PURDUE UNIVERSITY

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PURDUE FORAGE DAY

JUNE 26, 2008

SPONSORED BY THE PURDUE UNIVERSITY COOPERATIVE EXTENSION SERVICE AND THE INDIANA FORAGE COUNCIL

Hosted by
Gary and Ann Hodupp - Jonesboro, Indiana

8:00 a.m. - 9:00 a.m. Register, purchase lunch tickets and view equipment and displays

9:00 a.m. – Noon Educational topics and/or view displays

• **Forage Producers and the Indiana Sales Tax**
George Patrick
Purdue University Department of Ag Economics Development
Indiana Department of Revenue representative

• **Considerations Regarding Forage Fertilization**
Keith Johnson
Purdue University Department of Agronomy

• **Feeding Value of Co-ensiled Forage and Wet Distillers Grains**
Lori Snyder and Ricardo Arias
Purdue University Department of Agronomy
Nicole Schmelz
Purdue University Department of Animal Sciences

• **Possible Double-crop Forage Crops that follow Winter Wheat**
Dave Robison
The CISCO Companies
Brad Shelton
Purdue University Cooperative Extension Service Educator, Washington Co.

• **Attributes of a Viable Lignocellulosic Biofuel Forage Crop**
Chad Martin
Purdue University Agricultural and Biological Engineering Department

• **What Size of Forage Harvest Equipment Should I Buy?**
Dennis Buckmaster
Purdue University Agricultural and Biological Engineering Department

Noon - 12.45 p.m. Lunch and view displays

12:45 p.m – 1:15 p.m. Interview of Gary and Ann Hodupp and Awards Presentation

1:15 p.m. – 4:00 p.m. Equipment Demonstrations
Mowers - Tedders and Rakes - Balers, Wrappers, and Other Related Equipment

Forage Day's Host

Gary and Ann Hodupp– Jonesboro, Indiana

Gary and Ann Hodupp own and operate the Hodupp Hay Farm near Jonesboro, IN. Gary has been farming his whole life. They have 4 children, Brad, Amanda, Tina and Madi.

Brad and his wife Jamie help with the farming and Gary and Ann hope that one day they will take over.

Gary and Ann have approximately 500 acres of hay. They do custom baling as well as their own. The forage is packaged as big square bales, small square bales, round bales, or silage bales.

Gary, Ann and their family welcome you to this year's Purdue Forage Day. They hope you enjoy the day and are able to take home some beneficial information.

EQUIPMENT COMPANY SUPPORT

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Seed Solutions / Winfield Solution
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The CISCO Companies

FORAGE QUALITY CONTEST SUPPORTERS

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Corland Seeds LTD
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A special thank you is extended to Sure-Tech Laboratories for subsidizing the cost of forage analysis. The laboratory is located in Indianapolis and can be reached by calling (317) 243-1502.

FORAGE PRODUCERS AND THE INDIANA SALES TAX*

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Tax increases, like the recent increase in the Indiana sales/use tax from 6% to 7%, attract the attention of many individuals. According to the Indiana Code, the person who acquires tangible personal property in a retail transaction is liable for the tax on the transaction and shall pay the tax to the retail merchant as a separate, added dollar amount. The retail merchant shall collect the tax as agent for the state. Thus, an Indiana forage producer can encounter the Indiana sales/use tax in two ways:
1.) As a purchaser of property subject to tax.
2.) As an individual making sales of property subject to tax.
Only retail sales of tangible personal property, not services or real estate, are subject to tax. Furthermore, there are a number of exemptions for farmers and agricultural production which can be confusing to both buyers and sellers.

* This article draws heavily on the Indiana Department of Revenue Information Bulletin #9, Sales Tax, "Agricultural Production Exemptions," January 2003 and 45 Indiana Administrative Code. These are available at http://www.in.gov/dor/reference/files/sib09.pdf and http://www.in.gov/legislative/iac/iac_title?iact=45. Appreciation is expressed to Alan Miller for helpful comments on earlier versions.

Purchases

The general rule for the application of sales or use tax is that a purchase of tangible personal property to be used in Indiana is subject to tax unless a specific exemption is available. The sales tax applies to purchases in Indiana, while the use tax applies to Indiana sales where sales tax was not charged at the time of purchase or out-of-state purchases which were not subject to sales tax or which were subject to a lower rate of sales tax than in Indiana. For example, an Indiana use tax of 2% would be due on an out-of-state purchase on or after April 1, 2008 which had been taxed at a sales tax rate of 5% by another state.

Sales Tax Information Bulletin #9 (January 2003) says there are "several exemptions from sales and use tax relating to agricultural production. The exemptions are limited to purchases of animals, feed, seed, plants, fertilizers, insecticides, fungicides, and other tangible personal property; and agricultural machinery, tools, and equipment **directly used in direct production of food or commodities that are sold for human consumption or for further food or commodity production."** (emphasis added) The property purchased must be integral and essential to the production process of food or commodities. In addition to directly using the property in direct production, the person acquiring the property must be a farmer. A “farmer” is one who is occupationally engaged in the commercial production of food or agricultural commodities for sale or further use in producing food or commodities for sale. Persons who do not intend to operate at a profit or who produce food and agricultural commodities as a hobby are not occupationally engaged in farming and their purchases are subject to tax.

Operations similar to pony farms, riding stables, or the production and raising of dogs and pets are not classified as farms for sales tax purposes. Information Bulletin #9 gives an example of an operation which raises animals to be used in laboratory research. Because the animals are not intended for nor are sold for human consumption, the operation cannot purchase animal feed exempt from tax. A second example involves the purchase of horses to be used as riding animals. Such a purchase would be taxable because the animals are not directly used in the direct production of food or agricultural commodities. Purchase of animals used for sporting purposes (e.g., racing and gaming horses) and their feed and other inputs are not exempt from sales tax under the agricultural exemptions.

There are a number of items which, although used in agriculture, are not directly used in direct production and do not qualify for the agricultural exemption. Wearing apparel, appliances, hand and power tools, lawn or garden equipment and any motor vehicle required to be licensed for highway use are some examples. Fencing materials and building materials are gray areas.

Fencing materials are taxable if the fence is used only as partition fence between adjoining landowners or to keep wildlife, stray animals, or trespassers from entering cropland or farm premise. However, fencing materials are exempt if used to confine livestock during breeding, gestation, farrowing, calving, nursing, or finishing. Building materials are taxable if used in the construction or repair of non-exempt buildings. Confinement livestock buildings which serve a breeding, gestation, farrowing, nursing, or finishing function are generally exempt.

Electricity used to dry forages is considered to be directly used in direct production and would be exempt from sales tax. If exempt use of electricity is the predominant use of electricity on a meter, the purchase of electricity is exempt. If the use of electricity is not predominantly exempt (less than 50%), the sales tax is paid to the utility and a claim for refund for the percentage of exempt use is filed with the Indiana Department of Revenue. The taxpayer must file Form ST-200 and submit it to the Department, and the Department then issues either an exemption letter if under 50% to file a claim for refund or a Form ST-109 if over 50%.

Sales

In general, the sales tax applies only to retail sales. Many of the sales made by farmers are “wholesale sales” rather than retail sales, and thus are not subject to sales tax. Wholesale sales, according to Sales Tax Information Bulletin #52 (September 1994), include sales of:

1.) Tangible personal property, other than capital assets and depreciable property, to a person who purchases the property for the purpose of reselling it without changing its form. Sales of grain to grain merchandisers or sales of hay, other forages and some market livestock to dealers would be in this purchase for resale category of wholesale sales.

2.) Tangible personal property for direct consumption as a material in the direct production of other tangible personal property produced by the buyer in their business of manufacturing, processing, refining, repairing, mining, agriculture, or horticulture. Sales of corn, soybeans, and other grains and livestock to a processer, as well as forages to a qualifying farmer, would be examples of this type of wholesale sale.

3.) Tangible personal property to a person who purchases the property for incorporation as a material or integral part of tangible personal property produced by the buyer in their business of manufacturing, assembling, constructing, refining, or processing is also a wholesale sale. This would include sales of some livestock and other agricultural products for processing.

If an Indiana forage producer makes retail sales to purchasers who are not qualified for the agricultural exemptions or the other exemptions discussed above, the producer is required to collect and remit the sales tax to the Indiana Department of Revenue. These producers are considered to be Indiana Retail Merchants and must register with the Indiana Department of Revenue. Registration requires completion of Form BT-1 and an initial application fee of $25. Registration must be renewed every two years, but the new certificate is generated automatically if no tax is due or returns are missing. For further information, go to https://secure.in.gov/apps/dor/bt1/.

All retail sales of tangible personal property for delivery in Indiana are presumed to be subject to sales tax unless proven otherwise. The burden of proof is on the buyer and also on the seller, unless the seller receives an exemption certificate (45 IAC 2.2-8-12). Typically a buyer qualifying for the agricultural exemption would provide Form ST-105, General Sales Tax Exemption Certificate, with the appropriate box checked to the seller. The seller is required to collect and remit sales tax unless the seller has received a properly completed exemption certificate or is able to prove that the purchaser actually used the item for an exempt purpose. Failure to comply may lead to penalties and interest charges for the producer. For further information on complying with the sales tax collection, reporting, and deposit requirements go to https://www.intax.in.gov/Web/.

Conclusions

Many of the inputs and machinery purchased by Indiana forage producers are exempt from sales tax if two conditions are met. First, the tangible personal property must be directly used in direct production of food or commodities or commodities which are sold for human consumption or for further food or commodity production. Second, the producer must be occupationally engaged in the production. Individuals who do not intend to operate at a profit or produce as a hobby are not eligible for the agricultural exemptions from sales tax.

Sales by Indiana forage producers are often wholesale sales which are not subject to sales tax. Other sales may qualify for the agricultural exemption and the seller should receive an exemption certificate, Form ST-105, from the purchaser. However, some sales may be made to purchasers who fail to meet the conditions for the agricultural exemptions discussed above. Such sales are subject to sales tax and it is the seller's responsibility to collect the tax from the purchaser and remit it to the Indiana Department of Revenue. Failure to comply with Indiana sales tax law can cause serious difficulties for producers. (Not for publication)

Questions have been raised whether the seed, fertilizer, pesticides and other inputs directly used in the direct production of corn to be used for the production of ethanol would qualify as being nontaxable under the agricultural exemptions. Clearly ethanol is a product of agricultural origin, but it is not intended for human consumption as food. However, production of ethanol from corn involves a joint product, distiller's dried grains (DDGS), which is used as an animal feed. Furthermore, corn can be used in a variety of ways and it is not certain that corn grown under contract for ethanol production will necessarily be used for that purpose. Thus, it could argued that the inputs directly used in the direct production of corn should be nontaxable under the agricultural exemptions even if the corn was eventually used for ethanol production.

Currently, Indiana Department of Revenue's policy is not to have farmers register as Retail Merchants. Sales of corn to an ethanol producer do not qualify for an agricultural exemption from sales tax, but they are exempt from sales tax under the manufacturing exemption. The Department does not require farmers to register as Retail Merchants, if the only reason for doing so is to sell corn to an ethanol producer.

PHOSPHORUS AND POTASSIUM FERTILIZATION OF ALFALFA

Sofia Lissbrant, Jeffrey Volenec, Sylvie Brouder, Brad Joern,
Suzanne Cunningham, and Keith Johnson
Purdue University, Department of Agronomy

Fertilizing alfalfa with phosphorus (P) and potassium (K) can increase yield and stand longevity. However, to maximize production and profitability, it is important to adjust fertilizer rates to meet the nutritional needs of plants in a field-specific manner. In this publication we first review important information regarding P and K deficiency symptoms, and current soil test recommendations. We then discuss recent results from Purdue University regarding fertilizer rates, importance of balanced fertility, timing of fertilizer application, and the influence of P and K fertility on alfalfa forage quality.

