planting Sordan in June.

Granted, the winter rye cover crop will require additional irrigation over Sordan alone. The average annual consumptive use requirement will increase to around 15.1 inches (a savings of approximately 10% over the standard Potato – Barley rotation). The soil loss, however, will not be increased; in fact, it will decrease to an average annual loss of 17.3 & 6.7 tons per acre per year for the same soils (a decrease of approximately 10%).

Option 2: If potato pathogens are not yet a problem, forget the sorghum crop, and consider using fall planted winter rye ONLY as your set aside crop.

The average annual consumptive use requirement could be decreased to around 10.2 inches (a savings of over 35% over the standard Potato – Barley rotation). Managed correctly, the soil loss could be kept at around 13.3 and 4.7 tons per acre per year for our two soil type.

Option 3: Go to a 3 year rotation of Potato – Barley – Sordan so you can use the barley crop residue to protect the soil during the Sordan establishment period.

A three year rotation would be excellent at reducing potato pathogens and increasing soil quality. Erosion would be 18.4 tons per acre per year; only 4 % less than a standard potato barley rotation. Water savings would amount to a 14% savings. This would also be an excellent one time rotation to use to straighten up a two year rotation when splitting pivots for the first time.

Option 4: A newer crop tried on Potato Grain fields is to use an annual ryegrass as a set aside crop, and take one hay cutting. No tillage till late fall or early spring, before going back to potatoes

The water savings could be significant, if only one hay cutting was planned. Consumptive use would average11.3 inches if only 6 inches of water were applied prior to hay cutting and then irrigation ceased for the year. Weed control would be significantly better, since any late summer rains would simply green up the annual rye prior to a killing frost. Erosion savings could be significant if no fall tillage was practiced. If fall tilled, it would be similar to potato barley erosion levels.

SAVE WATER – ALFALFA ROTATIONS

Annual consumptive use on alfalfa has been argued for several years. Consumptive use during the years of alfalfa hay production would be 27.8 inches. When you look at the whole rotation, including the alfalfa establishment year, and one year of oats or barley, the average annual consumptive use is only 20.8 inches.

Option 5: Fall planted winter triticale as a set aside crop after the alfalfa is plowed out would still allow one cutting of triticale hay in June.

This option would reduce the 20.8 inch average annual requirement to 19.6 inches for a 6% savings. Interestingly enough the soil erosion loss can be quite significant during the small grain portion of the rotation. This option would reduce the 6.3 tons/acre/year soil average soil loss to less than 2 tons per acre per year on our loamy sand soils.

Attachment: Impacts of Crop Rotations – IWR verses Soil Erosion (XWEQ)
Consumptive Use Values were calculated using the IWR (Irrigation Water Requirement) software developed by NRCS based on Blainey Criddle and the Alamosa weather station long term average climate records.

Soil loss estimates are based on the Excel Spreadsheet calculations for the Wind Erosion Equation developed by ARS / NRCS.

Attachment next page:

(This space for notes)

Attachment:

IMPACTS of CROP ROTATIONS - IWR vs. Soil Erosion								
Crop Rotation		yrs	(IWR) Irrigation Requirements			Average Annual Erosion T/AC/YR	
			CU	Effect ppt.	Net Req.	Loamy sand	sandy loam
Potato Rotations							
Potato Barley	p	2	17.8	1.0	16.9		
	b		17.5	1.2	16.3		
					16.6	19.1	7.4
Potato Sordan	p	2	17.8	1.0	16.9		
	s		10.5	0.7	9.8		
					13.3	39.4	16.6
Pot (wr) Sordan	p	2	17.8	1.0	16.9		
(winter rye cover)	wr		4.1	0.6	3.5		
	s		10.5	0.7	9.8		
					15.1	17.3	6.7
Pot Barley Sordan	p	3	17.8	1.0	16.9		
	b		17.5	1.2	16.3		
	s		10.5	0.7	9.8		
					14.3	18.4	6.9
Pot WW	p	2	17.8	1.0	16.9		
	ww		19.3	1.4	17.9		
					17.4	4.8	1.4
Pot WR - (SA)	p	3	17.8	1.0	16.9		
winter rye set aside	wr		4.1	0.6	3.5		
					10.2	13.3	4.7
Pot AR - (SA)	p	2	17.8	1.0	16.9		
(annual ryegrass)	ar		6.3	0.4	5.8		
					11.3		
Alfalfa Rotations							
Alfalfa - Oats or Barley		7					
establishment yr	ae	1	22.0	1.5	20.5		
	a	5	27.8	2.0	25.8		
	o	1	18.4	1.3	17.1		
					20.8	6.3	2.6
Alfalfa - W Triticale (SA)		7					
establishment yr	ae	1	22.0	1.5	20.5		
	a	5	27.8	2.0	25.8		
triticale set aside	t(sa)	1	4.1	0.6	3.5		
					19.6	2	0.7