Phosphorus and K are Involved in Many Important Plant Processes

Both P and K are considered macronutrients and are required by plants in relatively high amounts compared to other nutrients. Both P and K are essential for plant growth. Potassium is involved in a number of important physiological processes in plants including activation of several enzymes, synthesis and degradation of carbohydrates, synthesis of protein, and opening and closure of stomata, the pores in leaf surfaces involved in gas exchange and photosynthesis. Phosphorus is found in many cellular constituents including nucleic acids (DNA, RNA), phospholipids, ATP, and other high-energy compounds in plant cells. These compounds are necessary for photosynthesis, energy transfer, carbohydrate and protein synthesis, and lipid metabolism (Rhykerd and Overdahl, 1982).

Deficiency Symptoms of P and K Can Sometimes be Seen in the Field

Potassium deficiency of alfalfa can appear as chlorotic (yellow) spots along the leaf margin (Figure 1). These symptoms are especially evident on older leaves because K is mobile in plants and is preferentially transported from old to young leaves when K availability is limited. These symptoms are very distinct and easy to recognize.

Deficiency in P appears as reduced growth, and dark green or purple colored leaves (Figure 2). Symptoms of P deficiency in alfalfa are more subtle than K deficiencies and may be difficult to recognize.

[1]Paper is being submitted as an Extension publication in the near future.

Figure 1. Potassium deficiency symptoms in alfalfa. Photo: J. Volenec

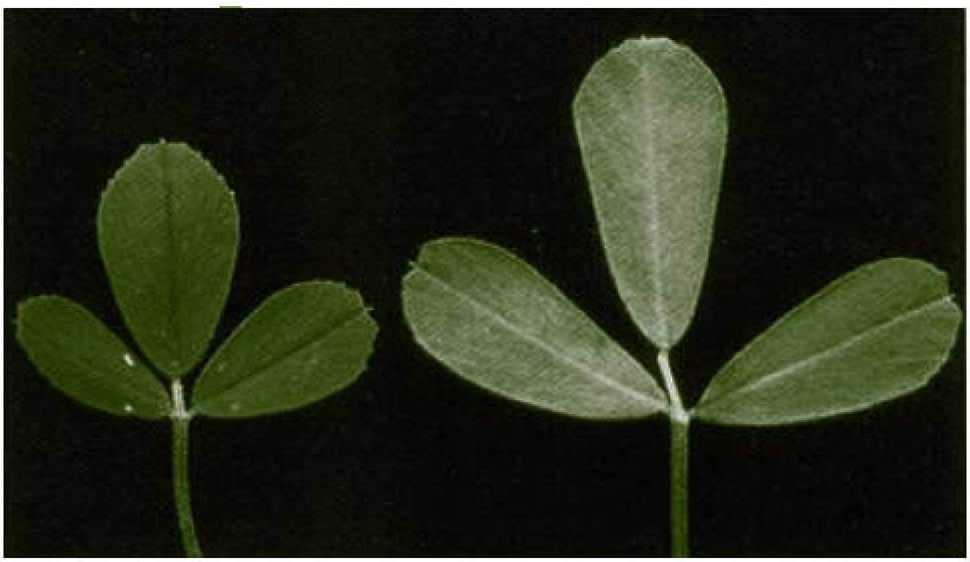

Figure 2. Phosphorus deficient alfalfa (left) versus P sufficient alfalfa (right). Photo: University of Montana. www.montana.edu/wwwpb/pubs/mt44499.pdf

Achieving and Maintaining High Alfalfa Yield Can Require P and K Fertilization

Alfalfa stands normally provide the highest yield in the first two to three production years and thereafter yield starts to decline. If the productivity of a stand decreases enough, it will be necessary to re-establish it. However, re-establishment involves additional costs, and therefore it may be more profitable to use improved management to keep stands high-yielding for more years. By adding sufficient amounts of P and K, alfalfa stands will persist better and remain high yielding longer.

Soil Test Recommendations Depend on CEC and Expected Yield

Current fertilizer recommendations for alfalfa include applying P if soil test levels are 90 lbs/acre or less (Table 1). For very low soil tests (30 lbs P/acre or less) recommended applications range from 115 to 165 lbs/acre of P_2O_5 depending on yield expectations. Recommendations for K vary depending on the cation exchange capacity (CEC) of the soil as well as the yield expectation (Table 2). At the same soil test level, a soil with a high CEC will need more K fertilizer than a soil with a low CEC. Fertilization with K should never exceed 300 lb K_20/A, regardless of CEC (Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa, 1996).

Table 1. Phosphate (P_2O_5) recommendations at different soil P test levels and yield expectations. (Adapted from Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa (1996), Table 17)

	Expected yield - tons per acre				
Soil test P (lbs/A)	**5**	**6**	**7**	**8**	**9**
	lbs P_2O_5 per acre				
30	115	130	140	155	165
40	90	105	115	130	140
50-80*	65	80	90	105	115
90	35	40	45	50	60
100	0	0	0	0	0

*Maintenance recommendations are given for this soil test range

Table 2. Potash (K_2O) recommendations at different soil K test levels, CEC, and a yield expectation of 5 T/A. (Adapted from Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa (1996), Table 22.)

	CEC (meq/100g)			
Soil test K (lbs/A)	**5**	**10**	**20**	**30**
	lbs K_2O per acre			
0-150	285*	300	300	300
151-200	150**	270*	300	300
201-250	40***	160†	270*	300
251-300	0	55‡	160†	270*
301-350	0	0	55‡	160†
351-400	0	0	0	55‡
400-	0	0	0	0

* For an expected yield of 6 T/A or more, apply 300 lbs/A

** For each additional ton, add 30 lbs/A, up to no more than 260 lbs/A

*** For each additional ton, add 10 lbs/A, up to no more than 70 lbs/A

† For each additional ton, add 30 lbs/A

‡ For each additional ton, add 10 lbs/A

Soil Test Recommendations May Need to be Re-evaluated

Purdue University researchers have shown that current recommendations regarding soil test P and K concentrations may be higher than necessary. With increasing fertilizer costs, a conservative approach to identifying fertilizer application rates may be more profitable than current recommendations that tend to be aggressive with respect to fertilizer application. Researchers from Purdue University are at this time collaborating with surrounding states with the objective of re-evaluating alfalfa fertilizer recommendations.

Highest Fertilizer Rates did not Always Result in Highest Yield

The amounts of fertilizer needed to provide high yield and good persistence of alfalfa depend upon the current nutrient status of the soil and yield expectations of the crop; the lower the initial soil test levels and the higher the yield expectations, the more fertilizer needed. However, over-applying fertilizer may not always result in higher yield. A study at Purdue University started out with low P (15 lbs/A) and medium K (140 lbs/A) soil test levels. Averaged across all of the years, highest yields were routinely obtained with applications of 50 lbs P_2O_5/A/yr and 300 lbs K_2O/A/yr, or 100 lbs P_2O_5/A/yr and 200 lbs K_2O/A/yr (Figure 3). Higher fertilizer applications did not result in significantly increased yield.

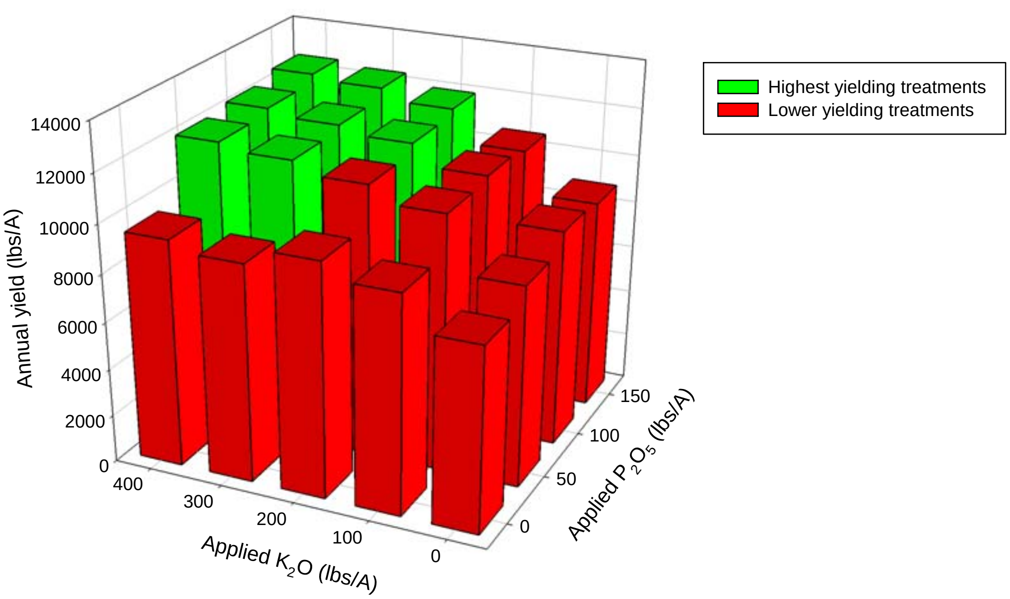

Figure 3. Highest yield was received when alfalfa was fertilized with 50 lbs P_2O_5/A/yr and 200 lbs K_2O/A/yr or more. There was no significant increase in yield when rates higher than 50 lbs P_2O_5/A/yr and 200 lbs K_2O/A/yr were applied (adapted from Berg et al., 2005, 2007).

Providing Both P and K Fertilizers is Critical for Plant Persistence

When fertilizing alfalfa it is essential to consider plant needs for both P and K. By testing the soil for P and K, and fertilizing accordingly, balanced soil fertility will be ensured. In the study at Purdue University, researchers found

Purdue University researchers showed that an alfalfa stand fertilized with 50 to 150 lbs P_2O_5/A/yr and 200 to 400 lbs K_2O/A/yr) had higher yields than unfertilized stands (Figure 5). Adequate

that alfalfa stands that were fertilized with P but not K yielded less than unfertilized stands. Some plots provided imbalanced fertility rates experienced complete stand loss, while unfertilized plots and those provided low rates of both P and K persisted, but were low-yielding (Figure 4).

fertilizer slowed yield decreases over time, resulting in progressively greater yield advantages due to P and K fertility as stands became older.

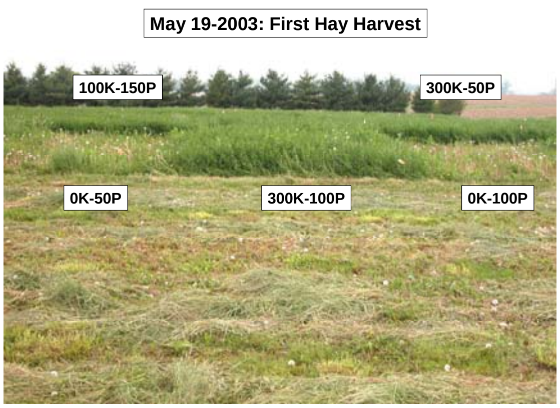

Figure 4. Photo of Purdue University study site. Note the two dead (0 K_2O, 50 P_2O_5 and 0 K_2O, 100 P_2O_5) plots with imbalanced fertility. All fertilizer applications are given as K_2O and P_2O_5 (lbs/A/year). Photo: J. Volenec.

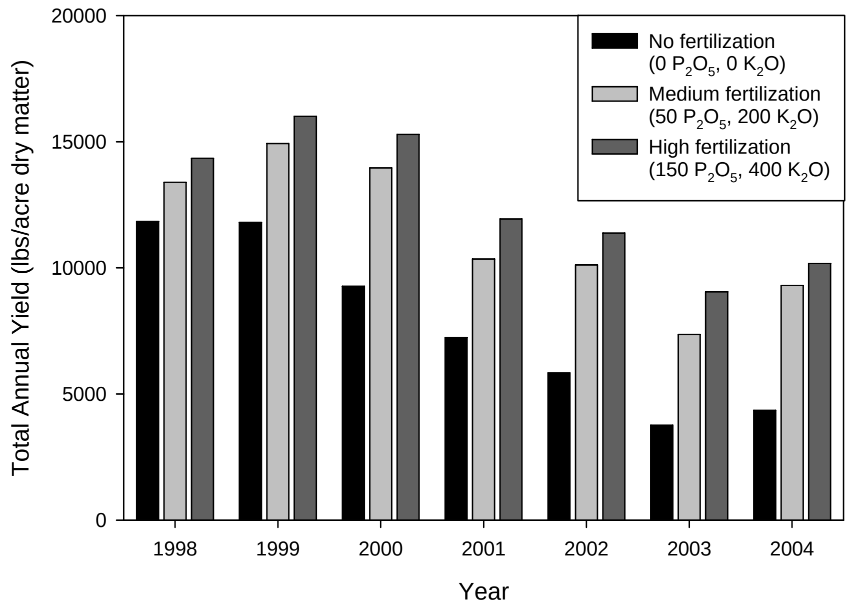

Figure 5. Influence of P and K fertilization on total annual yield. Soil test P and K concentrations averaged 15 and 140 lbs/A, respectively at stand establishment (Lissbrant et al., unpublished).

Fertilizers Should be Surface-Applied after the First and Last Forage Harvest of the Season

The Purdue University study has shown that applying P, and especially K fertilizer, in early spring before the first harvest often does not increase forage yield. At our location in west central Indiana, soils released considerable amounts of K over winter; a result we believe was due to freezing-thawing action of this soil. The released nutrients are generally used by plants during the initial growth in spring, and application of additional P and K after first harvest is recommended. A second application is recommended after the last harvest of the growing season. The most important reason for this is that increased availability of K may improve winter hardiness and alfalfa survival.

If more fertilizer is applied to the soil than what is removed by the plants, the risk of movement of nutrients to surface waters can increase. Phosphorus levels in the soil can especially increase by adding more P than required by the plants (Figure 6). Potassium levels in the soil are more difficult to increase (Figure 7). This is because “luxury consumption” of K by alfalfa can occur, meaning that plants take up K from the soil in excess of plant need. This often results in elevated K concentrations in plant tissues, increased removal of K from the field, and reduced economic returns.

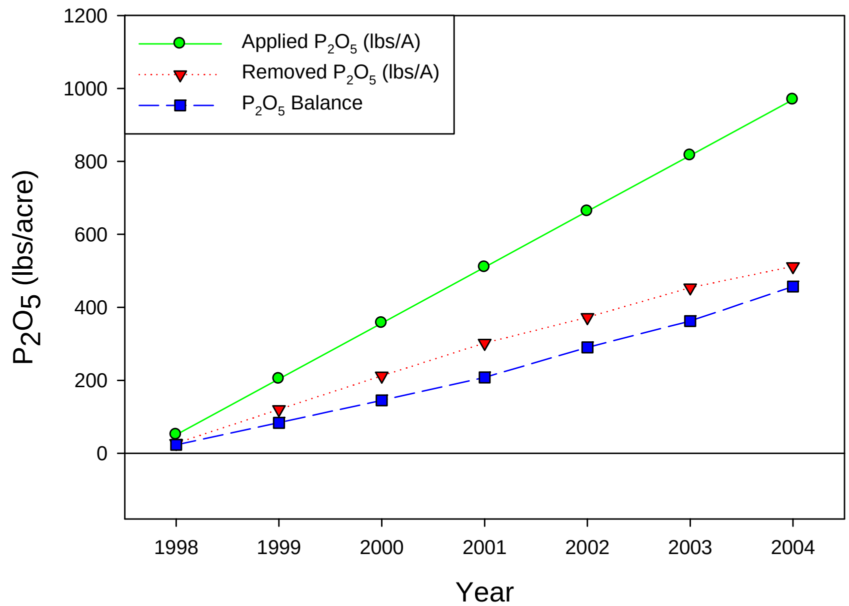

Figure 6. Applied P_2O_5, removed P_2O_5 in forage, and P_2O_5 balance (applied minus removed P) of a high fertility (150 P_2O_5, 400 K_2O lbs/A/year) plot. The balance is positive indicating that soil P levels are increasing (Lissbrant et al., unpublished).

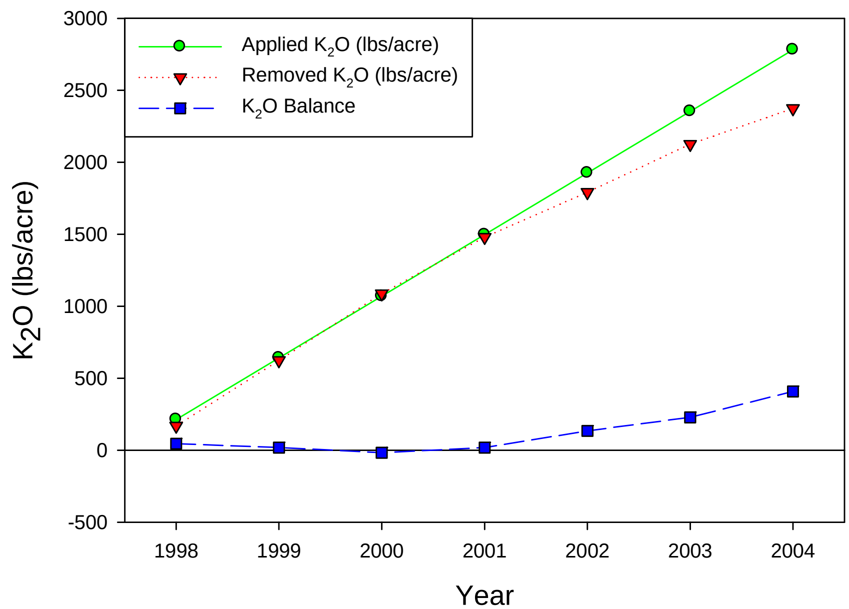

Figure 7. Applied K_2O, removed K_2O in forage, and K_2O balance (applied minus removed K) of a high fertility (150 P_2O_5, 400 K_2O lbs/A/year) plot. Even though K applications are high, the removal is equally high, resulting in a K balance close to 0 (Lissbrant et al., unpublished).

While fertilizer placement may be of importance in other crops, it is not possible to use deep placement or tillage to apply fertilizer to established alfalfa stands due to the risk of damaging the roots and crowns of plants. With broadcast application of P and K, most of the nutrients will remain in the top few inches of the soil since neither K nor P move vertically in most soils. Research at Purdue University has found that this is not a concern since most of the fine roots that are active in nutrient uptake, are located in the upper-most two inches of the soil (Figure 8). This root density pattern was similar in all fertility treatments.

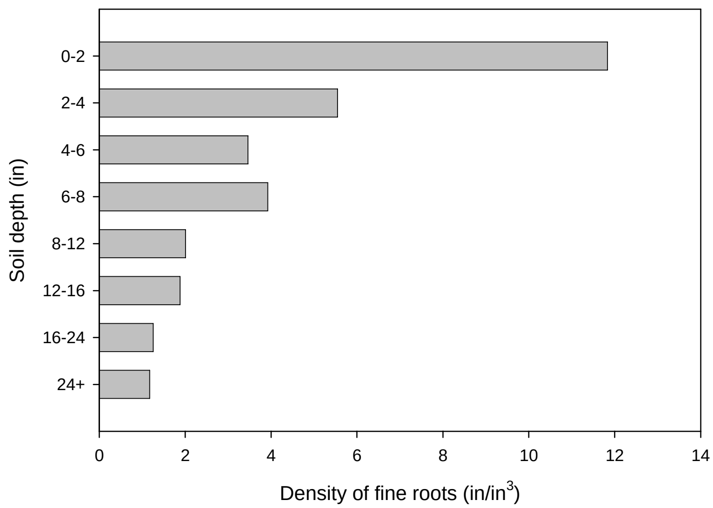

Figure 8. Vertical distribution of fine alfalfa roots with soil depth (Volenec and Brouder, unpublished).

Fertilizer Application Resulted in Slight Reductions in Forage Quality

As fertilizer is added to alfalfa and the yield increases, the morphology and physiology of the plants may be altered in ways that impact forage quality. Shoots get taller and thicker and the amount of leaves relative to the amount of stem tissue (leaf-to-stem ratio) often decreases in response to P and K application. With decreased leaf-to-stem ratio forage quality often declines. Table 3 shows an example of how digestibility decreased as yield increased with P and K application.

To compare the benefits and constraints caused by P and K fertilization of alfalfa we calculated the amount of digestible nutrients produce per acre. This is done by multiplying the percent digestibility by the forage yield to get the digestible nutrient yield.

Digestible Nutrient Yield = % Digestibility/100 x Yield

When comparing the digestible nutrient yield from different fertility treatments, Purdue University researchers found that higher yield easily compensated for slightly reduced digestibility of the forage in the high fertility plots (Table 3, Figure 9).

Table 3. Digestible nutrient yield for alfalfa fertilized with contrasting rates of P and K (Lissbrant et al., unpublished).

Treatment	Yield	Digestibility*	Digestible Nutrient Yield
	lbs/acre	%	lbs/acre
0 K_2O 0 P_2O_5	1087	86	927
200 K_2O 50 P_2O_5	2324	83	1915
400 K_2O 150 P_2O_5	2542	81	2063

* Values adjusted for organic matter (ash content removed)

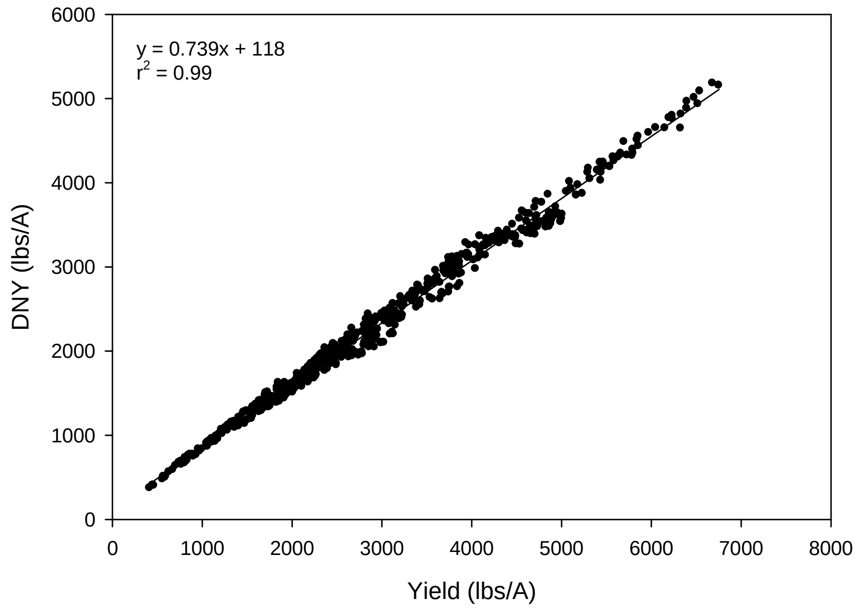

Figure 9. Relationship between yield and digestible nutrient yield (DNY) (Lissbrant et al., unpublished).

Animals differ in their protein requirements. Depending on the use of the alfalfa, it may be of interest to regulate the amount of protein in the forage. Soil fertility and fertilizer regimes can affect forage protein concentration, resulting in higher protein concentration in low P and K fertility fields and lower protein concentration in high fertility fields (Figure 10). Nevertheless, research at Purdue University showed that the high fertility - high yielding stands provided sufficient protein concentration to satisfy the protein requirements of dairy cows in lactation, and only slightly less than the requirements for dairy cows in early lactation. The small reduction in protein concentration resulting from P and K fertilization were more than offset by the large difference in forage yield. Factors such as cutting management will have greater influence on forage quality than will fertility.

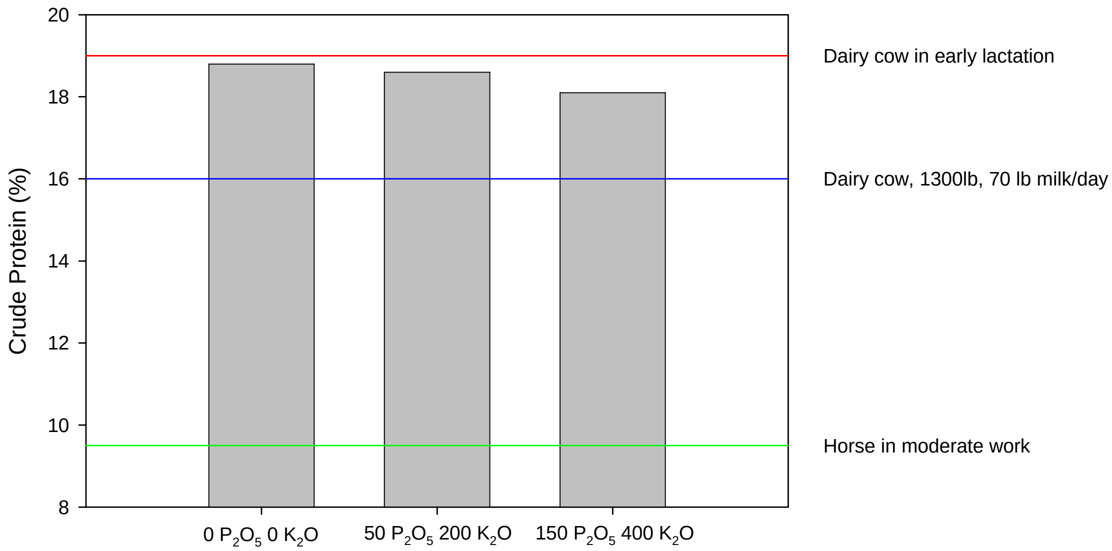

Figure 10. Protein concentrations for alfalfa fertilized with contrasting rates of P and K fertilizer (Lissbrant et al., unpublished). The reference lines indicate the dietary protein requirements for horses in moderate work, lactating dairy cows producing 70 lbs of milk per day, and dairy cows in early lactation (Perry et al., 2003).

Adding excessive K can reduce economic returns because of wasted fertilizer, but can also lower the value of the forage. If the concentration of K in the forage exceeds 3% of dry weight the animals consuming it may become afflicted with milk fever which is caused by hypocalcemia (low blood calcium). This potentially fatal disease is most prevalent in cows shortly after calving. By monitoring soil test levels and applying fertilizers as split applications, the risk for excess K in the forage and milk fever can be reduced.

The forage can be tested for P and K concentrations if sampled and sent for analysis. This is a good way of checking the nutrient status of the forage, especially if there is suspicion of low or high P and K levels. Table 4 provides general guidelines regarding deficient, sufficient, and excessive tissue P and K concentrations.

Table 4. Deficiency, sufficiency, and excess concentrations of P and K in alfalfa plant tissue. (Adapted from Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa (1996), Table 24).

	Deficient	Sufficient	Excess
Phosphorus (%)*	<0.25	0.26-0.70	>0.71
Potassium (%)*	<2.0	2.01-3.5	>3.51

*Top 6 inches sampled prior to initial flowering

Key Points to Remember

- P and K positively influence alfalfa yield and stand persistence
- Balanced nutrition is essential for high yield and persistence of alfalfa
- Apply P, and especially K, in split applications after first and last harvests in order to enhance productivity and avoid luxury consumption of K
- Broadcasting applications of P and K fertilizer work well since fine roots of alfalfa are abundant near the soil surface
- Fertilize for high yield; do not worry about forage quality. Higher yield will compensate for a slight reduction in forage quality
- Be careful not to over-apply K; luxury consumption occurs and high tissue K concentrations may increase the risk of milk fever

Where to Send Soil and Tissue Samples for Analysis

For contact information about ACP certified commercial laboratories, visit Purdue Extension at http://www.agry.purdue.edu/ext/soiltest.html

References

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THE EFFECTS OF CO-ENSILING WET DISTILLER'S GRAINS PLUS SOLUBLES WITH CORN SILAGE ON GROWTH PERFORMANCE OF BRED BEEF HEIFERS DURING LATE PREGNANCY

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Introduction:

The beef industry serves as one of the most important value-added enterprises in the U.S. with over a million farms and ranches benefiting directly from the sales of cattle (NCBA, 2006). In 2002, gross receipts from the sale of cattle and calves totaled over $45 billion and accounts for over 21% of all agricultural receipts. This makes the beef sector the single largest agricultural enterprise in the U.S. (USDA, 2006). It has been estimated that although the U.S. beef industry has less than 10% of the world's cattle population, it provides nearly 25% of the world's beef supply (USDA, 2002). Interestingly, small and medium-sized beef producers (less than 200 cows) account for 96.5% of the beef cow operations and 67 % of the U.S. beef cow inventory (USDA, 1997).

Despite increased consumption and growth within the industry, production agriculture is at a crossroads. Government subsidies given to the bio-fuel industries have contributed to the growth in the corn-based ethanol industry which, in turn, has resulted in future corn prices of over $7/bushel. The ramifications of the shift towards ethanol production are far reaching. The sudden increase in corn prices during the fall of 2007 has placed a heavy burden on beef producers. Small and medium-sized producers currently are not capable of utilizing commodity feeds with limited 'shelf-life', like wet distiller's grains (WDG), and this places them at a severe disadvantage compared to larger operations. The increasing cost of traditional feed grains (especially corn) which have been traditionally used in beef production has the potential to drive them out of business.

Garcia and Kalscheur (2004) reported successful storage and co-ensiling of WDG with corn silage, soybean hulls, and wet beet pulp. The challenge is that WDG are naturally low in pH and may inhibit the fermentation process; furthermore, how the ensiling process of the mixed ingredients affects spoilage at the face of the open silo structure and in the feed bunk is not known. Additional questions regarding performance of animals fed these mixtures, maximal inclusion rates to determine optimal end-product quality, and how these mixtures fit into small to medium-sized farm operations have not been answered.

Objectives:

The objectives of the current study are to evaluate the effects of co-ensiling corn silage and WDGS on performance of heifers during the third trimester of gestation.

About the Study:

This study was conducted at the Beef Unit of Purdue University with a total of 96 2-year old commercial Angus heifers with an average body weight (BW) of 1150 pounds and a body condition score (BCS) of 5.3 in their last trimester of pregnancy. They were sorted in 16 groups by weight and body condition score.

In order to determine the effect of the co-ensiled product, 3 more diets were evaluated for a total of 4 diets as follows (Table 1):

1. Corn silage with soybean meal as control (**CON**); given that is the traditional diet for the winter in our region.
2. Corn silage co-ensiled with WDG in a proportion 3:1 (Dry matter basis) of corn silage and WDG respectively (**CO-EN**)..
3. Corn silage with dry distiller's grains (DDG) added at feeding time (**CS+DDG**)
4. Corn silage mixed with WDG added at feeding time (**CS+WDG**).

The diets were formulated to meet requirements (NRC, 1996) for Angus heifers during the last trimester of gestation and balanced to be equivalent one from another (Table 2). The heifers were fed once a day for the 62 day long trial.

To measure growth performance, the heifers were weighed and body condition scored at the beginning and the end of the study and the weights were corrected to remove the any weight produced by pregnancy itself. The most important performance indicators measured in this study were:

- Feed consumption in terms of dry matter intake (DMI)
- Average daily gain in weight (ADG)
- Efficiency measured as gain to feed ratio (G:F)
- BW (Final BW and overall change during the study)
- BCS (Final BCS and overall change during the study)

Results and Discussion:

For our indicators above we found the following results (Table 3):

a) DMI: the Heifers fed the CS+DDG diet had decreased DMI (*P* < 0.01) compared to all other diets.
b) ADG: Heifers fed the CO-EN treatment had greater ADG (*P* = 0.03) than those fed the CON and CS+DDG diets.
c) G:F: The CO-EN fed heifers also tended to have greater G:F (*P* = 0.06) compared to those fed the CON and CS+WDG.
d) BW: Heifers fed the CO-EN treatment had greater overall gain in BW (*P* = 0.03) compared to the CON and the CS+DDG treatments, while the CS+WDG treatment was intermediate. However, there was no significant differences in final BW (*P* = 0.14) due to dietary treatment.
e) BCS: There was no significant differences in final BCS (*P* = 0.40) or change in BCS (*P* = 0.35) due to the diets.

The increased performance (ADG and BW change) observed with heifers fed the CO-EN treatment compared to CON and CS+DDG treatments may be due, in part, to differences in DMI. It is interesting to note, however, that there were no differences in performance between heifers fed the CO-EN and CS+WDG diets, but there was a tendency (*P* < 0.06) for the CO-EN heifers to be more efficient that all the other diets.

Conclusions:

Results from this study suggest that WDG co-ensiled with corn silage have equal or greater feeding value when fed to heifers in the last trimester of gestation compared to corn silage based diets supplemented with soybean meal, DDG or WDG at feeding time.

Implications:

Co-ensiling WDG with corn silage not only appears to enhance animal performance but additionally seems to be more palatable, easier to handle than TMRs with WDG and DDG added at feeding time, longer lasting in the feeders, and less susceptible to sorting by cattle and gravity; the co-ensiling process can be scheduled according to availability and pricing of the feedstuffs. This process can provide an economically viable feed source for any producer.

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Table 1. Ingredient composition of diets fed to heifers.

Ingredient	Diets[1] (% of DM)			
	CON	**CO-EN**	**CS+ DDG**	**CS+ WDG**
Corn Silage[2]	88.8	—	73.6	73.6
Soybean meal	10.2	—	—	—
Co-ensiled[3]	—	98.1	—	—
DDG[4]	—	—	24.5	—
WDG[5]	—	—	—	24.5
Mineral premix[6]	1.8	1.9	1.9	1.9

[1] CON = control (corn silage with soybean meal), CO-EN = co-ensiled, CS+DDG = corn silage plus DDG added at mixing, CS+WDG = corn silage plus WDG with solubles added at mixing.
[2] Corn silage: 35% DM, 9.1% CP, 40% NDF (DM basis).
[3] Co-ensiled corn silage with WDG 3:1 (DM basis).
[4] DDG = Dry distillers grains with solubles.
[5] WDG = Wet distillers grains with solubles.
[6] 70% $CaCo_3$, 11.5% inorganic mix, 18.5% NaCl.

Table 2. Composition of diets (DM basis) fed to heifers.

Ingredient	Diets[1]			
	CON	**CO-EN**	**CS+ DDG**	**CS+ WDG**
NEg, Mcal/Kg [2]	1.06	1.12	1.12	1.12
CP, %	12.2	12.5	12.4	12.4
Prot. Sol., % CP	44.7	41.6	38.3	34.5
aNDF, %	38.4	37.7	39.7	37.8
ADF, %	21.7	19.2	21.6	20.1
DM, %	38.3	36.1	38.8	40.5

[1] CON = control (corn silage with soybean meal), CO-EN = co-ensiled corn silage with wet distillers grains 3:1 (DM basis), CS+DDG = corn silage plus dry distillers grains with solubles added at mixing, CS+WDG = corn silage plus wet distillers grains with solubles added at mixing.
[2] Dietary energy and protein were formulated using tabular values (NRC, 1982).

Table 3. Effect of treatments on performance of Angus heifers during the last trimester of gestation.

	Treatments[1,2]					
Item	**CON**	**CO-EN**	**CS+DDG**	**CS+WDG**	***SE*[3]**	***P***
DMI, lbs	17.27[a]	17.73[a]	15.41[b]	17.95[a]	0.22	0.01
Initial BW, lbs	1149.3	1149.4	1155.9	1153.7	4.19	0.39
Initial BCS	5.43	5.36	5.33	5.27	0.09	0.36
ADG, lbs	1.83[b]	2.32[a]	1.96[b]	2.09[ab]	0.15	0.03
G:F	0.106	0.130	0.127	0.117	0.01	0.06
Final BW, lbs	1263.0	1292.6	1278.8	1283.3	11.9	0.14
Final BCS	5.62	5.73	5.54	5.48	0.15	0.40
Change in BW, lbs	113.56[b]	143.33[a]	121.28[b]	129.56[ab]	9.15	0.03
Change in BCS	0.19	0.38	0.21	0.21	0.11	0.35

[1] CON = control (corn silage with soybean meal), CO-EN = co-ensiled corn silage with wet distiller's grains plus solubles 3:1 (DM basis), CS+DDG = corn silage plus dry distiller's grains with solubles added at mixing, CS+WDG = corn silage plus wet distiller's grains with solubles added at mixing.

[2] Means within a row lacking a common superscript differ ($P < 0.05$)

[3] Standard Error

FEEDING VALUE OF WET DISTILLERS GRAINS FOR LACTATING DAIRY COWS WHEN CO-ENSILED WITH CORN SILAGE OR HAYCROP SILAGE

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Proper utilization of distiller's by-products as a feed ingredient has the potential to make Indiana's livestock industry significantly more attractive and competitive in domestic and global markets. Anticipated increases in the price of corn may be offset by readily available by-products, particularly corn distiller grains with solubles (DGS). The use of DGS in rations fed to ruminants is not novel. Changes in the availability and pricing are creating a market situation that greatly favors the use of DGS in Indiana. Therefore, it is critical that proper production, storage and feeding strategies for use of DGS are in place to enable small and medium-size operations to implement DGS feeding, while maintaining the quality standards of products and ensuring sustainability of these livestock industries. Activities at Purdue University are currently focused on determining the best storage and feeding strategies to enable small and medium sized dairy and beef producers to utilize DGS. This particular research summary focuses on our initiatives to evaluate co-ensiling strategies that enable effective use of wet distiller's grains with solubles (WDGS) in rations fed to lactating dairy cattle.

Background

Increasing bio-fuel production is a priority for federal and state governments as a strategy to decrease our nation's dependence on foreign oil. Price increases for the commodities used to produce bio-fuels are projected to increase with demand. Consequently a dramatic shift in feeding and production practices throughout the livestock industry is anticipated.

During the next several years there will be an estimated 1.4-1.9 million tons of DDGS produced by the ethanol industry expansion in Indiana. Distiller's grains can be effectively and economically used to meet protein requirements of ruminant animals. Wet distiller's grains are not an attractive option for small- to medium-sized dairy and beef producers due to the delivery volume needed to obtain favorable pricing, and limitations in storage length, and form.

One of the greatest limitations to the use of WDGS is storage and 'shelf life' Because WDGS is contains as much as 50% moisture it is susceptible to spoilage that results in reduced palatability and storage losses. Storage that limits surface oxygen exposure can be used to prolong storage life. The high moisture content presents a problem when stored in piles due to seepage and the density of WDGS exceeds the tensile strength of bag silos (Ag Bags). In many cases the use of WDGS is limited to operations that are able to utilize a semi-trailer load during a 7-10 day period. Therefore given a safe inclusion level of WDGS of 30-40% (dry matter basis) in most dairy rations the storage and handling issues described above act to limit the use of WDGS on small to medium-sized dairy operations. Therefore we have worked to provide options for storage of WDGS so that this feed resource can be used by small and medium-sized dairy operations. Our desire is that this information will help provide stability and sustainability to small and medium-sized operations and rural communities in the midst of a rapidly evolving and unstable era of production agriculture.

The objectives of this research were: 1) Develop and evaluate methods that will economically and effectively extend storage time (shelf-life) of bio-fuel co-products using complementary regional feedstuffs. 2) Determine the nutritive value of stored feeds containing bio-fuel co-products for cattle.

Experimental Methods

Two separate experiments were conducted to determine the effectiveness of co-ensiling strategies using WDGS with local feedstuffs. Experiment 1 evaluated the effects of co-ensiling WDGS with whole plant chopped corn and Experiment 2 evaluated the potential for co-ensiling with wilted haycrop silage.

Experiment 1: Coensiling WDGS with Corn

Whole plant corn fodder was harvested and either ensiled separately in an AgBag or was mixed in a TMR mixer at a ratio of 66:34 corn:WDGS and co-ensiled in an AgBag. Bags were opened after a minimum of 3 weeks and the value of the material was determined for lactating dairy cows in a feeding and production trial. The value of the WDGS corn fodder co-ensiled material (Corn Co-ensilage) was compared to a diet (Control) in which the individual feed ingredients were added at the time of mixing. Rations were balanced to meet NRC requirements based on milk production, composition and body weight, and fed as a total mixed ration with corn grain, soyhulls, grass hay and minerals and vitamins. Therefore the Control and Corn Co-ensilage diets contained the same proportions of WDGS and corn silage but only differed in regard to the calendar date when they were combined. The diets are shown in Table 1.

Experiment 2: Co-ensiling WDGS with Wilted Grass

Mostly grass mixed forage was harvest as haycrop silage (moisture) and either ensiled separately in an AgBag or mixed in a TMR mixer at a ratio of 37:63 haycrop silage:WDGS and co-ensiled in an AgBag. Bags were opened after a minimum of 3 weeks and the nutritive value of the feed was determined for lactating dairy cows. The value of the WDGS haycrop co-ensiled material (Haycrop Co-ensilage) was compared to a diet (Control) in which the individual feed ingredients were added at the time of mixing. Rations were balanced to meet NRC requirements based on milk production, composition and body weight, and fed as a total mixed ration with corn grain, soyhulls, grass hay and minerals and vitamins. Similar to experiment 1 the Control and Haycrop Co-ensilage diets contained the same proportions of WDGS and haycrop silage but only differed in regard to the calendar date when they were combined. The diets are shown in Table 1.

Experiments 1 and 2: Animals, Management and Data Collection

Co-ensilage feeds were evaluated using 32 mid-lactation Holstein cows in two separate experiments. Cows were housed in individual tie stalls. Milk production and feed intake were determined daily and milk composition was determined from samples taken once per week.

Sixteen cows were used for each co-ensilage evaluation. Cows were selected from the Purdue Dairy Research Center herd and used in a 3-period switchback design consisting of 21-day periods. At the beginning of the experiment eight cows received the co-ensilage diet and the remaining 8 cows were assigned to the control diet. The periods consisted of 14 days of adaptation to the diets followed by 7 days of data collection. At the conclusion of period 1 the cows were switched to the opposite treatment and the experiment continued with data collection during the last 7 days of period 2. Cows were then switched to their original treatment groups for the remaining 21 days of the experiment. Periods consisted of 3 contiguous 21 days.

Table 1. Ingredients and nutrient composition of diets.

	Treatment			
	Corn		Haycrop	
Item	Control	Co-ensilage	Control	Co-ensilage
Ingredient[1]				
Alfalfa Hay	5.03	5.01	5.03	5.01
Corn silage	33.28	2.73	33.28	33.25
Soyhulls	4.19	4.19	4.19	4.19
High moisture corn	10.55	10.54	10.55	10.54
Fishmeal	0.43	0.43	0.43	0.43
Soybean meal (48%)	3.77	3.77	3.77	3.77
Megalac R	0.46	0.46	0.46	0.46
Mineral supplement	7.16	7.15	7.16	7.15
Alfalfa haylage[2]	19.50	19.48		10.25
Direct cut haycrop silage			19.50	
Wet distillers grains (WDGS)	15.63		15.63	
Corn co-ensilage[3]		46.27		
Haycrop co-ensilage[4]				24.95
Total WDGS in diet	15.63	15.63	15.63	15.63
Nutrient				
CP	15.9	15.9	15.9	15.9
ADF	23.0	20.0	21.9	20.0
NDF	36.0	32.2	35.6	32.2
NEL, Mcal/lb.	0.70	0.68	0.69	0.68

[1] % DM. unless noted otherwise.
[2] Haycrop silage = wilted ensiled haylage (experiment 1) or direct cut ensiled (experiment 2) .
[3] Co-ensiled whole plant and WDGS (66:34 on dry basis).
[4] Co-ensiled haycrop silage and WDGS (37:63 on dry basis).

Results

There were no visual indications of mold or spoilage when Ag bags containing individual feeds and co-ensiled materials were opened. Analysis of co-ensiled feeds and corn silage and haycrop silage is given in Table 2. The moisture content of the haycrop silage was greater than targeted (65%) consequently sins of molding were observed for the haycrop silage. There were no similar indications for the haycrop co-ensilage.

Milk production, milk composition and feed intake did not differ for cows fed corn distillers grains that were mixed in the diet at time of feeding (Corn Control diet) or when WDGS was mixed with corn at the time of ensiling and fed as a component of the TMR (Table 3).

When haycrop forage was direct cut, ensiled and mixed with WDGS at feeding the cows ate less feed and produced significantly less milk (~ 5 lbs less) than if the same forage was co-ensiled with WDGS and fed as a component of the TMR.

Table 2. Nutrient composition of individual feeds or co-ensiled products.

	Corn		Haycrop		WDGS
Item	Silage	Co-ensilage[1]	Silage	Co-ensilage[2]	
Ingredient [3]					
DM, % as fed	35.51	37.25	30.60	36.42	40.1
CP	9.14	15.83	17.89	25.36	30.6
ADF	23.22	18.77	28.14	19.71	13.2
NDF	39.53	34.83	43.64	37.23	27.1
Fat	2.82	5.76	2.60	14.90	19.0
NFC	43.77	38.26	26.15	27.62	23.8
Ash	4.74	5.32	9.72	7.19	5.70
Ca	0.33	0.54	1.35	0.54	0.09
P	0.26	0.49	0.45	0.76	0.96
Mg	0.19	0.31	2.46	0.49	0.44
K	1.09	0.96	2.46	1.89	1.18
NEl, Mcal/lb	0.76	0.81	0.73	0.84	1.10

[1] Co-ensiled whole plant and WDGS (66:34 on dry basis) .
[2] Co-ensiled haycrop silage and WDGS (37:63 on dry basis).
[3] % DM. unless noted otherwise.

Table 3. Dry matter intake, milk production and composition

	Treatment					
	Corn			Haycrop		
Item	Control	Co-ensilage	SE	Control	Co-ensilage	SE
DMI, lbs/d	50.2	49.8	0.8	47.6	52.0*	0.7
Milk, lbs/d	79.21	78.59	1.49	78.0	82.2*	1.46
Milk composition, lbs/d						
Milk fat, lb/d	2.50	2.46	0.11	2.45	2.24	0.08
Milk protein, lb/d	2.08	2.11	0.06	2.03	2.05	0.05
Milk lactose, lb/d	3.21	3.22	0.11	3.26	3.26	0.07
Milk solids, lb/d	8.44	8.44	0.28	8.38	8.20	0.17
Milk composition, %						
Milk fat, %	3.10	3.08	0.10	3.15	2.85*	0.12
Milk protein, %	2.63	2.63	0.04	2.62	2.64	0.05
Milk lactose, %	4.03	4.03	0.07	4.17	4.14	0.06
Milk solids, %	10.57	10.55	0.18	10.75	10.44	0.18
SCC, 1,000 cells/ml	92	89	16	76	240	90
MUN, mg/dL	9.37	11.21*	0.37	9.85	11.19*	0.33
BW change, lbs	5.7	12.5	4.4	12.1	14.1	3.7
BCS change	0.0	0.1	0.0	0.0	0.1	0.0

* denotes differences ($P < 0.05$) between control and co-ensilage (within co-ensilage type)

Conclusions, Implications and Opportunities

The goal of this research was to evaluate a system that would permit small and mid-sized dairy producers (50 to 100 cows) to utilize WDGS in a feeding program. The inclusion rate of wet distillers is safely limited to approximately 15 to 20% of the ration dry matter. Therefore on whole farm basis the use of WDGS by small producers may be limited because the total amount that can be fed daily is mismatched with the delivery quantities required to take advantage of favorable pricing. Because the storage interval for WDGS is limited (usually 7 to 10 days) before spoilage occurs small and medium sized producers may not be able to effectively utilize WDGS. Due to the bulk density of WDGS direct storage in AgBags is not possible. Co-ensiling WDGS with low quality forages has been shown by other researcher to be an effective mode of storage however the value of such co-ensiled products in rations for high producing dairy cows may be limited. Therefore, our objective in co-ensiling WDGS with corn silage was to provide a vehicle to reduce the density and extend the storage life of WDGS in a system that was amenable to small and medium sized dairy producers. Data from the present study indicates that the feeding value of WDGS when co-ensiled with corn or when fed alone is equivalent and therefore provides and option for small and medium sized producers in utilizing WDGS.

Forage quality is often limited due to conditions at harvest. Weather conditions can result in a necessity to harvest at less than optimal moisture for preservation or a less than ideal maturity for optimal nutrient quality. We extended the potential for co-ensiling WDGS with forages to include haycrop forages. Forage was harvested in this experiment in late fall when daylight and temperature frequently limit the ability to dry forage down to a moisture content that will ensure preservation. Our experimental conditions used mixed legume forage that was direct cut and co-ensiled with WDGS at a target moisture content of 65% for the combined material. We were unsuccessful in drying the forage to similar moisture content and placed it in the silos at 30% dry matter. Consequently the forage when preserved alone showed evidence of reduced keeping quality but when direct cut grass was co-ensiled with WDGS there was no evidence of molds and cows ate more feed and produced more milk. At least two factors may be responsible for the beneficial effects of WDGS to improve the feeding value of direct cut forage 1) the moisture content was reduced by the addition of WDGS and 2) WDGS is acidic due to the addition of acids at the termination of the corn ethanol production process. Therefore the starting pH of the co-ensiling process is likely to be lower and therefore reduces the likelihood of growth of undesirable bacteria (Clostridia) during the ensiling process.

These data indicate the feeding value of corn silage and WDGS is not altered when combined at the time of feeding or premixed and co-ensiled. The feeding value of direct cut haycrop forage is considerably enhanced when co-ensiled with WDGS. Co-ensiling with corn silage provides an option that will extend the storage life of WDGS, whereas co-ensiling with direct cut forage provides possibilities to increase the opportunities for forage harvest and storage when daylight or weather conditions are unfavorable for making dry hay or haylage.

FORAGE DOUBLE-CROP OPTIONS

Brad Shelton
Washington Co. Cooperative Extension Service Educator

Mother Nature was not kind to forage producers in 2007. While 2008 has definitely been a different ball game, some producers may still be running short on hay. Annual forages played a viable role in offering feed options in 2007 but those unusual conditions aren't the only time to consider your double-crop options.

Where Do Your Double-crop Opportunities Exist?

- Following wheat harvest as a forage or grain
- Rotational crop between alfalfa seedings
- Smother crop when replacing Kentucky 31 tall fescue
- After harvesting grain crops in late summer

Summer Annuals

- Sorghum-sudangrass / sudangrass
  Ideally, seeded when soil temperatures reach 70°F at a rate of 25-35 lbs/acre Pure Live Seed, at an inch of depth. Usually ready to graze 30-45 days after seeding and will typically provide 4-6 tons dry matter per acre. Fairly palatable. A genetic mutation discovered at Purdue University known as the 'brown mid-rib' trait resulted in decreased lignin, increased digestibility and palatability of these warm-season grasses. As the name indicates some varieties will exhibit a brown mid-rib.
- Pearl Millet
  Seeded when soil temperatures reach 70°F at a rate of 15-20 lbs/acre Pure Live Seed, at ¾-1 inch of depth. Highly palatable, drought tolerant and typically yields 3-5 tons dry matter per acre. Can not withstand cool temperatures as well as sorghum-sudangrass or sudangrass. .
- Teff
  Relatively new to forage industry in mid-west. Originated from Ethiopia where it has been used for making flour for cooking. Very small seeds. Planted when soil temperatures reach 70°F at a rate of 4-5 lbs/acre Pure Live Seed at ¼" of depth. Preliminary results in Indiana indicate yields will be 3+ tons dry matter per acre and decent quality. Quality levels of teff were very similar to sorghum-sudangrass, sudangrass and pearl millet. Will teff become a standard Indiana producers will be able to rely on? Time will tell.

2007 Feldun Purdue Ag Center Summer Annual Demonstration Plot – Dry Matter Yield. Plot seeded May 15, 2007. 150lbs total N per acre applied during season.

	Teff	Pearl Millet	S x S	Sudangrass
Harvest Date		Tons/Acre		
3-Jul	1.6	1.0	1.6	2.0
17-Aug	2.4	2.1	1.7	1.8
Total	4.0	3.1	3.3	3.8

Potential Hazards of Summer Annuals

Prussic Acid Poisoning

A hazard of sudangrass and sorghum-sudangrass. Grazing should not be initiated until after forage reaches 24-36" in height as young, rapidly growing plants are likely to contain high levels of prussic acid. Generally, any stress condition that slows plant growth can increase prussic acid levels. Plants grown on soils low in phosphorus and potassium but fertilized well with N have a greater potential for prussic acid. Animals should not be allowed access until 7-10 days after a killing freeze as prussic acid compounds are slowly released.

Nitrate Toxicity

An issue when plants are stressed by drought, shade and low temperatures (<55°F). Nitrate toxicity can affect sudangrass, sorghum-sudangrass and millet as well as other crops. Animals under physiological stress are more susceptible to nitrate toxicity. Nitrate content is generally highest in young tissue and normally accumulates in stems. Nitrates can accumulate in mature tissue of sorghum-sudangrass and sudangrass. After a good rain, nitrates will be metabolized over the course of 10-14 days, allowing the plant to be grazed. Ensiling forage reduces nitrate levels by approximately 50 percent. Nitrate concentrations are not reduced in hay. Green chopped forages should be fed immediately after cutting to prevent plants from respiring, increasing toxicity hazards.

Winter Annuals

- Cereal grains

  Winter wheat has long had a reputation for winter grazing in the Plains states. Fall seedings of wheat and other grains such as spring oats, cereal winter rye, and winter triticale (cross between wheat and rye) seeded at 90-120 pounds/acre can provide 2-5 tons of dry matter/acre in the spring. Spring oats seeded in August provide high quality forage in fall before frost. Wheat, cereal rye, and triticale will provide some grazing in fall but most forage will grow in spring. Cereal rye will provide higher yields but not as palatable. Seeding cereal grains for grazing should be complete by late August for fall grazing.

- Italian Ryegrass

  Also known for foraging livestock in the winter months in the southern US. Seeded at 15-30 pounds it can produce higher quality feed than cereal grains in late spring. Winter hardiness is an issue with some varieties. Those varieties that survive the winter will grow aggressively in the spring and can be difficult to kill.

Turnips

Seeded at 2-4 pounds/acre, turnips can grow quickly and provide nutrient dense forage in 70-90 days. Livestock will need a source of roughage such as corn stalks, low quality hay or stockpiled fescue to balance-out the possible negative effects of this highly digestible forage.

Forage type turnips can provide 2-3 grazings as long as the bulbs are not damaged. Once turnip tops cease to grow, bulbs will provide adequate nutrition. Turnips can cause bloat and acidosis.

Economics

Even if one is short on hay, date of planting and potential yield need to be taken into consideration, as purchasing more hay may be more economical and a sure-thing versus utilizing annual forages. Establishing summer annuals can approach $150 per acre with seed, 150lbs of nitrogen per acre and charge of $15 per acre for use of a no-till drill. If the soil needs to be tilled first or if the forage will be made into hay or chopped for silage the cost increases even more. As we learned in 2007, Mother Nature doesn't always play nice. Annual forages are definitely an option, but it boils down to how much risk one is willing to assume and how and when forages will be utilized.

ATTRIBUTES OF A VIABLE LIGNOCELLULOSIC BIOFUEL FORAGE CROP

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The production of energy from biomass feedstocks has received much attention across the U.S. in recent times. This is due in part because of the country's desire for domestically produced energy, and to minimize carbon emissions and other greenhouse gases. Lignocellulosic biomass feedstocks can be categorized into woody feedstocks (e.g. dedicated fast growing trees for energy such as hybrid poplars and willows, wood residues, wood chips and mill wastes), agricultural crop residues (e.g. corn stover and wheat straw) and herbaceous energy crops (e.g. switchgrass and miscanthus) The imposing opportunity for production of energy crops may create a diversification strategy for agriculture producers especially those on marginal farm ground or to collect crop residues such as corn stover where soil erosion and residue management levels permit. However, new challenges exist for advancing the supply chain from production to marketing of the biomass feedstock which is a very low density feedstock when compared to corn grain or soybean. A greater interest in this area has evolved, and involvement in research and development is underway in the area of biomass energy crops at Purdue University and other institutions around the world.

How this will impact the agricultural sector will be determined through new policies and subsequently new market demand. This article will present introductory concepts of how lignocellulosic biomass may be considered as a viable biofuel crop, and challenges with handling of low density bulky materials.

Bioenergy from Lignocellulosic feedstocks

Lignocellulosic biomass refers to plant based materials used as an energy source. The components of lignocelluloses are cellulose, hemicellulose, and lignins, which can be found in dense fibrous forage crops. The utilization of these biomass feedstocks can either be adopted in the following applications:

- Co-fired as a supplement with a primary fuel such as coal for the purpose of electricity generation;
- production of cellulosic ethanol through chemical conversion processes;
- in solid fuel pellets for home space heating;
- biomass gasification which is a process which converts the material to synthesis gas used to generate electricity or can be converted to liquid fuel distillates such as Fischer-Tropsch Diesel.

A recent study by the U.S. departments of Agriculture and Energy of biomass availability reported that there was about 1.3 billion dry tons of biomass available for fuel and power production in the U.S. (Perlack et al., 2005). From the study, corn stover had the potential to be the largest source of agriculture-derived biomass. Switchgrass is considered a bioenergy crop which is a warm season, sod forming grass, allowing it to combine good forage attributes and soil conservation benefits typical of perennial grasses. The deep and substantial root system of switchgrass provides it an advantage over adverse weather conditions as it relates to water and nutrient availability. Switchgrass has been viewed as a model plant species because of its perennial growth habit, high yield potential, compatibility with conventional farming practices, and high value in improving soil conservation and quality (Moser and Vogel 1995).

Cofiring Biomass with Coal

Coal is currently the primary source of electricity generation in the United States. When biomass materials are cofired with coal, decreases occur in emissions of greenhouse gases such as carbon dioxide (CO_2), Sulfur Dioxide (SO_2), Nitric Oxide and Nitrogen Dioxide (NO_X), and Mercury (Hg), (Grabowski, 2004). Cofiring has been a traditional method of introducing new or different fossil fuels in power plants. Cofiring biomass with coal is a low cost method for power plants to generate "green power" while maintaining adequate performance and generating capacity, as well as controlling their emissions to regulatory levels. When combusted, the Btu value of various biomass feedstocks ranges from 6,500- 8,500 Btu per pound on a dry basis. Coal has a Btu rating at 10,000 – 12,000 per pound (Ileleji, 2008).
Biomass has properties which may be favorable, but could also be not as favorable for cofiring. Biomass material with high moisture content decreases the Btu value. Managing this primary consideration may involve indoor storage to maintain quality and Btu value.

Table 1. Biomass Energy Utilization Depends on the Following Variables

Fuel Availability	Supply of biomass fuel must be within economical production radius usually at 50 miles or less.
Fuel Characteristics	When combusting biomass: Low-ash, low chlorine, low alkali fuels like wood waste are recommended to minimize ash deposition, slagging and fouling rates compared to high-alkali, high-ash, and high-chlorine fuels like straws
Fuel Logistics	Fuel preparation, handling and storage: • This will depend on the fuel type to be used, • Preparation such cleaning, size reduction and feeding are very site specific and so application in one project might not apply to another, • Particle size will depend on the type of combustion system and fuel handling needs for feeding into the reactor, Plan for fuel storage and sampling for quality control.

Source: Ileleji, 2008.

Cellulosic ethanol

The production of ethanol from cellulosic feedstocks is a pending opportunity on the forefront of research and development efforts. Compared to other crops for energy sources such as corn to ethanol, the sugars found within cellulose and hemicellulose are tightly bound to lignin which is a dense and cellular composition. The cellulose and hemicellulose must be released from the lignin before the sugar can be available for fermentation to take place.

Biomass sources for cellulosic ethanol are not only energy crops such as switchgrass, but also other feedstocks such as woody biomass, and other lignocellulosic feedstocks. Cellulosic ethanol poses challenges unique to become competitive with corn to ethanol production because of the lack of infrastructure associated with costs of production, harvest, transportation, and processing (Eggeman and Elander, 2005).

The current status of biomass energy crops is that none are not being commercially grown in the United States at present although a few demonstration projects are underway with DOE funding in Iowa and New York (Haq, year?). Purdue University has been conducting research on cofiring switchgrass at the coal fired electric utility plant on the campus in West Lafayette. One of the major focus of this research is to understand and develop robust handling systems for fuel preparation and feeding of lignocellulosic biomass into thermochemical reactors such as boilers in a power plant for power generation. Below are photos of the project at Purdue University.

Switchgrass plot at Purdue's Agricultural Research Center in Throckmorton

Switchgrass harvesting at Throckmorton

Switchgrass bales being unloaded at Purdue University's Wade Power Plant Facility, West Lafayette, IN

Biomass supply chain

To establish lignocellulosic biomass as a reliable resource for effective energy production, the infrastructure for production, harvest, transportation, storage, pre-treatment, and handling needs to be established.

Harvesting biomass

The scenario for removing the stover is not appropriate for all areas in which the soil characteristics and operational resources available should be considered. Table 2. Shows some of the harvest methods investigated in a study by Tyner and Brechbill (2008).

Table 2. Corn Stover Removal according to Harvest Method

Harvest Methods	**Percent of Available Stover Removed**
Windrow behind combine, bale	38.0 %
Rake into windrow, bale	52.5 %
Shred stalks, rake into windrow, bale	70.0%

Source: Tyner, 2008.

Transportation of biomass

A major consideration of the use of biomass energy crops in the U.S. is that it has a low bulk density hindering the economics of transporting the feedstock to the energy production facility. This creates a localized economic opportunity, and energy production facilities designed to cater to the local available resources. The costs of transportation of both corn stover and switchgrass are based upon the following assumptions from distances from 5 to 50 miles in intervals of 5 miles, and either utilizing custom, or owned equipment.

- Highway diesel: $3.93 per gallon (EIA, 3/31/2008
- Truck driver wage rate: $14.37 per hour (BLS, 2006)
- Semi-tractor and flatbed trailer
- Gas mileage: 6.73 miles per gallon
- Driving speed: 50 miles per hour
- 26 bales per load
- Loading/unloading time: 20 minutes (Tyner, 2008).

The following tables document the incremental costs associated with the costs of transporting relevant biomass energy crops such as corn stover and switchgrass.

Table 3. Cost of Transporting Corn Stover per Ton

	Custom	**500 acres**	**1000 acres**	**1500 acres**	**2000 acres**
5 miles	$35.94	$42.18	$37.91	$36.49	$35.78
10 miles	$37.33	$42.85	$38.58	$37.16	$36.45
15 miles	$38.71	$43.52	$39.25	$37.83	$37.12
20 miles	$40.10	$44.19	$39.92	$38.50	$37.79
25 miles	$41.48	$44.86	$40.59	$39.17	$38.46
30 miles	$42.87	$45.53	$41.26	$39.84	$39.13
35 miles	$44.25	$46.20	$41.93	$40.51	$39.80
40 miles	$45.64	$46.87	$42.60	$41.18	$40.47
45 miles	$47.02	$47.55	$43.28	$41.85	$41.14
50 miles	$48.40	$48.22	$43.95	$42.52	$41.81

Source: Tyner, Purdue University. 2008

Table 4. Cost of Transporting Switchgrass per Ton

	Custom	**500 acres**	**1000 acres**	**1500 acres**	**2000 acres**
5 miles	$55.76	$57.80	$55.16	$54.28	$53.84
10 miles	$57.15	$58.48	$55.83	$54.95	$54.51
15 miles	$58.53	$59.15	$56.50	$55.62	$55.18
20 miles	$59.92	$59.82	$57.17	$56.29	$55.85
25 miles	$61.30	$60.49	$57.84	$56.96	$56.52
30 miles	$62.69	$61.16	$58.51	$57.63	$57.19
35 miles	$64.07	$61.83	$59.18	$58.30	$57.86
40 miles	$65.46	$62.50	$59.85	$58.97	$58.53
45 miles	$66.84	$63.17	$60.52	$59.64	$59.20
50 miles	$68.22	$63.84	$61.19	$60.31	$59.87

Source: Tyner, Purdue University. 2008

Processing Biomass

Opportunities in the future may exist to locate a holding and conditioning facility in rural areas to prepare the biomass for the export and utilization on the biorefinery (cellulosic ethanol) or power plant (cofiring). The processes considered would be:

1. Cleaning of the biomass material
2. Sorting and size reduction
3. Grading and densification of the material
4. Blending
5. Compaction for bulk transportation
6. Pre-processing to upgrade stover feedstock
7. Bulk material transported by rail or truck

Conclusion

Many questions remain unknown about biomass supply for biofuels within Indiana and surrounding states. More research and development will be occurring before producers become involved in the production and distribution of energy crops across the U.S. In addition, market stimulation must occur first before production of biomass energy crops can be established, and the subsequent supply chain to make these types of biomass energy a viable opportunity.

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SIZING FORAGE MACHINERY

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A comparison of typical custom rates for forage harvest operations to the value of the hay or silage harvested illustrates the importance of correct machine sizing and operation. Hay and silage harvesting machinery and associated labor costs are often the single largest contributor to the cost of producing and delivering forages. Furthermore, because of the weather interdependence, machinery capacity affects losses, forage quality, and subsequent growth.

This manuscript covers some basic machinery management principles and provides some benchmark figures for selecting haying machinery. Topics of capacity, equipment matching, and power requirements are addressed. The focus is size and capacity, with some content related to machinery features; paint color is not addressed.

Hay Making

Capacities and cost

There are four factors which can limit the capacity or productivity of any agricultural machine: power, throughput capacity, speed, and/or traction. Hopefully in hay and silage operations, traction is not limiting. Here are a few examples of these factors limiting capacity.

- Power limited: high capacity baler with a 75 hp tractor attempting to harvest a high yield windrow
- Power limited: 9 ft disc mower-conditioner with a 50 hp tractor
- Throughput capacity limited: 140 hp tractor with a relatively low-capacity twine-tie baler in a high yield windrow situation
- Speed limited: high capacity baler with suitably sized tractor, but the windrow originated from a 9 ft mower (without raking 2 together) in a low yield situation (you can only drive so fast before the pickup lags)
- Speed limited: sickle bar mower-conditioner (at some speed, cut quality will deteriorate)
- Speed limited: raking at excessively high speeds may increase losses

Somewhat analogous to economic analysis of supply and demand, there are two views toward capacity: 1. What capacity is needed? and 2. What capacity does a machine (or machinery set) have? Area capacity has units of acres/hour while material capacity has units of tons/hour. Area capacity ($C_{a,ac/hr}$) required is a function of land area to be covered (A_{ac}), calendar days available to accomplish the work (B_{days}), working hours per day ($G_{hrs/day}$), and probability of being able to do the work on any random day ($PWD_{decimal}$) (ASABE 2007a, 2007b, 2007c). Required area capacity is:

$$C_{a,ac/hr} = \frac{A_{ac}}{B_{days} G_{hrs/day} PWD_{decimal}} \quad [1]$$

The probability of a working day for hay making is affected by soil conditions, the operation to be performed and weather. A complicating factor for haying operations is that baling requires mowing and raking to be completed. The probability of a working day for baling, then, is lower than the PWD for either previous operation. Because baling and raking require more particular crop conditions (i.e., moisture), there will also be less time per day available for these than for mowing. As one direct consequence of these facts, a baler must have a higher capacity than the mower or rake.

Area capacity of a machine is a function of operating speed (S_{mph}), width (W_{ft}), and field efficiency ($E_{f,decimal}$).
consequence rather than an input; one example would be a baler with a limited throughput capacity or limited power available. Once the capacity requirement is estimated (equation 1), finding a reasonably suitably sized machine is straightforward (use equation 2 and solve for width).

Power requirement is affected by throughput required (or throughput is affected by power available), so power must considered. Yield may affect the optimal swath manipulation choices so that speed is not limiting capacity significantly (see 4th example above).
Table 1 illustrates several hay machinery set examples for different operations. Included are benchmark labor requirements and costs. Another source

$$C_{a,ac/hr} = \frac{S_{mph} W_{ft} E_{f,decimal}}{8.25} \quad [2]$$

Field efficiency for forage operations typically range from 0.65 to 0.8 and account for turning, breaks, overlaps, and other factors which keep one from achieving 100% of the machine's capacity 100% of the time. Field efficiency of round balers is relatively low because they need to regularly stop to tie or wrap and eject bales.
Throughput (or material) capacity is area capacity (computed for a machine or as the requirement) times yield ($Y_{tons/ac}$).

$$C_{m,tons/hr} = C_{a,ac/hr} Y_{tons/ac} \quad [3]$$

In some instances, material capacity may be the limit and speed becomes a

of benchmarks for cost is published custom rates. According to Indiana custom rates of 2007, to mow-condition, rake, and bale hay with 2 tons DM/acre yield, the cost is about $35/ton DM for small square bales and $30/ton DM for net wrapped large round bales.

Features and matching

Wise machinery selection requires an evaluation of crop conditions and capacity requirements. Sometimes it boils down to personal preferences, dealer inventory, and service. A visit with a knowledgeable salesperson is often required. A properly match of tractors to mower, rakes, and balers requires some study of the advertising literature or operators manuals.

Operation & size	Mower	Rake	Baler	Transport system	Labor (hrs/ton DM)	Cost ($/ton DM)
Small square bales 20 to 60 acres 100 to 300 tons DM/year	9 ft	Single rake	Low capacity	2 wagons	1.4 to 2.1	42 to 69
Small square bales 40 to 80 acres 200 to 400 tons DM/year	8 to 12 ft	Tandem rake	Medium capacity	3 wagons	1.0 to 1.4	36 to 52
Small square bales 60 to 120 acres 300 to 600 tons DM/year	12 to 14 ft	Tandem rake	High capacity	4 wagons or auto bale wagon	0.5 to 1.0	29 to 41
Large round bales 20 to 60 acres 100 to 300 tons DM/year	9 ft	Single rake	Low capacity	1 wagon	1.2 to 1.4	44 to 67
Large round bales 40 to 80 acres 200 to 400 tons DM/year	8 to 12 ft	Tandem rake	Medium capacity	1-2 wagons	0.9 to 1.1	36 to 43
Large round bales 60 to 120 acres 300 to 600 tons DM/year	12 to 14 ft	Tandem rake	High capacity	2 wagons or truck	0.7 to 0.9	28 to 33

Table 1. Typical haying machinery sets with benchmark labor requirements and costs (Rotz, 2001).

The following features information may help identify questions to ask.

Mower-conditioners can have different cut and condition combinations. In general, sickle mowers require less power and cut cleaner, but they have a lower "speed limit". Although disc mowers require more power, their capacity is higher, they can cut lodged crops, and, if there is enough power available, practically never plug. Figure 1 illustrates the power requirement ranges for the two types of mowers.

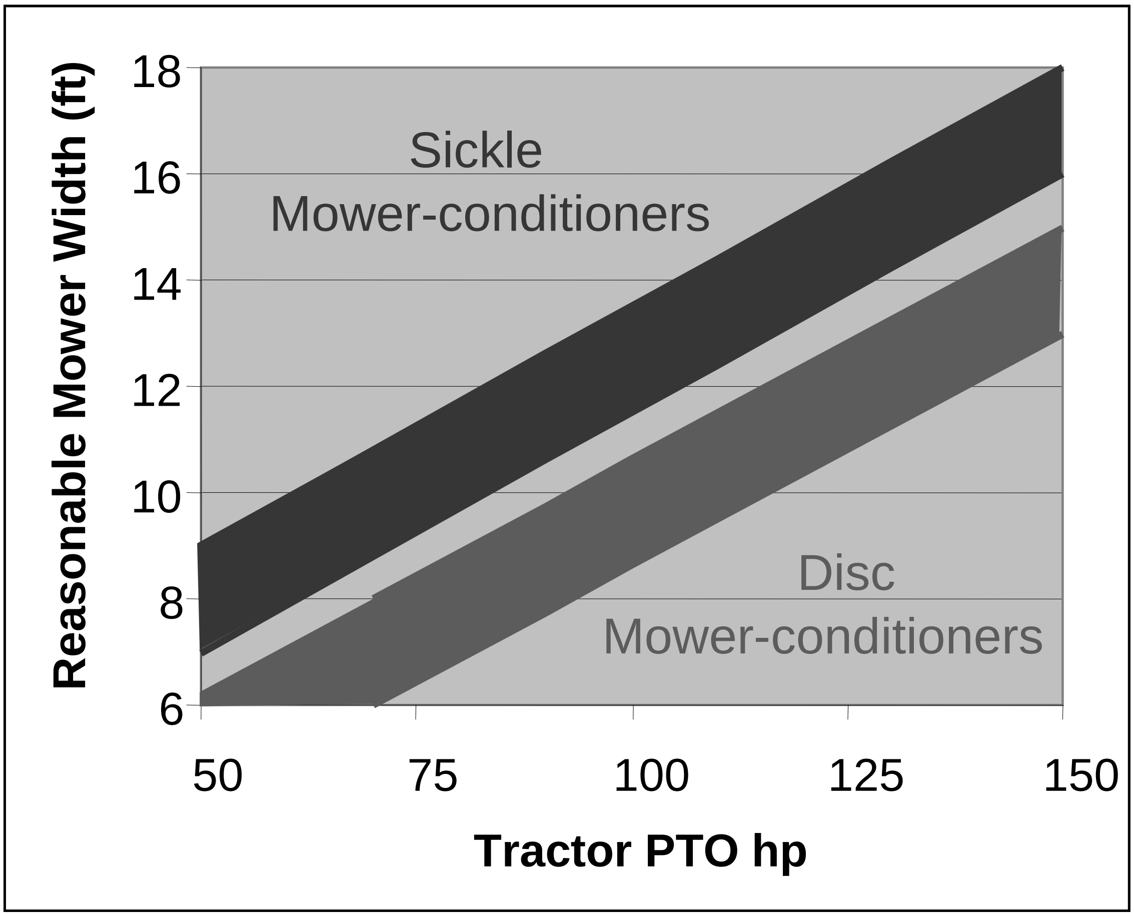

Figure 1. Tractor power requirements for sickle and disc mower-conditioners.

Conditioners speed the rate of forage drying by generating more pathways for moisture to leave the crop (primarily stems). Roll conditioners (rubber or steel) are good in legumes which have thick stems. Flail conditioners scuff the plant; they are more appropriate in grasses because the flails can cause high leaf loss in legumes. Regardless of the conditioning mechanism, more aggressive conditioning will increase drying rate, but also potentially increase losses.

Of the three common types of rakes, parallel bar rakes result in the lowest loss; they can be ground or hydraulically driven. Wheel rakes can allow higher speeds, but may result in more rock movement. Rotary rakes are becoming more common and will not result in large losses if properly set and operated.

Round balers now have several options worth serious consideration. These include bale slicing, net wrap, silage special options (for heavier, "sticky" bales), variable speed pick-up, automatic controls, integrated plastic wrapping (for silage). Although net wrap is more expensive, the increase in productivity can often pay for the difference (which leaves the other benefits of net over twine as pure gain). Some round balers can be safely operated with as little as 45 hp while others may be able to fully utilize over 100 hp; check the operator's manuals or advertising literature. Round balers, even with net wrap, have a relatively low field efficiency. A relatively high capacity round baler with throughput capacity near 30 tons/hr will likely lead to a day-long average near 15 tons/hr; this is because the operator will not "run on the edge" of plugging and the wrap/eject cycle keeps field efficiency (time actually picking up and baling) below 70%.

Large rectangular balers have throughput capacities approaching 50 tons/hr. They require more power than round balers, but because they do not need to stop for wrapping and ejecting, field efficiency is typically 15% higher. Power requirements range from 90 to 200 hp. With high capacity balers, more windrow planning is required. For example, if a large rectangular baler is expected to harvest a crop yielding 2.5 tons/acre at 40 tons/hr with a travel speed of 6 mph and a field efficiency of 0.85, the baler needs to cover 16 acres/hr. This requires the effective cut width to be 26 ft; two or three swaths must be raked together.

Bulk Silage Harvest

Harvester power and capacity

Of the four capacity limiting factors (power, throughput capacity, speed, and traction), power and throughput capacity are generally most applicable to silage harvest operations. Hopefully, forage harvest operations are not traction limited; that is, the soil is firm enough for the machines to move without excessive slip. In general, forage harvest operations are not speed limited, either. An upper bound on field speed may be a capacity limit in situations where there is plenty of harvester power with a small haycrop windrow to pick up and chop. Capacity in forage harvest situations, then, is most often limited by power or machine throughput capacity. A well matched pull-type harvester and tractor or a well designed self-propelled harvester should result in these two potentially limiting factors yielding a similar upper bound on capacity.

A good rule-of-thumb is that harvester throughput ($C_{m,tons/hr}$) in grasses and legumes can approach harvester horsepower divided by 4 in good field conditions (full windrows; Buckmaster, 2006). For example, if transport and unloading are not bottlenecks, a 400 hp self-propelled harvester could harvest 100 tons of haycrop silage per hour; this would be 35 tons DM/hr if the silage was 65% moisture. Harvester power efficiency for corn silage is, at best approximately 2.5 hphr/ton; this corresponds to 60% more capacity (per unit power) than with haycrop silages. A 400 hp harvester can harvest approximately 160 tons of corn silage per hour (400/2.5).

Silage into storage: blower, bagger, & bunker packer

Logistics at the unloading site are critical to system performance. If silage cannot be packed, blown, or bagged fast enough, the storage site can become the bottleneck of the overall harvest system.

Silo blower manufacturers advertise maximum capacity of approximately 110 tons/h with haycrop silage and 180 tons/hour with corn silage. Maximum capacity may not be maintained consistently throughout a day or longer since the blower will not be operating at 100% all of the time; also, operators may not push the capacity toward the plugging threshold. With 75% utilization, a blower and tower silo system, with adequate tractor power could store 82 tons haycrop/hr or 135 tons corn silage/hr. These values are consistent with silo filling rates we observed on farms. If the transport system was sufficient, a blower/tower silo system could keep a 340 hp harvester operating at full capacity. An even larger harvester could be operated at full capacity if the blower had a receiving platform to allow for higher utilization.

Blower power requirement will depend on the blower type, silo height, and throughput (Rotz and Coiner, 2005). Forage blower power efficiency is approximately 2.1 hphr/ton with haycrops and 1.6 hphr/ton with corn silage. The ratio of blower power efficiency to harvester power efficiency suggests that for every 1 hp of the forage harvester in haycrop silage, there should be approximately 0.5 hp available to the blower. This guideline would apply only up to approximately 175 hp since blower throughput capacity would be limiting if more power was available. For corn silage, each 1 hp of harvester should have a match of approximately 0.6 hp available to the blower – up to approximately 200 hp.

Silage baggers are advertised with capacities exceeding 500 tons/hour. Bagger capacity can be limited by the throughput capability of the machine or available power. Baggers require approximately 1.5 hphr/ton for haycrop silage and 1 hphr/ton for corn silage; this is about 60-70% as much power as a forage blower (Rotz and Coiner, 2005). In addition to having a properly sized bagging machine, the bagger should have approximately 40% as much power available as the harvester in order to assure adequate capacity to place silage into storage.

Proper packing of silage into bunker silos, trenches, or stacks requires adequate packing weight, packing time, and a proper layering technique. The Holmes and Muck (2002) model was used to estimate the weight (and likely power rating) of tractors required to maintain pace with harvesters with varying capacity. Good management practices of 65% moisture silage, maximum packing layer thickness of 6 in, and a target density of 16 lb DM/ft^3 were assumed. Figure 2 illustrates the packing mass required to achieve the target density while keeping up with varying harvester power levels. As one example, a 300 hp harvester harvesting corn silage should be matched with a minimum of either two 43,000 lb tractors or one 60,000 lb tractor (off the chart) moving and packing silage in a bunker. Packing with less tractor weight will result in lower density (higher losses, less capacity). There is a practical limit of approximately 160 lb per PTO hp rating; weighting a tractor more than this may cause premature axle or transmission failure (check operators manuals). The 160 lb/PTO hp was used to generate the right axis of Figure 2. Figure 2 slightly overestimates packing weight required; although a 300 hp harvester (previous example) has capacity of 120 tons corn silage/hr, silage will arrive at the bunker at a slightly lower rate due to field efficiency and transporter interactions.

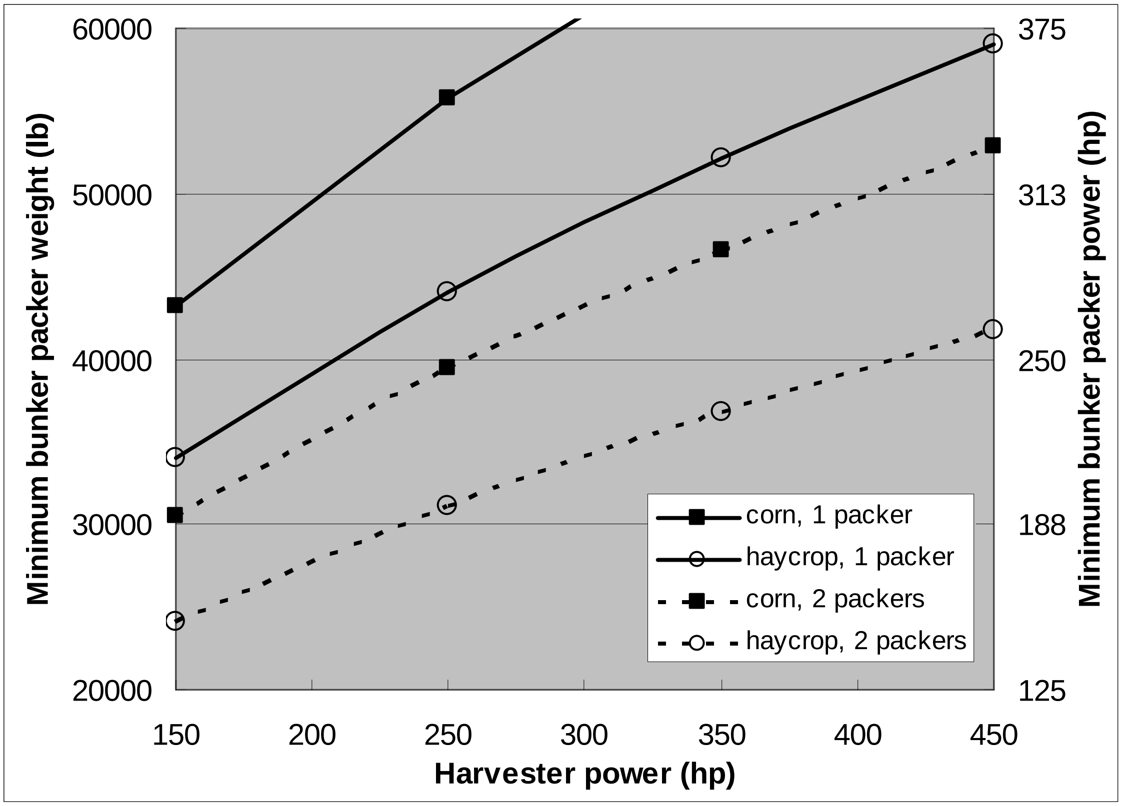

Figure 2. Tractor weight requirements for adequate bunker silo packing (right axis assumes total ballast of 160 lb/hp – refer to operators manual for limitations).

Tools availability

For a limited time, attendees of the 2008 Indiana Forage Day may access and download some tools and further information on this topic. The URL is:

http://cobweb.ecn.purdue.edu/~dbuckmas/INFOR08

Available there are:

- *Haying machinery aids.xls* which is an Excel workbook containing a simple capacity estimator and a simple tractor cost calculator
- *Benchmarking tractor costs.pdf* which is documentation for the tractor cost calculator
- *IN custom rates EC-130-W.pdf* which is Indiana the 2007 custom rates fact sheet printed by Purdue University
- *Mach_FORAGE_field_Operations_2005.pdf* which is a

University of Illinois fact sheet related to machinery costs

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